White Paper

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Condair Stainless Steel Air Gap Insulation

Introduction

Every system should be designed to operate at optimum efficiency in order to reduce energy use and operational costs, and steam humidification systems are no exception.

One of the most common methods of steam humidification is to directly introduce steam into the duct work of a building. This is typically done using distributor tubes or manifolds. As can be seen, depending on the type and size of distributor used, a steam humidification system can lose as much as 15-20% of its output in the form of condensate. Condensate losses result in decreased efficiency and lower humidifier output which means that systems may need to be oversized in order to meet the required humidification load. Additionally, heat from the distributor can be transferred to the air stream resulting in unwanted air stream heat gain. In order to prevent these effects, the distributor can be insulated to prevent heat transfer to the air and surroundings.

Nortec's stainless steel air-gap insulation is one of the most effective steam distributor insulation technologies on the market today. Typically when insulation materials are compared, the thermal resistance or R value is often used. However the R value alone doesn't provide the whole picture. As this whitepaper will demonstrate, it is important to consider the system performance as a whole to ensure that it is as efficient as possible.

Thermal Conductivity (k) vs. Thermal Resistance (R)

The *thermal conductivity, k*, is a measure of a materials ability to transfer thermal energy or conduct heat, and is measured in units of Btu/hr · °F · ft. For example, a material with a thermal conductivity of 1 Btu/hr · °F · ft means that it will transfer heat at a rate of 1 Btu/hr, through an area of 1 sq. ft. and a thickness of 1 ft. The thermal conductivity depends only on the physical structure of the matter, meaning that it is independent of the physical dimensions of the insulation.

The *thermal resistance, R,* is a measure of a materials ability to resist thermal transfer, and is measured in units of ft · °F · hr/Btu. The thermal resistance is dependent on the thermal conductivity, as well as on the length, thickness, and geometry of the insulation.

An analogy can be made between the diffusion of heat and electrical charge. The conduction of electricity is dependent on the electrical resistance, just as the conduction of heat is dependent on the thermal resistance.

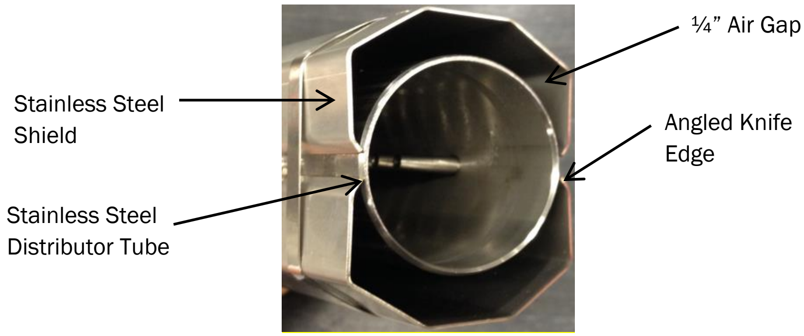

Figure 1: Cross Section of Insulated Distributor Tube

There are three modes of heat transfer that can affect the performance of a distributor: conduction, convection, and radiation.

Nortec’s stainless steel air gap insulation is designed to address all three using a combination of stainless steel shielding and air.

The primary method of heat transfer for steam distributors is convection. In order to reduce this effect, the stainless steel shield creates a ¼” air gap between the distributor and the shield. The air gap is sized to provide excellent thermal resistance, which prevents heat loss from the distributor and minimizes the convection to the airstream. As well, the air gap is designed to prevent the formation of any significant convection currents within the shields which could reduce performance.

There are small angled ‘knife edges’ in the stainless steel shield at the point of contact with the tube. Since this is the only point of contact, the small surface area of the shield’s cross section allows for minimal conductive heat transfer between the two materials.

Heat transfer through radiation accounts for only a small fraction of the total and is minimized through the smooth, reflective surface of the stainless steel shield.

In order to calculate the R value for a system that is composed of multiple materials, such as the stainless steel air gap insulation, the individual R value for each material must first be calculated. Once each individual value is calculated, they are combined while taking into account whether the heat is flowing in series or in parallel through each material. The result is called the overall thermal resistance.

Using methods presented in *Fundamentals of Heat and Mass Transfer, 6th edition, F.P. Incropera* [1], Nortec has calculated and validated using real-world testing, the overall thermal resistance of stainless steel air gap insulation to be:

$$R_{Overall} = 0.66 \frac{ft \quad {}^{\circ}F \cdot hr}{Btu}$$

What Does it Mean?

The R value can be used to indicate how effective a material or system is at preventing heat transfer; however, it does not really tell us much about system performance. In order to properly size a humidification system it is necessary know the required load, which should also include steam line and distributor losses.

In addition to the R value, a very easy way to illustrate the effectiveness of the stainless steel air gap insulation is to compare the condensate losses between an uninsulated and insulated distributor. Knowing the condensate losses for both will allow the user to calculate the associated operational cost savings.

Figures 2 and 3 below show the condensate losses per linear foot of tube for uninsulated and insulated distributor tubes and headers at various temperatures and duct velocities.

The following example is an excerpt from our white paper entitled “Insulating for Efficiency – Improving Energy Efficiency in Steam Humidification Applications” which explains how to calculate total condensate losses as well as operational cost savings for both uninsulated and insulated distributors. The full white paper is available for download directly from our website at www.humidity.com.

Table 1: Combined Losses Example

Design Conditions:	New York City JFK AP Annual (O°F and 50% RH)
Total Volume:	30,000 CFM
Outside Air:	24,000 CFM
Return Air:	6,000 CFM
Space Conditions:	72°F and 35% RH
Duct Temperature:	55°F (Before Humidifier)

In this example, air in the duct will be flowing at 1000 feet per minute and will be maintained at 55°F. The calculated humidification load is approximately 125 lbs/hr.

A) Uninsulated Distributor

1. First, the specific losses for the tubes can now be found by referencing Figure 2 below. At 1000 feet per minute and 55°F duct temperature, the uninsulated tubes would lose **0.44 lbs/hr per linear foot.**

2. Next, the size and quantity of the distributor tubes must be established. The duct height is 60 inches and 12 inches must be deducted for header height; thus tubes **48 inches long** are required. At 6 inch center to center tube spacing, **11 tubes** are required.

Figure 2 shows the condensate losses per linear foot of tube for uninsulated and insulated distributor tubes various temperatures and duct velocities.

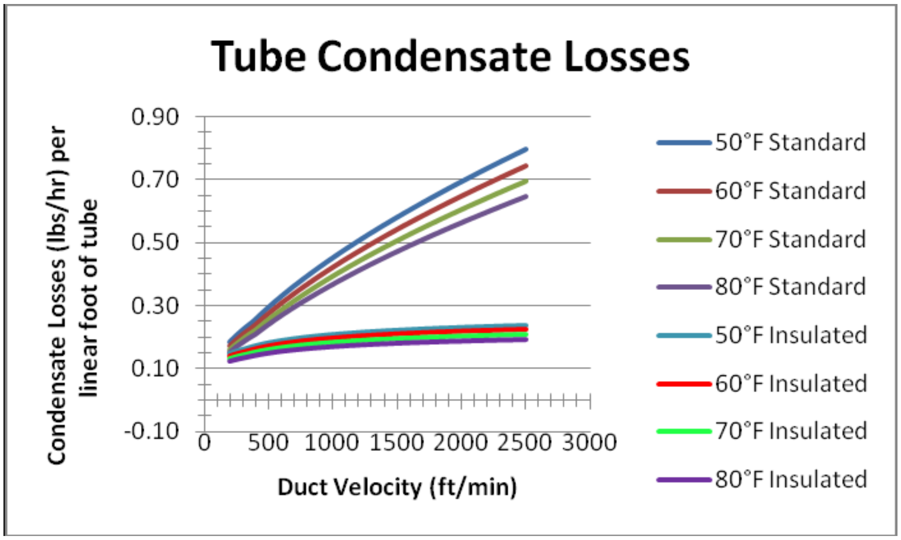

Figure 2: Condensate Losses per Linear Foot of Tube

3. Next the linear length of the tubes must be calculated for use with the Figure 2.

11 tubes x 48 inches = 528 inches = **44 linear feet of tube**

4. Multiplying to find the total tube losses:

$$\text{Uninsulated Losses} = 44 \text{ ft} \times 0.44 \frac{\text{lbs}}{\text{hr} \cdot \text{ft}} = \mathbf{19.4} \ \frac{\textbf{lbs}}{\textbf{hr}}$$

5. Next the header losses must be considered. The header length in this case will be approximated as the duct width. This is a reasonable approximation as it accounts for the square condensate boxes at each end of the header as well as the round header tube. Thus the header length is 72 in, or **6 ft.**

   Figure 3 shows the condensate losses per linear foot of tube for uninsulated and insulated headers various temperatures and duct velocities.

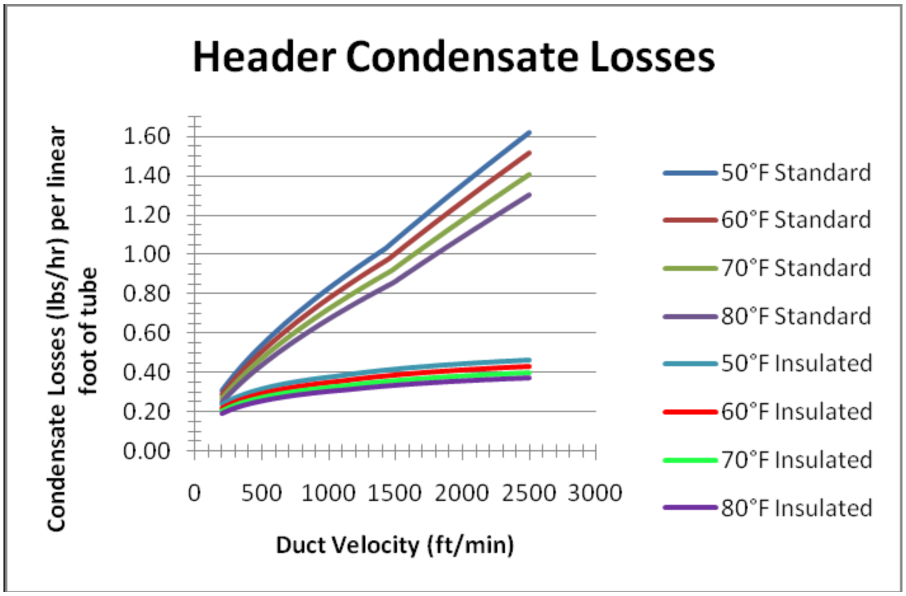

Figure 3: Condensate Losses per Linear Foot of Header

6. From Figure 3, at 1000 feet per minute and 55°F the specific losses would be 0.80 lbs/hr per linear foot.

7. Header losses can be determined by multiplying by the length:

$$\text{Uninsulated Losses} = 6\text{ ft} \times 0.80\,\frac{\text{lbs}}{\text{hr}\cdot\text{ft}} = \mathbf{4.8}\,\frac{\mathbf{lbs}}{\mathbf{hr}}$$

8. Combining the header and the tubes the total losses for this configuration can be determined:

$$\text{Uninsulated Losses} = 19.4\,\frac{\text{lbs}}{\text{hr}} + 4.8\,\frac{\text{lbs}}{\text{hr}} = \mathbf{24.2}\,\frac{\mathbf{lbs}}{\mathbf{hr}}$$

B) Insulated Distributor

1. The above case can be repeated for the insulated distributor. The insulated distributor would be dimensionally identical to the uninsulated header, however the specific losses for the tubes and header will change. From Figure 2, the tube losses are found to be **0.20 lbs/hr per linear foot of tube.**

2. Multiplying through to find the total insulated tube losses:

$$\text{Insulated Losses} = 44\text{ ft} \times 0.20\,\frac{\text{lbs}}{\text{hr}\cdot\text{ft}} = \mathbf{8.8}\,\frac{\textbf{lbs}}{\textbf{hr}}$$

3. Likewise from Figure 3, the header losses are found to be 0.36 lbs/hr per linear foot. Multiplying by header length gives the total insulated header losses:

$$\text{Insulated Losses} = 6\text{ ft} \times 0.36\,\frac{\text{lbs}}{\text{hr}\cdot\text{ft}} = \mathbf{2.2}\,\frac{\textbf{lbs}}{\textbf{hr}}$$

4. Finally, summing the losses from the header and tubes gives the total losses for the insulated distributor:

$$\text{Insulated Losses} = 8.8\,\frac{\text{lbs}}{\text{hr}} + 2.2\,\frac{\text{lbs}}{\text{hr}} = \mathbf{11.0}\,\frac{\textbf{lbs}}{\textbf{hr}}$$

A quick comparison of the total losses illustrates the effectiveness of the insulated distributor:

Uninsulated Losses: **24.2 lbs/hr**
Insulated Losses: **11.0 lbs/hr**

This means that at full system output, the losses for uninsulated tubes would represent almost 20% of the system output. By comparison, insulated losses represent only 9% of the system output; a significant improvement.

It is important to note that both the duct air temperature and air velocity will affect the condensate losses of a distributor. Table 2 shown below illustrates the effect of duct air velocity on condensate losses for the same size SAM-e. As the air velocity increases, the condensate losses also increase. This is due to a higher volume of cooler air passing over the distributor which results in more heat transfer and in turn higher condensate losses. It is clear that an uninsulated SAM-e will generate more condensate than an insulated SAM-e of the same size, particularly at air velocities over 500 feet per minute.

Table 2: Condensate Losses at Various Duct Velocities

Duct Velocity	Air Temperature	Uninsulated Losses	Insulated Losses
300 fpm	55°F	11.7 lbs/hr	8.4 lbs/hr
500 fpm	55°F	15.6 lbs/hr	9.5 lbs/hr
1000 fpm	55°F	24.2 lbs/hr	11.0 lbs/hr
1500 fpm	55°F	30.7 lbs/hr	11.8 lbs/hr

This example highlights the benefits of insulating steam distributors in terms of reducing condensate losses and energy savings.

Operational Cost Savings

Energy savings are only part of the picture, building owners need to remain profitable in order to stay in business and as a result require buildings that are as inexpensive to operate as possible. Insulated steam distributors, by virtue of their increased energy efficiency, decrease operational costs. It is relevant to quantify just how much money can be saved by using insulated distributors.

Consider the example presented above. The average humidification season lasts from late September to late April, and involves roughly 2000 hours of humidifier operation. Knowing the expected hourly losses, it is possible to calculate the total seasonal losses:

Table 3: Season Losses

Seasonal Losses	
Uninsulated	2000 hrs x 24.2 lbs/hr = 48.400 lbs per season
Insulated	2000 hrs x 11.0 lbs/hr = 22,000 lbs per season

The seasonal losses can be quantified in terms of operational costs required to generate the lost steam. Two energy sources are primarily used in the generation of steam; natural gas and electricity.

In the case of natural gas; a cubic foot of natural gas has a lower heating value of approximately 1000 BTU/ft3 (a reasonable estimate due to the varying composition of natural gas across North America). This means that for every cubic foot of natural gas that is burned in a combustion process, 1000 BTU are available as heat. In 2008, the average commercial price of natural gas was $11.31 per 1000 cubic feet, not including distribution charges [2].

In the case of electricity; a typical steam humidifier will consume 0.38 kW of electricity per pound of steam being generated (a reasonable approximation based on typical boil times). In 2008, the average consumer price of electricity in the United States was $0.12 per KWH, not including demand or distribution charges [2].

In addition, there are charges associated with both the delivery of water to be used in humidification systems, and disposal fees. Wasting water not only costs money, but may also negatively impact the environment. This is especially true in areas where fresh water is in shortage. Saving water is not only economically smart, but also good environmental practice.

Table 4: Savings with Insulated Distributors in Above Example

Distributor	Gas	Electricity	Water
Uninsulated	$ 588.46	$ 2,207.04	5796 gal
Insulated	$ 267.49	$ 1,003.20	2635 gal
Savings	**$ 320.97**	**$ 1,203.84**	**3161 gal**

Table 3 displays the cost of the losses for the example presented earlier. The cost advantages of insulated distributors are clear; significant energy savings lead to significant cost savings. This effect is further compounded on projects where there are multiple humidifiers and steam distributors serving different zones. The overall savings add up quickly over time. Additionally, the payback on the additional cost of insulation is very short; often the costs can be recovered within 12-16 months of operation.

Conclusion

It is evident from the example above that the addition of insulation can greatly improve efficiency and reduce operational costs of a steam distribution system.

It is also clear that in order to illustrate the benefits and effectiveness of insulation for this type of distributor system as a whole must be evaluated as opposed to simply comparing the overall R values. In doing so, it is possible to determine the system losses and size the humidification system to ensure that it will always be able to meet the required load.

As engineers and building designers continually look for areas in which they can improve building efficiencies and reduce operational costs, whether it's a new building or an existing building retrofit, insulating the steam distribution system is one of the easiest and most cost effective places to start.

References

[1] Incropera, F.P. [et al.] (2007). *Fundamentals of Heat and Mass Transfer* (6th ed.). Hoboken, NJ: John Wiley and Sons.

[2] "Energy Information Administration: Natural Gas Prices," http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_a.htm Accessed Jan. 5, 2009

Why Condair?

Condair specializes in the design and production of superior humidification systems. We create the most appropriate solutions to meet your specific needs in the most efficient and cost effective way. To this end, we draw upon our extensive experience to develop an ever growing range of products manufactured to our stringent ISO 9001:2000 certified quality standards that will provide our customers with maximum reliability, minimum maintenance and a choice of energy sources.

When you choose Nortec Humidity, you are choosing the company that has built a reputation for superior quality humidification systems. Only with Condair can you select a system operating with electrode steam, subsonic air nozzles, high pressure nozzles, steam injection, steam exchange, or gas-fired technology.

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