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Health and hygienic humidification

C A C Pickering and W P Jones

Technical Note TN 13/86

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PREFACE

This Technical Note brings together information on diseases which have been found to be associated with air conditioning systems. It also describes the humidification process in air conditioning and sets out good practice to achieve humidification without hazarding the occupants - that is the provision of safe humidification.

Part One covers the diseases associated with air conditioning. The author is Dr C A C Pickering, Consultant Chest Physician, Wythenshawe Hospital, who has had many years of practical and research experience of diseases and illnesses amongst building occupants.

Part Two deals with humidification and good engineering practice in the selection and avoidance of contamination in humidifiers. The author is Mr W P Jones, Consulting Engineer, who has had extensive experience in the design and operation of air conditioning systems. Mr Jones has also taken an active part in CIBSE Task Groups concerned with procedures to avoid health hazards in air conditioning.

The publication of this BSRIA Technical Note has been sponsored by The Colt Foundation which promotes and encourages research into social, medical and environmental problems created by commerce and industry. The Colt Foundation provided support for Dr Pickering and his colleagues to study the causes and medical attributes of humidifier fever and this work was the stimulus to this publication. Dr Pickering has presented the medical aspects of humidifier fever and other diseases associated with air conditioning in terms which should be understandable to the building services profession. Mr Jones has added his wisdom on air conditioning to provide straight forward guidance on humidification for the building services practitioner.

The support of The Colt Foundation is gratefully acknowledged and in particular the encouragement given to this project by Mr Jerome O'Hea of the Foundation.

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SUMMARY

This paper brings together descriptions of diseases associated with air conditioning and good practice in humidification in air conditioning systems. Its objective is to indicate the health hazards associated with humidification and to provide guidance to designers and maintainers of such equipment.

Diseases which have been known to arise in air conditioned buildings are described, and drawing on the few published case studies that exist the probable source of infection is indicated. In many of these cases the humidifier has been implicated. The medical symptoms of the diseases are also described.

The humidification process in air conditioning and available types of humidification equipment are outlined. Good practice in the selection and operation of humidifiers to avoid the possibility of these causing infectious contamination in air conditioning systems is set out.

Introduction

There has been some recent and growing concern that air conditioning systems could be responsible for spreading infections amongst building occupants. Some of this linking of ailments with the air conditioning systems is probably emotive rather than well founded, but there have been a few cases where the source of the infection in a building has occurred in the air conditioning plant. Two such diseases which have been linked to air conditioning are humidifier fever and legionnaires disease. Although an outbreak of these is very rare there is an onus on the air conditioning industry to ensure that systems are designed, operated and maintained to avoid the possibility of contamination occurring in the plant and the infection being spread throughout the building by the system. This technical note offers information and guidelines to see that infections via humidifiers are avoided in air conditioning.

Bacteria can colonise where surface moisture and nutrients occur and this happens, or can happen in humidifiers. It is also possible to colonise bacteria in cooling towers, warm water systems, showers, etc and for infections to arise from these. The main emphasis of this technical note however is the avoidance of infectious contamination of humidifiers as used in central air conditioning systems serving commercial and industrial buildings.

The provision of humidifiers in air conditioning has been based on the need for controlled relative humidities either for particular activities in buildings or for the comfort of the occupants. The normal comfort range for people is 40% - 70% RH. In some cold climate countries values lower than 40% are accepted, although these can cause electrostatic discharge problems.

These are good health reasons for providing controlled humidification. There is evidence that at below 40% RH the infection rate from airborne micro-organisms increases with the drying of nasal passages. Conversely very high relative humidities encourage the growth of mould and dust mites. Mid-range values of relative humidity are preferred.

The message for safe humidification is to ensure that bacteria are not cultivated. Surface water should be avoided or treated on the advice of a specialist. Particular operating temperature ranges also increase the risk of growth of certain micro-organisms. In the case of humidifier fever it is suggested that growth can occur in the range 4°C -35°C with greater hazards at the higher temperatures. With legionnaires disease the range to be avoided is 20°C - 46°C. Steam humidification is inherently safer but even these systems need careful design and maintenance.

The cases where a building infection has been traced to the humidifier are very few. Most systems seem to operate quite satisfactorily. However these few cases should make the industry aware of the potential health hazard that exists and to respond by following good practice to ensure safe humidification.

Part One
DISEASES AND AIR CONDITIONING

1. Diseases associated with air conditioning systems

There are two main categories of diseases which are associated with air conditioning systems. These are:

1) Infections (fungal, viral, bacterial).

2) Allergies (bronchial asthma, extrinsic allergic alveolitis, humidifier fever).

These diseases may arise in air conditioned buildings in a number of different ways. One is the circulation of live organisms, from a single infectious individual perhaps attached to droplet nuclei, which are then distributed in the room by the air circulation or by the return air system and recirculated through the air conditioning system to other parts of the building and so infecting third parties. Other ways are by the contamination of the ducting, or the humidification system by the growth of micro-organisms. The incoming air itself may be contaminated with micro-organisms, instances of this have been described (1) as a result of vapour drift into air intakes from nearby cooling towers and as a result of the excavation of contaminated land alongside an air intake to an air conditioning system. These infective problems are particularly likely to arise in a hospital situation where there is a population with potentially impaired immune defences.

2. Infections

Fungi, bacteria and viruses are classes of micro-organisms which can only be seen using a light or electron microscope. Viruses are the simplest and can only reproduce in living cells. Bacteria and fungi can be cultivated on artificial media. They differ with respect to their cell wall structures and the presence or absence of a nuclear membrane.

Various fungal, bacterial and viral infections have been described as arising from air being circulated by air conditioning systems.

2.1 Fungal infections

Fungal infections in man predominantly occur in a group of the population who are immunosuppressed. These include patients who are elderly, and those immunosuppressed by malignant disease or as a result of the treatment they are receiving for their malignant disease. It may also arise in individuals being treated with organ transplants who are deliberately immunosuppressed to prevent them rejecting their new organs.

Fungal spores are generally present in the atmosphere. They may become airborne as a result of excavation of soil and may also arise from bird droppings. The spores, when inhaled by an immunosuppressed individual, may grow in the lungs and produce a progressive type of pneumonia with disseminated spread through the body with abscess formation by the fungus in many varying organs. The resulting disease is difficult to treat and associated with a high mortality. Outbreaks of such diseases have occurred in renal transplant patients infected via the hospital ventilation system. In one case as a result of the contamination of an exhaust duct with pigeon droppings, infected by the fungal spore of aspergillus fumigatus. The bird protective grille at the outlet had been allowed to corrode and fall off and by chance the exhaust fan on this contaminated ducting had also failed. There were two other similar exhaust systems serving the Renal Transplantation Unit which were working and these caused air to be drawn into the contaminated exhaust ducting contaminating the air of the Transplantation Unit. Other outbreaks of respiratory disease associated with fungal spores have been described as a result of contamination of inlet filters which became coated with aspergillus spores finally penetrating the filter itself, or as a result of badly fitted inlet filters allowing fungal spores being generated from an adjacent building site to enter the ventilation system and the building itself.

2.2 Bacterial infections

Tuberculosis is a bacterial infection. It is a droplet infection spread from person to person, primarily as a result of coughing. It can be highly infectious and large numbers of people may be infected by one source case. An epidemiological study of an outbreak of tuberculosis in a US Naval vessel suggested that the disease was spread by the air conditioning system of the vessel (1).

Legionnaire's disease

This disease was first described in 1977 following an outbreak of pneumonia amongst a group of veterans attending a convention in a hotel in Philadelphia (2). The disease occurred both amongst veterans in the hotel in which the convention was held (Legionnaire's disease) and also in some passers by outside the hotel (Broad Street pneumonia). In the course of the investigation of this disease the gram negative bacteria which causes Legionnaire's disease was identified for the first time. However, the source of the outbreak was not identified. In view of subsequent experience it seems likely that the source arose from the air conditioning system of the hotel itself. The failure to identify the source of the organism was probably the result of the poorly developed methods of isolation of this organism used at that time.

The causative organism, Legionella pneumophila, can be grown from most surface waters and water supplies in this country. However, the organism, in order to produce disease, probably requires to be present in fairly large numbers. This is not achieved except at higher water temperatures such as are found in cooling towers and in other warm water systems. For example it has been found growing in hot water supplies and shower heads. The elderly and the immunocompromised appear to be specifically at risk.

The disease presents with an initial 'flu-like' illness associated with a sustained fever. During this period gastro-intestinal upset is frequently seen. The individual then goes on to develop a severe pneumonia, usually associated with mental confusion. It responds primarily to only two antibiotics which are not normally used as first line treatment in a community based pneumonia. As a consequence appropriate antibiotic treatment is often not instituted until late in the disease, which is a contributing factor to the high mortality which is associated with Legionnaire's disease.

Recommended prevention measures include the appropriate regular maintenance and treatment of cooling towers combined with the prevention of vapour drift from cooling towers entering the air inlet of air conditioning systems. Common drainage systems serving cooling towers, condensation trays and humidifier units in air conditioning systems should also be avoided to prevent the possibility of cross-contamination.

The legionnaire organism may also produce an entirely different symptom complex called Pontiac fever (3). Some years prior to the Philadelphia event an outbreak of respiratory disease had occurred in a health department in Pontiac, USA. In this outbreak, 95% of the employees in this building developed a benign, self limiting feverish illness. The incubation period of this illness was short, being 24-48 hours. The attack rates tended to be highest in those exposed in the morning rather than the afternoon or evening. This feature coincided with the switching on of the air conditioning system. The illness was characterised by 'flu-like' symptoms with generalised aches and pains, malaise and headache. There were no lower respiratory tract symptoms. These symptoms resolved after 5-6 days on no specific therapy. At this time an unidentified organism was isolated in guinea pigs infected by material from the air conditioning system. These combined with sera from infected individuals taken at ten day intervals (paired sera) were frozen and stored. Examination of these samples eight years later revealed the organism to be Legionella pneumophila and the paired sera of the infected individuals showed rising levels of antibody against this organism implying Legionella pneumophila to be the cause of this outbreak of Pontiac fever. An investigation of the air conditioning system had identified two possible ways in which the incoming air may have been contaminated by the organisms which were isolated from the water of the evaporative condenser. The exhaust air from this evaporative condenser discharged from the roof of the building and it was possible for this exhaust air to contaminate the fresh air intake of the building, either on the roof or through leakage paths between the exhaust air ducting and the air intake ducting. No outbreaks of Pontiac fever have been described in the UK associated with ventilation systems. The reason for the two totally different diseases apparently produced by the same organism remains unexplained.

2.3 Viral infections

There have been outbreaks of viral infections, such as measles spread in schools, apparently from a single source case via the ventilation system. The virus is distributed as droplet nuclei. These small particles are formed from the evaporation of large particles expelled by infected individuals coughing or sneezing. Droplet nuclei have the capacity to remain suspended in the air for long periods of time, unlike dust or droplets which rapidly settle out of the circulating air.

Anecdotal evidence from individuals moving from naturally ventilated to air conditioned offices suggest that upper respiratory tract infections are both more frequent and prolonged in air conditioned offices. This may be occurring simply as a result of direct contact with many individuals in a large open plan office or by the circulation of virus particles through the ventilation system.

3. Allergies

3.1 Asthma

Asthma was first identified as being caused by a humidification system in the United States where an outbreak of bronchial asthma occurred in a family using a cool mist vapouriser in their home. The vapouriser had become contaminated by a fungus of the Rhodotorula species. When the cool mist vapouriser was turned on there was a rapid rise in viable organisms and spores in the air of the room. This was associated with exacerbations of asthma in a number of members of the family. Subsequent investigation of this type of humidifier in a variety of different homes revealed frequent contamination of the unit by fungi and bacteria.

Outbreaks of occupational asthma have also occurred as a result of contamination by micro-organisms of cold water spray humidifiers in air conditioning systems. The occupational nature of the workers' asthma was confirmed by regular measurements of lung function at home and at work, which demonstrated the presence of airways obstruction at work, improving when away from work at home.

In one investigation the relationship between the individual's asthma and the humidifier at work was clearly demonstrated when the mains water supply to the building burst halfway through a month's recordings of peak expiratory flow rates (PEFR). The burst was not repaired and the air in the building was subsequently not humidified. Since it is believed that the causative agent is microbial in origin and the maximum concentrations are to be found in the humidifier sump, the airborne levels of antigen in the building should fall in the absence of humidification. This individual's asthmatic symptoms and his measurements of PEFR improved as soon as humidification ceased. Another investigation showed that the cleaning of the humidifier was followed by an improvement in asthmatic symptoms in the majority of those affected. However, the unit rapidly became recontaminated, despite the use of biocides, with a recurrence of the occupational asthma in those affected. It was necessary finally to completely replace the cold water spray humidifier with a steam humidification system in order to alleviate the asthmatic symptoms.

3.2 Extrinsic allergic alveolitis (hypersensitivity pneumonitis)

This group of respiratory diseases are allergic in origin and predominantly affect the peripheral gas exchanging part of the lungs and the small terminal airways supplying the gas exchange area. Disease results from the inhalation of the spores of various different types of micro-organisms. It is associated with many different types of occupation, the particular occupation determining the organism involved. However, the characteristic symptoms and physical signs are common to all the causative organisms. In the United Kingdom it is most frequently seen amongst farmers, mushroom workers and bird fanciers.

The organism responsible for farmers' lung is a thermophilic actinomycete, Micopolyspora faeni. This same organism has been described in the USA contaminating both air conditioning systems in offices and in homes, producing an identical disease to farmers' lung although the individual may never have been near a farm in his life. The symptoms that occur in an individual are determined by his type of exposure. Given a low dose continuous exposure to the antigen he suffers from chronic symptoms of progressive breathlessness and often when first seen by a doctor has advanced lung damage. If exposed intermittently to a moderate or heavy exposure of the antigen, then he may suffer acute symptoms clearly identified as being occupational in origin. Characteristically his symptoms will develop 3-4 hours following his exposure. The initial symptoms are of a 'flu-like' illness with a fever, generalised aches and pains progressing after 5-6 hours to breathlessness sometimes associated with a cough. These symptoms will then resolve, if no further exposure is encountered over the next 12-24 hours. Physical examination in the acute stage of the disease reveals an individual who is feverish, sometimes breathless at rest and, listening to their respiratory tract characteristically reveals crackles towards the end of a breath in. Lung function tests also show a characteristic pattern with small lung volumes and impairment of gas transfer. Almost all outbreaks of this type of disease which have been described associated with air conditioning systems have occurred in the USA. Recently the first outbreak of allergic alveolitis associated with a cold water spray humidifier has been reported in the United Kingdom. The specific organism in this outbreak of disease has not been identified. Tests in hospital involving inhalation of crude material taken from the walls of the humidifier reproduced the individual's disease. Thermophyllic actionoycetes, the organism most frequently implicated in the United States, was not isolated from this particular humidifier and it is likely that the temperature of the water would not promote their growth. Early identification of the particular type of respiratory illness is important, since it leads to lung damage characterised by pulmonary fibrosis, which is then irreversible.

3.3 Humidifier fever

This condition was first described in the late 1950s by a Swiss physician (4), who reported an outbreak of systemic and respiratory symptoms amongst a group of workers in a carpentry workshop, which was found to be due to a contaminated humidifier. The symptoms of humidifier fever are again delayed in onset, developing 5-6 hours after starting work. They vary considerably in severity from a low grade fever, associated with muscle pains and a headache to severe influenzal type symptoms, a high fever and severe breathlessness. The symptoms are similar to those of an allergic alveolitis. An unusual feature of this respiratory illness is its periodicity across the working week. The symptoms which these individuals experience occur only on the first day of the working week, the individual being able to work without symptoms over the remainder of the week. In persons working a seven day week with no interruption from the workplace the symptoms of humidifier fever do not occur. The respiratory physiological changes are similar to those seem in an allergic alveolitis. A further major difference is that whereas in allergic alveolitis there are characteristic x-ray changes, in humidifier fever, even with radiographs taken at the height of the illness, no x-ray abnormalities are demonstrable. The changes in this condition also appear to be completely reversible, such that even in individuals exposed with symptoms for a number of years, no residual abnormalities of lung function have been demonstrated. A characteristic finding in humidifier fever is the presence of precipitating antibodies directed at extracts made from material taken from the humidifier (humidifier antigen). These antibodies although found in most affected individuals are not diagnostic of the disease since they are detectable in a significant proportion of unaffected but exposed persons. They are not found in control subjects working in naturally ventilated buildings or in buildings with uncontaminated ventilation systems.

The cause of humidifier fever has not been identified. It tends to occur in cold water spray humidifiers which have become heavily contaminated with micro-organisms. There have been a number of suggested causes where individual micro-organisms have been identified on the basis of the presence of specific antibodies present in those affected. These organisms include the amoeba - naegleria gruberi, a bacteria - bacillus subtilis and the endotozin of cytophaga species and flavo bacterium. However, no challenge tests have been carried out with these organisms to actual confirm that they are the cause of the symptoms of humidifier fever. It has, however, been clearly established that the cause lies within the cold water spray humidifiers, since extracts of both water and solid material taken from contaminated humidifiers will reproduce the disease when the affected individuals are challenged in a laboratory situation. The control of outbreaks of humidifier fever has proved difficult. Of primary importance is maintaining the cold water spray humidifiers free of contamination with micro-organisms. Biocides are frequently used to control the growth of gram negative bacteria in cold water spray humidifiers. In one outbreak, in which the author was involved, the symptoms of humidifier fever continued despite the introduction of biocides into the system. Indeed the introduction of chemicals into these systems is itself potentially undesirable, since the long term effects of exposure to working populations of these chemicals is unknown. Of fundamental importance in this problem is the design of the humidifier chambers, so that they can be easily maintained and cleaned and the presence of stagnant water should be avoided. This latter feature appears to be essential in the development of the symptoms of humidifier fever. The selection and maintenance of humidifiers to avoid the occurrence of humidifier fever are discussed in Part Two.

Part Two

GOOD HUMIDIFICATION PRACTICE

4. Methods of humidification

Fundamentally, two methods of humidification are in use in air conditioning: the evaporation of liquid water and the injection of dry, saturated steam. The heat transfer processes and the temperatures involved are different and this is significant when considering the risks of humidifier fever.

4.1 The evaporation of liquid water

This method has been used throughout the world for many years, principally to reduce the temperature of an airstream by evaporative cooling but also to achieve a necessary control over humidity for certain industrial applications. The airstream to be humidified is passed over a very large wetted surface area, usually provided by an enormous number of water droplets in a spray chamber of some sort.

The physics of the heat and mass transfer may be seen by considering the simple case of a single droplet of water and assuming it to be completely evaporated by the airstream. A mass balance may be established:

$$M_1 + M_w = M_2 \qquad (1)$$

wherein M_1 is the mass of air and water vapour approaching the droplet, M_2 the mass leaving it, and M_w the mass of water droplet completely evaporated into the airstream. It is further necessary to strike an energy balance:

$$H_1 + H_w = H_2 \qquad (2)$$

in which H_1 and H_2 are the initial and final enthalpies of the airstream and $H_w$is the enthalpy of the evaporated water. Equations 1 and 2 can then be used with an equation for the enthalpy of an air-water vapour mixture to determine the temperature of the leaving airstream. With the important assumption that the water droplet is totally evaporated, it can then be shown (5) that the change of state of the airstream as it undergoes such a process of humidification is virtually along a line of constant wet-bulb temperature, on a psychrometric chart. Figure 1 illustrates this. The initial temperature of the droplet of water exercises very little influence on the slope of the process line. The sensible heat component of the liquid is only a small part of the enthalpy of water vapour and, as the evaporation proceeds, the temperature of the drop approaches an equilibrium value equal to the wet-bulb temperature of the airstream. Figure 1 shows that, between the possible water temperature limits of 0°C and 100°C, the angular displacement of the lines representing the extremes of the humidification process is only about 7° on the CIBSE Psychrometric Chart.

In the more common, practical case where a very large number of tiny droplets are produced by atomisation in a spray chamber through which air is flowing, most of the droplets are not entirely evaporated and fall into a collection tank for subsequent recirculation through the atomising nozzles. The recirculation rate of spray water flow is of the order of 1000 times the evaporation rate and the influence of the water temperature on the slope of the humidification process line becomes very great. For example, if the recirculated water is mechanically chilled the water droplets can be maintained at a temperature that is below the dew-point of the entering air and a process of dehumidification will occur. It is only when the recirculated spray water is neither chilled nor warmed that the process of humidification is along a wet-bulb line. Such a process is commonly termed adiabatic saturation.

These considerations of the physics of humidification are relevant to a study of humidifier fever or Legionnaires' disease because it is the temperature of the stored water which will indicate whether the growth of the associated micro-organisms is likely, or even possible, in the climate of the UK.

In the southern parts of the UK the maximum wet-bulb temperature seldom exceeds 20°C and is less than this for more than 99% of the time. In fact, the design value generally adopted for air conditioning systems in the London area is 19.5°C. If the lower limit for the significant multiplication of the Legionnella pneumophila bacillus is taken as 20°C it follows that mechanical ventilation systems using spray chambers for the humidification of outside air will introduce virtually no risk of Legionnaires' disease. In the northern part of the country the risk will be even less because outside wet-bulb temperatures will be lower.

With air conditioning systems the use of spray chambers has been rare for many years (although many old installations may exist) but, even when used today, water would be mechanically chilled to temperatures in the range of 7°C to 15°C to achieve the aims of the system. The real risk arises however if the airstream leaving a nearby cooling tower can enter the outside air intake of the air conditioning system. This is because the water in the cooling tower can be at a temperature well above 20°C.

On the other hand, there is a risk of humidifier fever with humidification methods relying on the evaporation of water in spray chambers or from wetted surfaces because the micro-organisms causing it appear to thrive in a temperature range of 4°C to 35°C.

4.2 The injection of dry steam

If dry, saturated steam is injected into an airstream that is not at 100% relative humidity, humidification will occur. A simple, theoretical examination, assuming all the injected steam is accepted by the airstream, is again based on establishing equations for a mass and energy balance, similar to equations 1 and 2, and using an equation for the enthalpy of an air-water vapour mixture to determine the state of the airstream leaving the humidification chamber (5).

The change of state of the airstream as it undergoes humidification by a process of steam injection is virtually up a line of constant dry-bulb temperature on a psychrometric chart.

The angle made with the dry-bulb line is about 4° in the region of the chart in everyday use, as Figure 2 shows. The enthalpy of the injected steam influences the inclination of the process line to the line of constant dry-bulb temperature. The lowest pressure at which it is possible to inject steam is marginally above atmospheric and this sets the lower temperature limit for the process at 100°C. The upper limit is set by the fact that saturated steam has its highest enthalpy at a pressure of about 30 bar, with a corresponding saturation temperature of approximately 234°C. Figure 2 shows these two limiting process lines for the injection of steam and it is seen that the angle between them is also about 4°. If the steam were superheated, the angular displacement would increase and, similarly, if the steam were wet it would decrease, eventually tilting in the opposite direction away from the dry-bulb line towards the wet-bulb line.

Clearly, as long as the injected steam is dry (or slightly superheated) and is entirely accepted by the airstream, there is no risk of humidifier fever or Legionnaires' disease. The steam is at a temperature exceeding 100°C and is sterile. No unevaporated water droplets enter the airstream. If the steam is not completely absorbed, either because too much is injected or because the humidity of the airstream is already too close to saturation, then puddles are likely to form in the ductwork or plant downstream. Such puddles will take up a stable temperature between the wet and dry bulb temperature of the airstream (less than 20°C because the wet-bulb of the airstream will be less than this) and there may be then a chance of the growth of micro organisms, in the presence of suitable nutrient materials. This may be a consequent small risk of humidifier fever, but not of Legionnaires' disease. It is evident that puddles of condensation must be avoided at all costs.

5. Types of humidifier

There are many types of humidifier on the market and the following types are some of those in more common use.

5.1 Units that evaporate water

a) Unheated pans

A trough of water is fixed to the underside of the duct and is fitted with the usual float-valve, overflow and drain. Absorbent material in the form of vertical fins may be positioned in the water and arranged to project into the airstream in order to increase the wetted surface area and so the humidifying efficiency. The process of humidification is one of adiabatic saturation along a line of constant wet-bulb temperature but the efficiency and rate of humidification is poor.

Such humidifiers are virtually pools of stagnant water. Scale and the product of corrosion plus dust from the airstream eventually pollute the water, unless the maintenance is very good, and provide suitable conditions for colonies of micro-organisms to develop, with a clear risk of humidifier fever.

b) Wetted elements

These are self-contained units comprising a centrifugal fan, shallow sump for the collection of unevaporated water, pump, water distribution system and a fill of some suitable material. The fill provides a very large wetted surface area and may be an open textured material (cellulose, plastic, metal etc.) over which water flows by gravity, being recirculated by the pump from the collection tank to the top of the fill. The unit may be attached to an air handling plant or a duct system or it may be located directly in a room. Adiabatic saturation occurs and there are excellent opportunities for the culture of objectionable micro-organisms unless the maintenance is excellent.

Other versions of this type of humidifier use a rotating drum that is usually covered with an absorbent, plastic material such as polyurethane foam, which passes through the water in the sump and then into the airstream.

With any of these types of wetted surface humidifiers, good maintenance and thorough cleaning are difficult because of the absorbent nature of the wetted material used for humidification. The risks of humidifier fever caused by micro-organisms remaining in the material, even after cleaning, must be significant.

c) Capillary cell air washers

These are full-scale air washers, forming part of an air handling plant. A large wetted surface is provided by using wetted cells, arranged diagonally across the airstream. Water is recirculated from a sump and distributed over the upper surface of the cells. The cells contain very large numbers of glass fibres, arranged parallel to one another and to the direction of air and water flow. The intimate contact between the airstream flowing through the cells and the wetted surface of the glass fibres produces a high humidifying efficiency. The process is one of adiabatic saturation.

Many problems of scaling (particularly in hard water districts) and the growth of slime have been reported in the past and washers of this type must be regarded as a significant risk.

d) Atomisation units
A stream of water is atomised by coming into contact with a rotating disc. Air flows through the mist of fine water droplets produced and adiabatic saturation occurs. With the majority of spinning disc humidifiers it is arranged that any water not evaporated falls into a collection tray and is drained to waste, downstream elimination plates assisting in this. If the unit works as intended there should not be any pools of unevaporated water. However, elimination plates are never 100% efficient and perfect drainage from the collection tray may not always occur. A question mark must remain against such humidifiers.

Other methods of automation are adopted and humidifier units and systems are available for commercial and industrial applications in various forms. In all cases the risk of humidifier fever must be dependent on the chances of stagnant pools of water forming and the quality of the maintenance.

e) Conventional air washers
A washer consists of a spray chamber in which a cloud of finely divided water droplets is produced by recirculating water from a sump in the bottom of the chamber. The recirculated water is atomised by pumping it through an array of nozzles across the section of the chamber. Several arrays of nozzles may be present, blowing spray water up or downstream or in opposition. A ball valve for cold water make-up from the mains is provided, together with a quick fill connection, drain and overflow. The humidification process is one of adiabatic saturation (unless the water is mechanically chilled).

The risk of the growth of colonies of micro-organisms is great and can only be dealt with by the most painstaking maintenance.

f) Sprayed cooler coils
These are similar to air washers. The difference is that the nozzles do not atomise the water recirculated from the sump tank but, instead,

distribute it over the face and depth of a cooler coil. The water drains down the fins of the cooler coil into the sump for recirculation. The very large wetted surface of the fins provides the source of humidification. Adiabatic saturation occurs except when chilled water flows through the tubes of the coil. This then gives a downward bias to the temperature of the recirculated spray water towards 7°C. Very stable control of the dew-point of the airstream is possible owing to the thermal inertia provided by the large mass of water in the sump.

The unit is bulky, expensive and prone to corrosion and scaling problems. Good maintenance is essential to combat this and to deal with the growth of slime. The risk of humidifier fever is the same as with air washers.

5.2 Dry steam injection methods

a) Steam generated at a central boiler plant

One or more jacketed steam pipes span the duct. Dry steam is fed both to the steam supply pipes (whence it is injected into the ducted airstream) and to their jackets. Figure 3 illustrates the arrangement. The purpose of the jacket is to surround the injection pipe with steam at the same temperature as that of the saturated steam injected. In this way no condensation will occur in the injection pipe and only dry steam will be fed into the ducted airstream. The airstream cools the jacket, however, and condensate forms at about 100°C within it which can then be returned to the boiler through a trap in the usual way.

The humidification process is virtually at a constant dry-bulb temperature if the steam is dry and not superheated. It is important that the steam supply and condensate drainage systems, both for the supply pipe and its jacket, are properly sized and controlled. It is desirable that a pressure-reducing set be included to ensure that the steam used for injection is quite dry. It is also important that the location chosen for the steam injection into the ductwork is one where the relative humidity is at a value that can accept all the dry steam injected.

There is no risk of humidifier fever when properly selected, installed and controlled.

b) Steam generated locally

This is similar to (a) above except that a small electrode boiler generates dry, saturated steam at a location close to the duct or air handling unit where the steam is to be injected. For this method to be successful the length of steam pipe between the generator and the place of steam injection must be kept to a minimum to avoid the risk of the steam becoming wet before injection. It is again vitally important that, at the place chosen for steam injection, the airstream must be at a relatively humidity that can accept the dry steam.

Properly selected, installed and controlled there is no risk of humidifier fever.

c) Steam pan humidifiers
Several proprietary units are available for steam injection in different forms. Some have performed with varying degrees of success, often partly due to imperfect installation and control. In principle, all are the same: a pan of water in the bottom of the duct is kept heated to a temperature of about 90°C and this is raised to 100°C to give boiling and steam injection when required under automatic control. There appears to be a chance that water droplets may be carried into the airstream, with the steam, in the case of some units. If this water carryover can be excluded, humidification should be safe if the units are properly selected, installed and controlled.

6. Safe humidification

All humidifiers that operate by injecting small droplets of water into the airstream or by exposing the airstream to a wetted surface, are intrinsically a risk, some more so than others. The risk is greatest when water is recirculated from a tank but is also present when puddles of water can collect downstream of the humidifier.
The following engineering recommendations are made:

1. Dry or slightly superheated steam injection should be used for all humidification purposes.

2. Spray water humidifiers and wetted surface humidifiers - particularly those using recirculated spray water - should not be used, except where the technical needs of the system make any other method unacceptable.

3. When spray humidifiers using recirculated spray water have to be used, for technical reasons, then an automatic flushing system, as described below and as illustrated in Figure 4, should be incorporated. The automatic flushing system shown in Figure 4 should be designed to operate during every 24 hours, within the off-period, according to the following sequence:

   a) A time switch starts the sequence

b) The recirculation spray pump is switched off

c) Two-position inlet valve, V_i (normally open) is closed

d) Two-position drain valve, V_d (normally closed) is opened

e) The sump tank empties under gravity

f) After a calculated time (to make sure the tank is empty) the drain valve, V_d, is closed

g) The inlet valve, V_i, is opened

h) The tank fills

i) After a calculated time (to make sure the tank is full) the recirculation spray pump is started and runs for a sufficient time to circulate all the water in the tank 3 times, or for 5 minutes, whichever is the greater time.

j) The recirculated spray pump is switched off

k) Sequence (c) to (j) is repeated

l) The plant is returned to normal operation.

When plants must run for 24 hours it should be arranged that humidity control be sacrificed once in every 24 hours, in the least critical period, so that the above sequence can be carried out. If this is not possible, then a continuous bleed should be provided and balanced to give a continuous blowdown, equal to 6 recirculated water tank changes, in every 24 hours, in addition to any other bleed provided.

4. Eliminator plates must be fitted on the downstream end of all spray water and wetted surface humidifiers, where these are used, and arranged to drain properly into the sump tank. Eliminator plates must be accessible for regular cleaning.

5. Water treatment must be provided for all recirculatory spray water and wetted surface humidifiers to deal with scale and corrosion and specialist advice should be taken.

6. Proprietary biocides should not be used as a continuous water treatment, because of the possible risks to human health they may introduce.

7. The water tanks, eliminator plates, baffles and wetted surfaces of all recirculatory spray water and wetted surface humidifiers must be thoroughly cleaned and maintained at least once in every three months. Under no circumstances must algae or slime be allowed to form. Slime and algae must be diligently scrubbed away and sodium hypochloritie solution (household bleach) liberally applied, scrubbed into the contaminated areas and then rinsed away with generous quantities of clean, fresh, cold water. The specialist advice for water treatment must take account of the periodic use of bleach for slime control and its possible effect on scale formation or corrosion.

8. Sprayed water cooling coils should have their finned surfaces and their elimination plates cleaned with steam lancing at least once in every three months.

9. Water piping distribution systems, including pumps, strainers, nozzles and all other components must be regularly inspected, cleaned and kept free of dirt, scale, the products of corrosion and any other debris. Components must be replaced when necessary.

10. Proper water levels in sump tanks, spray pressures and bleed rates must be maintained.

11. When dry steam injection is used for humidification the injection pipe should be jacketed with saturated steam at the same pressure, properly controlled and trapped, to ensure that no condensate droplets are distributed into the airstream.

12. The steam distributed from a central boiler plant to an air handling unit for humidification should be passed through a pressure reducing set to ensure it is dry, or slightly superheated, before injection at the humidifier.

13. Steam injection should be done at a position in the ventilation or air conditioning system where the relative humidify of the airstream is at a value that can accept the injected steam without the formation of water droplets.

14. The set-points and differential gaps or proportional bands of the humidistats controlling steam injection should be selected so as to be compatible with the proper control of the injected steam and the absolute avoidance of liquid water droplets in the humidified airstream.

15. The humidification and dehumidification systems should be interlocked so that their simultaneous operation series is not possible.

16. If close control over humidity is necessary, for industrial purposes, it should be coupled with correspondingly close control over temperature to ensure the stable operation of the humidification system.

17. Spray water or wetted surface humidifiers must not be used directly in the conditioned space.

18. The proper safety precautions must be taken and proper safety procedures adopted for all humidification and water treatment systems.

19. The effluent and/or blow-down from water treatment systems must only be discharged into the sewers with the approval of the relevant authority.

20. The design and installation of all humidification and water treatment systems must be such that back-siphonage and/or contamination of any other water service is impossible.

21. Ductwork and plant must be adequately lagged where steam injection is provided for humidification.

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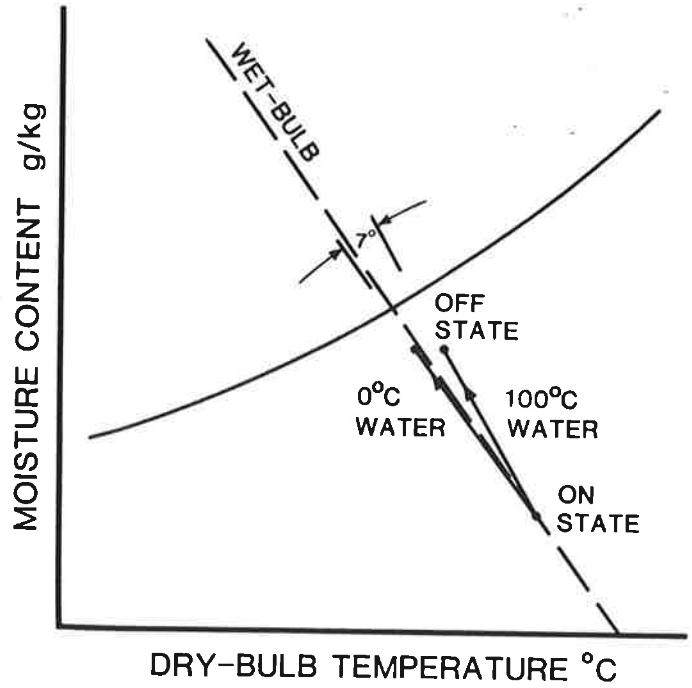

FIGURE 1: Spray water injection

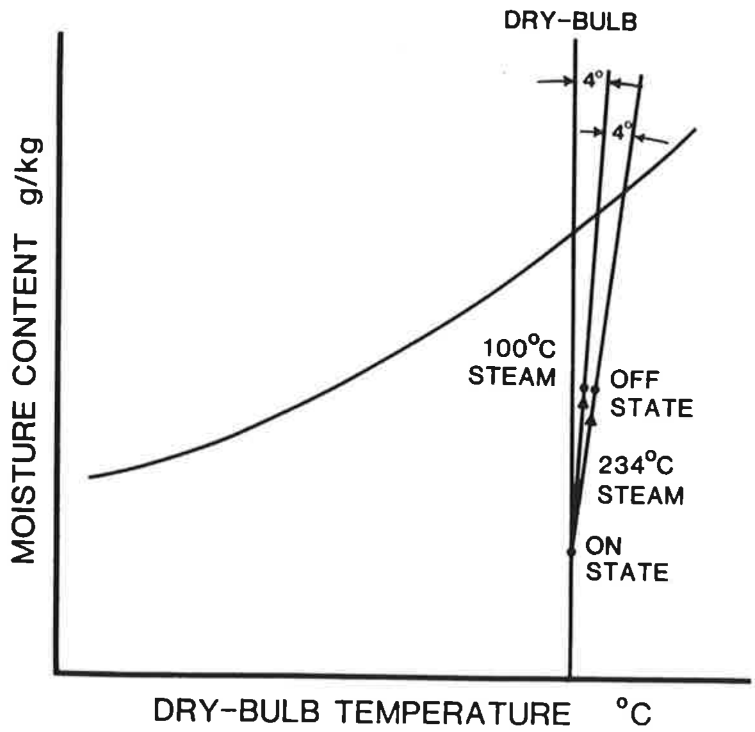

FIGURE 2: Dry steam injection

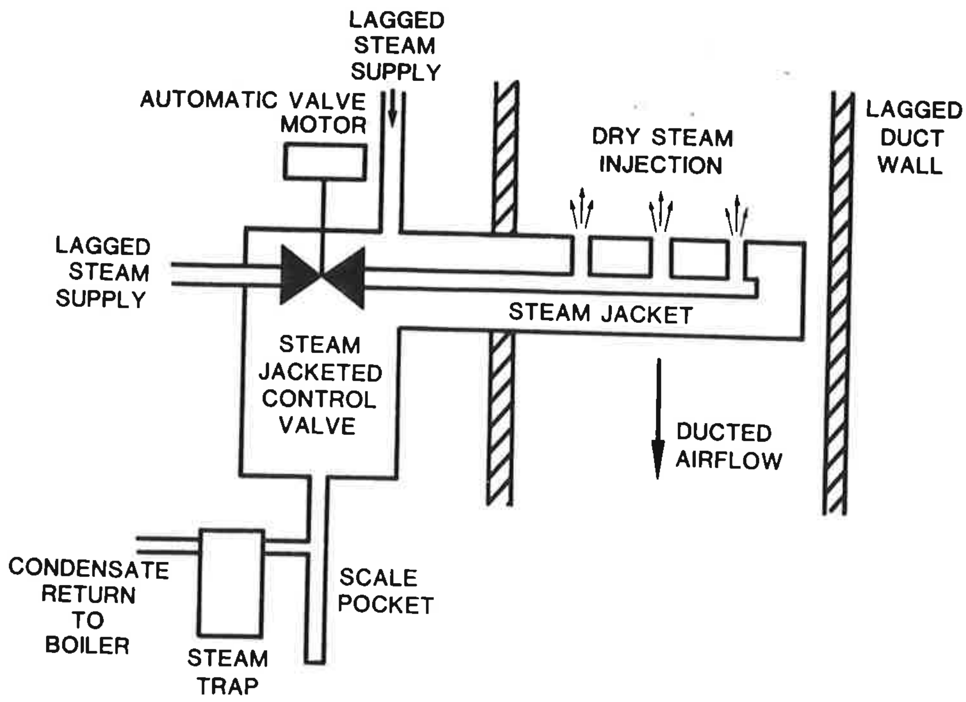

FIGURE 3: Diagrammatic arrangement of dry steam injection

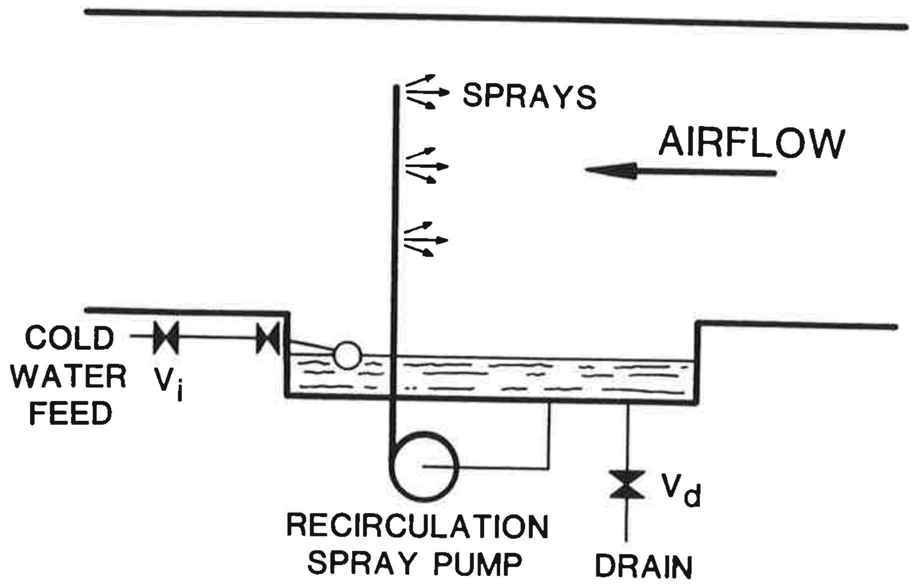

FIGURE 4: Automatic spray water flushing arrangement

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