# A Review of Industrial Air Conditioning Related Diseases and their Effects on Production
## (A case Study of Legionnaire Disease in the Textile Industry)

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**Abstract:** An air conditioner has enormous effects on its users through its air-conditioning processes for many years. Hence, this research is focused on the various air conditioning related diseases, especially the Legionnaire diseases and their effects on production in the textile industry. The study displays the negative effects of the Legionnaire diseases on production as well as highlighting its causes, signs and symptoms, diagnosis and the recommended associated treatments. The study ends up educating all refrigeration technicians, mechanics, engineers and students on this disease and its effects on their various domains of operation. The research used both primary and secondary data. Primary data was collected using questionnaires. Secondary data were mainly gathered from related articles, journals from the internet, published and unpublished books and other sources on the area of study. The data gathered were analyzed using simple statistics such as percentages and figures.

***Keywords:*** *Air condition, Building syndrome, Disease and Textile, Legionnaire.*

## 1. Introduction

One area of great concern related to air conditioning but not strictly to cooling is building related diseases. Work in the textile industry has been associated with many symptoms involving the respiratory tract. Also, ambient conditions influence open-end spinning and performance of yarn in weaving and legionnaire disease problems on operating personnel. Legionnaires' disease has a false but enduring status as an exotic plague. In reality, this disease is a common form of severe pneumonia, but its infections are infrequently diagnosed. Failure to diagnose Legionnaires' disease is largely due to a lack of clinical awareness. In addition, legionellae, the bacteria that cause this disease, are fastidious and not easily detected (Fields, Benson, & Besser, 2002). Legionnaires' disease, also known as legionellosis is a form of a typical pneumonia caused by any type of Legionella bacteria. Signs and symptoms include cough, shortness of breath, high fever, muscle pains, and headaches. Nausea, vomiting, and diarrhea may also occur. This often begins 2–10 days after exposure (Fields, 2002).

There are several generally recognized areas of concern with respect to Indoor Air Quality (IAQ), materials which emit pollutants' primary emitters and secondary sources/sink re-emitters, indoor combustion, outdoor sources, biological sources and occupant activities. These sources are generally grouped into three broad classes: construction materials, interior fixtures and furnishings, and consumer products (Brent, 1994).

Cunha, Burillo, & Bouza (2016) made a study stating the history behind this disease. Bacteria of the genus Legionella were discovered during the investigation of a major pneumonia outbreak in members of the American Legion attending their annual meeting in 1976 in Philadelphia. The causative microorganism was an unknown bacterium and was designated Legionella pneumophila. The term given to the infection was Legionnaires' disease, which refers to the pneumonic form of legionellosis. About 29 (16%) of 182 patients died, since this new type of pneumonia did not respond to β-lactam antibiotics. Legionnaires' disease is usually spread by the breathing in of aerosolized water or soil contaminated with the *Legionella* bacteria. Experts have stated that Legionnaires' disease is not transmitted from person to person. Fig 1 presents the effects of the disease on the human anatomy, especially on the lungs of the patient.


*Fig 1. Legionella bacteria (Jennifer, 2019)*

In 2014, one case of possible spread from someone sick to the caregiver occurred. Rarely, it has been transmitted by direct contact between contaminated water and surgical wounds. The bacteria grow best at warm temperatures and thrive at water temperatures between 25°C and 45°C (77°F and 113°F), with an optimum temperature of 35°C (95°F). Temperatures above 60°C (140°F) can therefore kill the bacteria. Sources where temperatures allow the bacteria to thrive include hot water tanks, cooling towers, and evaporative condensers of large air conditioning systems, such as those commonly found in hotels and large office buildings. Though the first known outbreak was in Philadelphia, cases of legionellosis have occurred throughout the world (Fields, 2002).

## 2. Brief review

Fatigue and illness: Harmattan day is best countered by sitting in an over-conditioned environment. But, that will most likely cause you to have constant headaches and to feel fatigued even when you just had breakfast, or woke up. Fatigue and headaches usually become chronic for those who chose to sit under the air conditioner for a long time. Also, working or living in a constantly cooled-off room will make you experience constant mucous membrane irritation, along with breathing difficulties. This can be deadly for those with lung problems, but it also affects those who are perfectly healthy by making them more vulnerable to flues, contracting colds and other diseases (Lawson, 2015).

Problems with breathing: As stated by Lawson (2015), germs and many other micro-organisms that cause breathing problems use the air to travel. Air conditioner is making their journey easier, and is helping them spread out. Also, having the windows shut and the air conditioner on causes these disease-carriers to circulate around you all the time and traps them. The worst disease that is air-borne is Legionnaire's Disease, known to be fatal by causing pneumonia and fever. The only solution to this problem is to create a constant flow of fresh air and to refresh your air conditioned environment every 15 to 20 minutes.

### *2.1 Causes and Transmission (Study on Scene)*

After the outbreak of the disease, many surveys were taken to examine its causes. Glick et al., (1978) stated in their research, the probable relationship of illness to exposure in the health department building became apparent early in the epidemic. Initially, only employees who had been in the building on Monday, July 1, became ill. Exposure prior to Monday, July 1, did not produce illness, with the possible exception of one employee who was present in the building early June 29 as well as on July 1, and became ill during the evening of July 1. Many visitors and one employee who had not been in the building at all in the latter part of June, and some of them never before, developed illness after exposure on July 1. There were no common exposures outside the building. A survey in adjacent buildings of the county service complex and in the community detected no unusual incidence of illness. There was no common exposure to foods in the employee group, nor had all affected persons used water from the building for drinking or washing. Moreover, numerous visitors became ill without prior consumption of any food or water from the building. In addition, illness in six investigators who had minimal community contact provided strong evidence for localization of exposure in the health department building. Thus, simply being in the health department building appeared to constitute exposure, since no specific activity appeared to entail exclusive or increased risk. Particular areas in the building did not appear to be associated with higher risk, nor did any section of the building clearly confer protection. The explosive onset of the epidemic, as well as lack of evidence supporting other modes of exposure, suggested airborne spread of disease and drew attention to the air-conditioning system. Certain days were associated with higher risk than others.

The air-conditioning system was turned off on Saturday, July 6, and persons newly exposed that day did not become ill within the range of expected incubation periods, but did become ill approximately 40 hours following exposure to the building, after the system was restarted on Monday, July 8. Moreover, attack rates were higher in persons exposed during that morning than in those first exposed in the afternoon or evening, suggesting increased risk after restarting the air-conditioning system. Again, late Thursday morning, July 11, the entire air conditioning system was turned off for approximately one-half hour and then restarted. Five persons present in both the morning and the afternoon became ill; two persons present only in the morning did not become ill, while five persons present only in the afternoon became ill. Investigation of the air-conditioning system.

By July 25, extensive laboratory and environmental investigation had not yet uncovered an etiologic agent. Since all epidemiologic evidence pointed to the air conditioning system, a detailed examination of the structure and function of the system was undertaken. The air-conditioning system consisted of two air circulation systems that were separate but had ducts next to each other. The first system cooled refrigerant gas for the second system, which cooled air for the entire building.

The first system circulated air from the basement through an evaporative condenser to the outside via a metal duct and discharge vent on the roof at a point less than 2 meters from the outside air intake of the second system. The air of the first system flowed through water sprayed within the evaporative condenser from a reservoir at the base of the unit to which algaecide was periodically added. This air was supersaturated with water from the sprays as it moved up the metal duct. The second air circulation system used fresh air from outside, as well as a percentage of recirculated air from the building, to cool the building. Outside air was passed through a low efficiency filter,

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cooled, and dehumidified in the air-conditioning unit proper, and distributed throughout the building by a system of supply-air ducts.

On July 29, several openings were made in one of the six main supply-air ducts of the air-conditioning system. Looking through these holes revealed that condensate from the water aerosol in the evaporative condenser discharge duct could, and in fact did, at times drain directly into an adjacent supply-air duct through cracks in both duct systems. Furthermore, by means of smoke artificially generated and a non-toxic tracer gas dispersed in the discharge duct of the evaporative condenser, it was readily established that exhaust air from the evaporative denser could contaminate the independent circulation of conditioned air in ducts supplying the building. This occurred both by simple leakage from duct to adjacent duct and by airflow between closely spaced exhaust and intake vents on the roof.

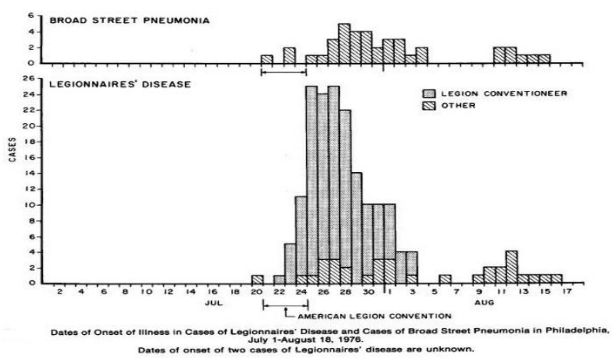


Fig 2: Legionnaires' disease out breaks (SITRA, 2008)

***Table 1. Legionnaires' disease outbreak***

| Suspected Source | Cases | Deaths | Date | Location |
|---|---|---|---|---|
| Cooling tower | 7 | 0 | 31st Dec 2006 – 1st Jan 2007 | Australia, Sydney |
| Unknown source | 4 | 0 | Nov 2006 – Jan 2007 | Phuket, Thailand |
| Cooling tower | 26 | 2 | July – Sept 2006 | Paris, France |
| Cooling tower | 30 | 2 | July 2006 | Amsterdam, Netherlands |
| Cooling tower | 149 | 0 | June 2006 | Pamplona, Spain |
| Cooling tower | 10 | 1 | Feb 2006 | Sydney, Australia |
| Cooling tower | 20 | 0 | Dec 2005 | Torrevieja, Spain |
| Cooling tower | 127 | 21 | Oct 2005 | Toronto, Canada |
| Cooling tower | 21 | 0 | June 2005 | New Rochelle, NY, USA |
| Indoor ornament fountain | 17 | 1 | Summer 2005 | Rapid City, SD, USA |
| Air scrubber | 52 | 10 | May 2005 | Fredrikstad, Norway |
| Cooling tower | 86 | 21 | 2004 | Pas-de-Celais, France |
| Cooling tower | 172 | 7 | 2002 | Barrow, UK |
| Cooling tower | 28 | 7 | 2001 | Stavanger, Norway |
| Cooling tower | 449 | 6 | July 2001 | Murcia, Spain |
| Whirlpool and humidifier | 200 | 32 | 1999 | Bovenkarspel, Netherlands |
| Cooling tower (widely accepted) | 221 | 34 | 1976 | Phildepia, PA, USA |

Source: SITRA, 2008

As compared to our modern textile factories, air conditioning has been the main source of circulating the Legionnaire disease. Hence, posing a great threat to the production industry.

*2.2 Signs and Symptoms*

The symptoms of Legionnaires' disease generally develop between two and 10 days after exposure to Legionella bacteria. The earliest symptoms include chills, headache, body weakness, fatigue, and a fever of 103 degrees or higher, and can get progressively worse over the first few days. As the condition progresses, other signs and symptoms include: a severe cough that may produce mucus or blood which is usually the first sign of a lung infection; shortness of breath and chest pain; and gastrointestinal issues, like vomiting, diarrhea, or nausea. It is worth noting that Legionnaires' disease can share symptoms with many other conditions—like the common cold or the flu, or a related condition called Pontiac Fever (Prevention, 2016).

**3. Humidifier Fever**

Humidifier, fever is not an infection but an allergic reaction to certain micro-organism, which can grow in the stagnant water of the humidifier's reservoir, when the unit is not in use on weekends. The concentration of micro-organisms is sprayed into the space causing a reaction of headaches and flu-like symptoms. As the concentration is diluted by replacement water, the reaction diminishes until is hardly apparent by the end of the working week. Unlike the legionnaire disease, if the affected one moved out of the contaminated space, the reaction stops.

Sick building syndrome is the most difficult to understand as there seems to be no one causes that can be identified as the main reason for its incidence. Insufficient ventilation, poor air quality, inadequate maintenance and lack of individual control have all been related to central plant in large building. Parts of the problem could be caused by people expecting air conditioning to provide the ideal environment for them and when it does not, dissatisfaction occurs. The syndrome does not seem to happen in the smaller installations.

Yarns are frequently conditioned so that they will not snarl, untwist or kink when used for further processing. Such conditioning tends to bring all the yarn to standard moisture regain so that uniform properties are obtained which facilitate slashing and other processes. Three systems are often used to accelerate this process. The first of these systems involves spraying the yarn with fine mist of water containing a small proportion of wetting agent. In the second system yarns are conditioned by exposing them to an atmosphere kept at 90 RH and 120 for an hour. The air is normally circulated and automatically controlled to the desired conditions.

Maintenance of optimum atmosphere conditions is important in weaving. Although the strength and elongation of cotton yarns increase with increasing humidity maximum efficiency is not obtained from loom operatives at very high humidity. Moreover, the strength and elasticity of starch films begin to decrease when humidity exceeds 80% -85% the net result is therefore detrimental for weaving. A fast moving warp will require more humidity since the yarns are not exposed to conditioning for a long period as with slower weaving wraps. Relative humidity in the range of 75% to 85% are generally recommended for cotton weaving. While cotton increases in strength as its moisture content increases, just the reverse is true for rayon. Therefore weave-room humidity from 65-72 RH at 78% are recommended.

Comprehensive studies conducted by SITRA (2008). The importance of ambient atmospheric conditions in the processing and testing of textiles is well known. Some of the most important physical properties of textile fibres are closely related to their behavior in various atmospheric conditions. Changes in temperature and relative humidity of the atmosphere result in change in weight of the textile material as well as its strength and breaking elongation. Control of atmospheric conditions in a textile mill also ensures reasonable comfort for the operators and prevent deterioration of operative efficiency. From a technological point of view also, ambient atmospheric conditions play an important part. Practically all textile fibres shows increased pliability and greater immunity to static electricity where increase in moisture may be deposited on the fibres and they become sticky during processing. Thus there is an optimum level of temperature and relative humidity at which chances of adhesion between fibres are minimized.

A considerable amount of heat is liberated in the spinning and weaving departments from the processing machines themselves. A little heat is added by the people working and also there by the electric lights provided. A substantial amount of heat also comes in particularly during the dry season, through the roof, walls and windows. Had there been no requirement of ambient relative humidity, the heat load could have been disposed of merely by good ventilation. Air conditioning system is therefore required to maintain relative humidity within close limits if there are no requirements of ambient by good ventilation. The system generally used is textile mills with the evaporated cooling type and forced air circulation.

Air-conditioning plants used in textile mills consist of a circulating fan, an air washer or humidifier, which is meant to saturate the air, and ducts which circulate the air to different parts of the conditioned space. As the air is saturated with moisture adiabatically, its dry bulb temperature goes down to its wet bulb temperature. By circulating this cool air in the conditioned space, the heat load is taken care of and simultaneously a reasonably comfortable temperature is maintained in the department. Relative humidity is adjusted by varying the quantity of moisturized air in the loom shed. Water atomizing nozzles are also provided in the conditioned space in order to boost the relative humidity in the department to a sufficiently high level. In the plant the departmental air is to be re-circulated through the air washer in order to conserve heat during rainy season. In more sophisticated plants, the recirculation is achieved by means of forced exhaust system. The exhaust fan draws air from the department through an underground duct and through air filters and pushes it back to the air washer or to the outside atmosphere. Again, in still more sophisticated air circulating plants, a refrigeration system is also provided. It makes the working more possible to provide very comfortable conditions while maintaining relative humidity at the stipulated levels, even when the outside atmospheric conditions are adverse. Air-conditioning plants for textile mills may be divided into where high relative humidity levels are to be maintained as in the loom-shed, the common practice is to provide supplementary humidification. The main plant is designed to maintain relative humidity to about 60% to 65% and the supplementary humidification system is provided to raise the relative humidity to the required level of around 80%. It is, however, possible to achieve an ambient relative humidity of 80% without supplementary humidification. Such a system where supplementary humidification is eliminated is called all-air system (Fig.3).

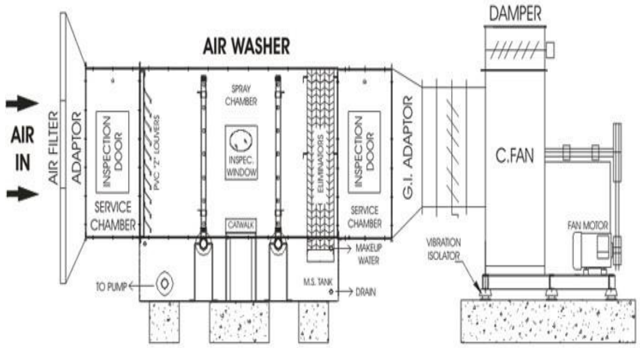


*Fig 3. Air washer sections (Dvna, 2013)*

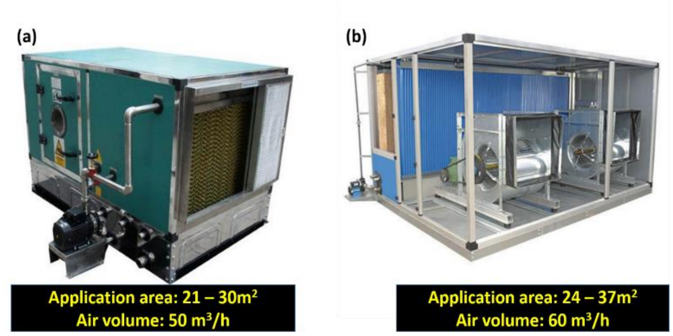


*Fig 4: Air washer unit. Source (Indiamart, 2013)*

The one with supplementary humidification is called the split system, because the task of raising the humidity is split between the main plant and the supplementary humidification plant. Air circulation capacity of the main plant in the case of all-air system should be quite high, about three times, as compared to the split system. This would result in high capital cost and high operational cost.

With supplementary humidification, it is found that the relative humidity is not as uniform as desired. Due to water being sprayed in the conditioned space, liquid particles of water can reach right up to the looms before they evaporate completely. When the water evaporates, its dissolved solids are liberated in the form of the powder. This powder is abrasive and corrosive and has an adverse effect on the weaving process as well as the machinery. It has been found that a loom-shed with all-air system gives better production efficiency than one with supplementary humidification. Experience of mills is that the benefits from the all-air system are large enough to compensate for its capital running cost.

Without supplementary humidification, one has to depend on the main plant only for raising the relative humidity. So it is obvious that the relative humidity of the saturated air from the main plants should be higher than that to be maintained in the conditioned space. For example, if one wants to maintain 80% relative humidity in the loom-shed, the relative humidity of the air from the air washer should be more than 80%. Normally, with the well designed and well maintained air washer, it should be possible to achieve 95% relative humidity after the air washer. But operational studies by SITRA (2008) indicate that the relative humidity of air coming from the air washer is 80% or lower in many cases. With the split system, this does not create a serious problem as the relative humidity is made up by the supplementary humidification to the required level.

With the all-air system, if the air washer efficiency is not up to the mark supplementary humidification is not available to come to aid. This is an important factor in considering the all-air system for a loom-shed.

If the all-air system is to be chosen, one should be very careful about the capacity and design of the plant. Maintenance of the plant is critical and all the support it needs by way of men, material, and supervision should be provided ungrudging and promptly. If these are not likely to be forthcoming, it is better to continue with the conventional split system of air-conditioning in the loom-shed. The disadvantages of the all-air systems are; [i] high capital cost, [ii] high operating cost, and [iii] the necessity for very good maintenance. But it is better because of, [a] uniform conditions in the loom-shed and therefore improved loom-shed performance, [b] less corrosion, and [c] better comfort. Firstly, because of much higher rate of air circulation, there is greater air movement leading to improved comfort. The more important reason to improve comfort is that the dry bulb temperature in the room is lower in the case of the all-air system than that in the split system for the same level of relative humidity (Manohar, 2005).

### 4. Equipment Design and Construction

The design and construction of equipment is a challenging subject, dealing with a purposeful activity directed towards the fulfilment of human needs. This requires consideration information such as feasibility of certain systems within the limiting factors namely; physical reliability economic worthiness and financial feasibility (Manohar, 2004). Chilled water unit equipment is pre-engined and built on a production line where the manufacturer has designed the unit to work within pre-selected conditions, using standard components which includes a preset refrigeration circuit to achieve those conditions.

In reference to the research and design work at hand, the researcher is of the view that, the implementation of this project would modify a portion of the old plant. In the chilled water system there are separate units. The main plant, consisting of fan, air washer and other accessories are located in a plant room which is outside the conditioned space. Only the distribution system is in the conditioned space. The distribution duct is connected with the plant but is not integrated to it as one unit.

The air circulation fan is of the axial flow type. They are the most suitable for high discharge against low pressure head; when the pressure head is large, multi-stage axial flow fans are used. Their efficiencies are generally higher than that of the centrifugal fans. So whenever energy saving is an important factor, they are preferred (Manohar, 2004).

### *4.1 The Existing Plant before Modification*

The existing plant before modification is an air washer system. This system employs the use of the chilled water is sprayed directly. The chilled water is sprayed over an arrangement called the air washer, which is situated in a spray chamber. The cold temperature air is then extracted from the chilled water and then blown into the conditioned room for cooling. This arrangement would have been proper had it not been the legionnaire's disease which is related to water sprays. When within a particular temperature range becomes contaminated with the micro-organism called legionella pneumophila.

The organism occurs naturally and is not harmful under normal circumstances. It needs to multiply in contaminated water to cause the problem. At temperature below 20C it will hardly multiply, and above 60C it dies, therefore the ideal water temperature for operation should be around 40C.

The problem mentioned therefore, necessitate the replacement of the air washer with an air-handler which will eliminate the chilled water coming in direct contact with the cold temperature air being lowered into the space.

### *4.2 Modification*

With modification the chilled water passes through tinned tubes arrangement. With the water passing through the tubes possibility of contamination does not exist, therefore the problem of the legionella and it's completely eliminated. With the air handler replacing the air washer the air-circulation duct can now be positioned at distance closer to the unit than it is with the air washer.

The air-circulated duct can now takes over from there and distribute the air throughout the conditioned space by means of diffusers. The duct is connected to the air conditioning plant by means of a duct system called the static region system. Air from the conditioned space is returned to the air handler through holes to an underground return air ducts, through filters and fans. There are several return air griller in the floor to ensure that the air is evenly exhausted as possible from the conditioned space.

### *4.3 Problems after Modification*

Problems likely to be encountered after modifications are the ability to maintain the relative humidity levels in the conditioned space to the levels that they were before the modifications.

With the air washer system, the relative humidity of the air coming from the washer is likely to be about 80-85% therefore by the time it gets into conditioned space it is around 60-65% which is the set conditions for the mill. With the replacement of the relative humidity is likely to come down to 70-75% from the handler. Therefore, by the time the air reaches the floor of the spinning hall it would be around 50-55%, which is outside the humidity ratio range of the mill.

Direct atomization by centrifugal humidifiers is one of the means of raising humidity but it carries with it the disadvantage of throwing directly lots of water particles over a small area resulting in high humidity and corrosion of machine parts. The other is pneumatic atomizer which is better in many respects namely, good atomization, better distribution of humidity and less corrosion.

Compared with centrifugal humidifies they have other maintenance problems such as large number of mounted overhead, long pipes, compressor etc. This makes the system also expensive to install and operate. Another option left is to make use of the ambient relative humidity. With a humidistat installed in the conditioned space, the level of the relative humidity in the room can be checked and if it falls outside the predetermined levels the humidistat will then activate the louvre blades of the hall to open admitting into the hall fresh air with higher relative humidity to augment the indoor air. Such a system of supplementary humidification is called all-air system. Reductions in room cooling load, due to variation in the weather or by presence of additional heat gains from occupants or electrical equipment, are met by changing the supply-air quantity with terminal variable air volume controller until the room air temperature is stabilized. The minimum quantity of supply air permitted corresponds to at least the fresh air need of the occupants, thus the turn down may be from 10% to around 20%.

The conditioned supple air enters the hall through ceiling liner diffusers. The plenum acts as a header box to distribute the air uniformly through the spinning hall, several branch offs form distributed evenly. A throttling valve between the plenum (main duct) and the branches ensure there is control of the airflow rate.

Varying the supply flow has a strong influence upon the distribution of air into the room and the movement of air within it. The supply air is diffused into the room along the length of the main duct, which runs through the center of the hall, and also branch off at equal distance at both sizes, through supply air diffuses. Thirteen, four-way distributors will be installed in the branches to distribute air to the space. Each branch will distribute 430L/S of air into the rooms.

## **5. Methodology**

This section discusses the methods and techniques employed by the researcher to obtain data for the study. It consists of methods of the population and sample size, sampling technique, data collection instruments, field experiences and methods of data analysis. Earlier on in the research proposal it was indicated that major part of the study will be carried on Juapong Textiles Factory and its surrounding areas. This project is dealing with Textile factories that already have an existing Air Supply System but since the project was to redesign the plant so that it can be a model for further improvement in the textile production using air conditioning, the researcher has tasked himself to redesign the duct system and possibly improve on the existing one to ensure increased production.

The single-duct variable air volume system is the type that I have adopted for use in this project, because it's the most suitable system employed for single-volume room such as sport hall, theatres, factories, etc. This is preferred due to their economy and controllability when applied to the air conditioning of the spinning hall. It is a cooling system with the air handling unit providing the lowest air temperature required. According to the values obtained from the load estimated for this project the volume flow rate for supply is 13.06m/s.

The supply duct system distributes air to the terminal units, register, or diffuses into the air conditioned space. Starting at the fan outlet, the duct can be fastened to the blower or blower housing directly or have a vibration eliminator between the blower and the ductwork. The duct system must be designed to allow air moving towards the conditioned space to move as freely as possible. Ducts are used to convey air [supply] return and re-circulated in an air conditioning space. In designing a conditioning duct system several factors must be considered such as the following;

a) Space availability
b) Noise level
c) Duct heat gain [or losses]
d) Duct leakages
e) Balances
f) Fire and smoke control
g) Initial investment
h) System operating cost

Ducts are usually rectangular, square or round. Round ducts are more energy efficient as they offer less resistance to air flow. Round ducts involve the use of less material to fabricate though square and rectangular ducts conform better to building construction and they fit into walls and ceilings better than round ducts. To space in building the tried today is to use smaller duct sizes which operate with about twice the normal air velocity. This requires the use of more powerful fans, which result in high running cost. In addition, high air velocity creates more noise. But this application is an industrial process noise is not major concern therefore that is the type that will be used in the design. A good duct design into use as large duct size is possible and less air pressure to give low velocity less power and lower noise.

There are three methods employed in duct sizing. These are Equal pressure drop, Velocity reduction and Static regain methods. Of these three is the equal pressure drop referred to as equal friction method, which is the most used method, especially for sizing low velocity system.

*5.1 Design procedures*

i. Study the building plan and arrange the supply [diffusers] and return air outlets to provide proper air distribution within each space. The type and number of diffusers requires for each space will be decided by the room dimension and the throw, spread and drop characteristic of the diffuser.
ii. Sketch the duct system, connecting the supply and return intake with the central station apparatus. Care must be taken to avoid running duct into building obstruction and equipment.
iii. On the sketch, label the duct section fittings, etc. for easy identification. Indicate the air volumes back to the unit to get the total air volume require of fan.

*5.2 Load Estimation*

i. The load affecting air temperature is from the sun transmission through the building structure and internal sources, such as equipment, lighting and people, whereas the load affecting humidity is mainly from ventilation, air and people. The size of the plant, distribution and terminal devices together control the complete system depends on this analysis.
ii. Estimating a load that is too small will lead to dissatisfaction by the occupants, whereas overestimating will lead to high capital cost, rapid cycling and therefore inefficient plant operation, and unnecessary maximum demands for power.

Table 2: Data from the field

| **Sources of Heat Load** | **Description** | **Quantity** | **Cooling Load Factor** | **Cooling Load Sensible** | **Cooling Load Latent** |
|---|---|---|---|---|---|
| External Walls | North East Wall | 175.68m$^2$ | 48w/m$^2$ | 8432.64w | |
| External Walls | South Wall | 225.92m$^2$ | 80w/m$^2$ | 18073.64 w | |

| | | | | | |
|---|---|---|---|---|---|
| Internal Walls | North Walls | 40m$^2$ | 15w/m$^2$ | 600w | |
| Internal Walls | West Walls | 175.68m$^2$ | 15w/m$^2$ | 26352w | |
| Roof | Roof | 2480.60 m$^2$ | 25w/m$^2$ | 62015w | |
| Lighting | Lighting | 40 | 40 | 1600w | |
| People | People | 30 | 60/80w/m$^2$ | 2400w | 1800 w |
| Spinning Machine | Machine | 86 | 5700w | 490200w | |
| Clearing Machine | Machine | 7 | 1178.4 | 12448.8w | |
| **Total** | | | | **622122.08w** | **1800 w** |

*5.2.1 Calculations 1*

Qs = 622122.08w
QL= 1800 w
QT = QS + QL
= 622122.08 + 1800
= 62399.08 + 1800
SHF = QS/QT
= 622122.08/62399.08

∴ SHF = 0.997115

*5.2.2 Calculations 2*

Supply Air temperature = 15˚C
Room temperature = 20˚C
Relative humidity = 60%
Total heat = 648.22
Hi = 43Kj/Kg
H2 = 86Kj/Kg
Ah = 86 – 43
= 43Kj/Kg
Q = ṁ Δ h
ṁ = 648.22/43
ṁ = 15.07Kg/s
V = 0.88 m$^3$/Kg

P = m/v
V = p x m
= 15.07 x 0.88

∴ Volume flow Rate = 13.2616

**6. Conclusion and Recommendation**

- Air conditioning has served us for many years. And having enjoyed every bit of its services, caution must be taken on its negative effects. Hence, this research has shown one of its deadliest side as to air condition related diseases. So that the information gathered can let us put in place good and rapid measures to curb its spread and effects on the textile industry.
- From all data analyzed, it could be seen that when the right temperature and humidity levels in factory are corrected and within the predetermined range, end breaks levels in the factory could be reduced from 212 to 84 marks in 24 hours at a temperature of 29$^o$C and humidity of 34%.
- The quality of the yarn would also improve in production and the difficulties associated with spinning and weaving of the cotton would be minimized. Getting the air condition plant working properly and delivering the correct temperature and humidity level, the factory can make huge turn over in product and returns on investment would be higher.
- The Legionnaire will grow in water at a temperature of 20$^o$C to 50$^o$C. However, the bacteria reproduce at the greatest rate in stagnant waters at temperatures of 35$^o$C to 46$^o$C. Legionnaire disease, therefore, could be controlled and contained under these range of temperatures if the right maintenance practices are carried out in the plant.
- It is therefore recommended that education be conducted on the causes and effects and control of Legionnaire disease. All refrigeration technicians, mechanics, engineers and students must be taught about this disease.

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**References**

[1] Brent, S.V. B. (1994). Indoor Air Quality and Textiles: An Emerging Issue. 46.
[2] Cunha, B. A., Burillo, A., & Bouza, E. (2016). Legionnaires' disease. *The Lancet*, *387*(10016), 376-385.

ISSN 2250-3153


[3] Fields, B. S., Benson, R. F., & Besser, R. E. (2002). Legionella and Legionnaires' disease: 25 years of investigation. *Clinical microbiology reviews, 15*(3), 506-526.

[4] Glick, T. H., et al. (1978). Pontiac fever: An epidemic of unknown etiology in a health department: I. Clinical and epidemiologic aspects. *American journal of epidemiology, 107*(2), 149-160.

[5] Lawson, E. (2015). 5 Health Problems caused by Air Conditioning. Retrieved from https://www.senioroutlooktoday.com/5-health-problems-caused-by-air-conditioning/

[6] Wiegerink, J. G. (1940). Effects of drying conditions on properties of textile yarns. *Textile Research, 10*(12), 493-509.

[7] Jennifer, R. (2019). Visual Guide to Legionnaires' Disease.

[8] Dvna Softech Private Limited. (2013). Air Washer Sections. From http://www.dvnasoftech.com/dvna/What-Is-Air-Washer.aspx

[9] Fraser, D. W, et. Al. (1977). Legionnaires' disease: description of an epidemic of pneumonia. New England Journal of Medicine, 1189-1197.

[10] The South India Textile Research Association (SITRA) (2008). Ambient Conditions in Textile Processing.

[11] Monhar, P. (2005). Refrigeration and Air Conditioning. 2nd Edition.



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