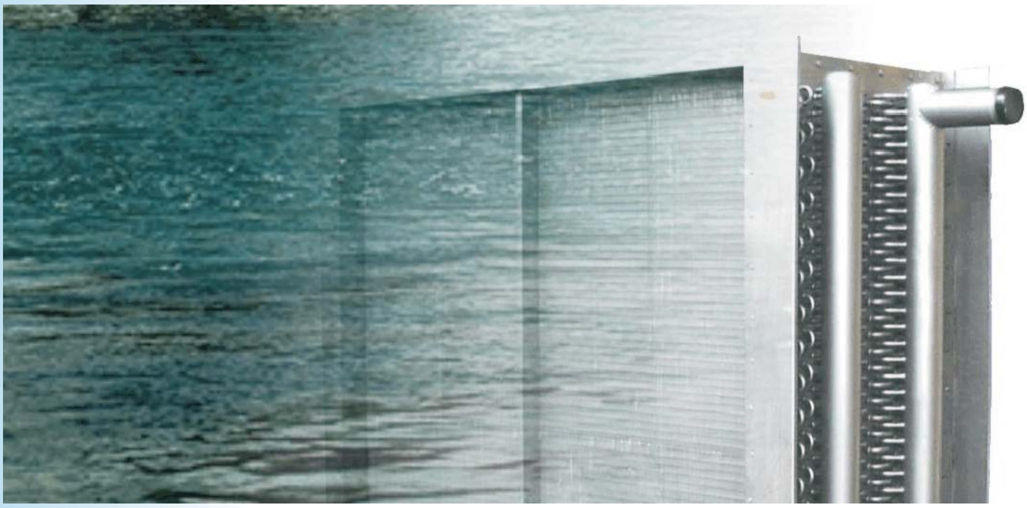
Application Notes 002



Heat Pipes for Enhanced Dehumidification

By Richard Meskimmon - Technical Manager

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S & P Coil Products Limited
www.spcoils.co.uk

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1. Introduction to S & P Coil Products Limited

SPC is a specialist manufacturer and supplier of fan convectors, coil heat exchangers, and HVAC equipment to the public and private sector.

SPC leads the way in HVAC technology and in responsiveness to customer needs. We thrive on innovation, on new technologies and new challenges. We stand for irresistible quality, exceptional customer care, and whole-life value for money.

For more than 20 years, we've applied our ingenuity to the heating, cooling, and dehumidifying of indoor environments and to the delivery of HVAC equipment that withstands the grind of daily use. The result is a range of products that are aesthetic, robust, and economical to run.

But new ideas aren't developed in isolation. They come from a service culture that takes pride in putting customers first. We listen and, if asked, we advise; we offer free site surveys and we always return your calls.

Our mission is simple to become your first-choice HVAC supplier, and to be the one company that provides a solution that exactly matches your needs.

Key facts about SPC:

- Our mission is to be your first choice for HVAC equipment
- Major supplier to local government and commercial sectors
- Unrivalled regional sales and technical support team
- Free site check / survey
- ISO 9001 and Investor in People

2. Executive summary

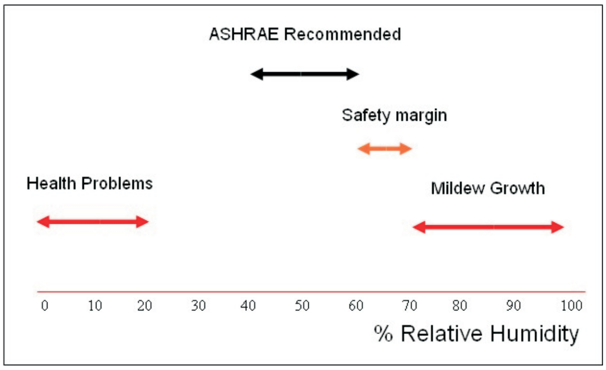
This application note provides an introduction to the process of dehumidification applied to both air conditioning and process environments. Traditional technologies are discussed based upon a psychrometric analysis which details the energy processes and costs involved in achieving the desired supply air condition.

A comparison is made between traditional dehumidification processes and that which can be achieved by enhancing this process through the addition of heat pipe technology, to both increase dehumidification potential and energy savings.

In order that the analysis is meaningful it is contextualized in terms of worked examples and practical notes regarding the installation of equipment, it also includes rules of thumb for preliminary design work.

3. The need for dehumidification

Air conditioning for comfort or process environments consists of a variety of different processes aimed at supplying air to a space at a condition that will provide a comfortable and healthy living, working or storage environment. For comfort conditioning this means maintaining a space condition which is not only at a comfortable temperature but also at a humidity level which is conducive to good health: 40% to 60% is widely regarded as the limit of the comfort relative humidity envelope with designers aiming for a space relative humidity of 50%. Relative moisture levels both above and below the comfort envelope give rise to health problems while high humidities can be responsible for damage to the building fabric and mould growth.



The processes involved in air conditioning can be some or all of the following:

Heating, Cooling, Ventilation,
Filtration, Humidification, Dehumidification

With the exception of dehumidification the above processes are all direct while dehumidification is traditionally achieved indirectly by cooling the air below its dewpoint temperature.

So called direct dehumidification is possible using desiccant dehumidifiers where the moisture in vapour form is absorbed by the desiccant and held as liquid. This desiccant then needs to be reactivated before the process can continue. This process in fact not only removes moisture from the air stream but simultaneously adds sensible heat to the air to increase its temperature.

The relative humidity of a space is approximately equal to the percentage of moisture within the air at the space temperature compared to the maximum amount of moisture this air would be capable of holding at the space temperature. As air is heated it becomes capable of holding more moisture so the relative humidity of the space falls. Conversely, as air is cooled its ability to hold moisture is reduced until it becomes saturated and moisture condenses out of the air on cool surfaces. The temperature below which the air must be cooled is the dewpoint temperature of the air.

It is the relative humidity of air rather than the absolute amount of moisture within the air that causes discomfort and fabric damage. Although dehumidification is strictly the removal of water in either vapour or liquid form, simply heating air is one method of reducing the relative humidity.

While the primary requirement of a dehumidification system is to maintain the humidity within the space that is being served, it is also important that the condition of the supply air is such that it does not create problems within the air distribution system. When supply air is cooled to strip out moisture the resultant air will be at a condition which is very close to saturation i.e. greater than 90% relative humidity.

If this air is distributed through ductwork without being reheated to a lower relative humidity level it will, over time, promote the growth of mould and bacteria. It is good practice, in order to ensure healthy ducting, to limit the relative humidity of ducted supply air to a maximum of 75%. In order to achieve this the saturated air must be reheated. This both reduces the relative humidity and results in an acceptable supply temperature.

Dehumidification is necessary in order to maintain comfort conditions within occupied spaces which are subject to a variety of moisture gains. These moisture gains can be from any or all of the following: infiltration, evaporation from moist surfaces, emission from people, diffusion through walls and moisture in the ventilation air.

While the ventilation moisture gain will be dealt with directly by the AHU through which it is introduced to the space, the other ‘internal’ gains must be offset by the dehumidified supply air.

4. Traditional dehumidification processes

Dehumidification applied to air conditioning and comfort applications invariably involves the condensation of moisture on the chilled surfaces of a cooling and dehumidifying coil. Desiccant dehumidification can only be justified for processes which require air to be supplied at extremely low moisture contents or where very accurate moisture control is required for industrial processes.

For air conditioning applications desiccant dehumidification can rarely be justified on the basis of the cost of the equipment, the amount of sensible heat added to the process air during the sorption process and the very limited volumes of air that can be handled.

A good design figure to use when considering the applicability of condensation dehumidification is a supply air moisture content of 0.006kg/kg. At moisture contents below this level there is a risk of the cooling coil, which is stripping out the moisture, freezing up, leading to the need for an active defrost facility and lack of accurate control. Fortunately, all comfort applications require air to be supplied at moisture contents well in excess of the above figure and hence are invariably serviced by condensation dehumidification.

There is some cross-over between the two competing methods of dehumidification but in typical air conditioning processes condensation dehumidification will be the only process considered and is what the remainder of this note will concentrate upon.

While the sorption dehumidification process involves a combination of dehumidification and heating, the condensation process involves dehumidification and cooling. For many air conditioning processes simultaneous cooling and dehumidification is desirable as it copes with both sensible and latent heat gains to the conditioned spaces.

Cooling coils typically work both dry and wet i.e. a portion of the fin surface is dry and performs only sensible cooling while the remainder of the fin surface is wet and actively condensing moisture as it cools the air. The air has to be cooled below its dewpoint before moisture begins to condense on the fin surfaces and there is a relationship between the leaving moisture content of the air and the final temperature to which it must be cooled. As a result, the air often needs to be overcooled in order to remove the necessary moisture.

The overcooling generates air which is lower than the temperature at which it needs to be supplied and the final stage in the dehumidification process involves reheating of the overcooled air to bring it back to the required supply temperature, while simultaneously reducing its relative humidity.

The traditional method of dehumidification therefore consists of overcooling the supply air to achieve the required moisture level and then reheating this air to achieve the required supply temperature. Heat is being taken out of the air only to be put back in later in the process and there is an energy cost associated with both the overcooling and reheating.

If the heat that is taken out of the air could be transferred around the cooling coil to the leaving air/reheat side then the total cooling load would be reduced and the reheat load reduced or eliminated. This is the effect of wrapping a heat pipe around a cooling coil.

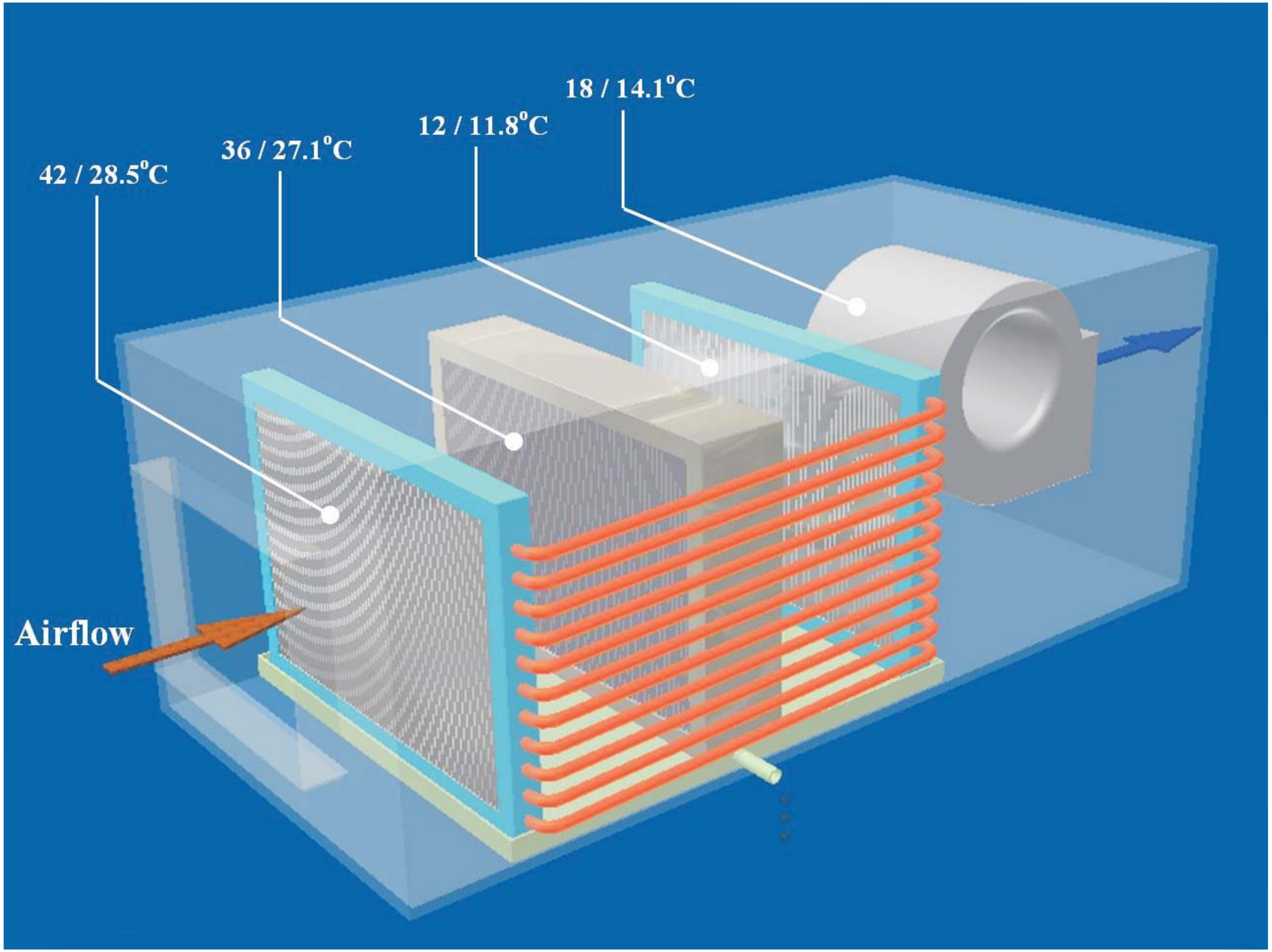


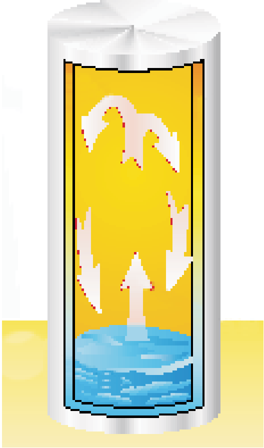
Figure 1: Heat pipe effect (described on previous page)

5. Heat pipes and their application in dehumidification

5.1 Description

A heat pipe is, from the viewpoint of a user of such equipment, a thermal super-conductor i.e. it is capable of transferring heat at high rates across negligible temperature differences. As a result, heat pipes have been widely used for specialist cooling applications and as heat sinks for directly cooling electronic components. Whenever there is an external temperature difference between the ends of a heat pipe heat will flow from the warm to the cool end. Due to the internal processes inside the heat pipe this heat transfer will be achieved with almost no temperature difference along the length of the pipe and the heat pipe will be virtually isothermal in operation. Because heat pipes efficiently transfer heat from warm to cool regions they have long been used in both process and comfort heat recovery applications to either preheat supply air using the heat of the extract air or precool supply air by allowing cool extract air to strip heat from it.

The internal operation of the heat pipe is key to its effective conductivity. A heat pipe consists of a hollow vessel containing only a mixture of the working fluid in both liquid and vapour form i.e. saturated. Whenever there is a temperature difference between the ends of the heat pipe the increased vapour pressure at the warm end excites boiling, with the vapours produced flowing at high velocity to the cooler end. At the cooler end the vapours can no longer exist in this phase and condense back to liquid. The liquid then flows back to the warm end to complete the cycle. The performance of the heat pipe is therefore reliant upon return of condensed liquid and many types of heat pipes have been developed to ensure that this happens. Traditional heat pipes are manufactured with the internal walls of the pipe covered in a wick structure to promote liquid return by capillary action.



This type of heat pipe is capable of transferring heat in any direction i.e. horizontally, vertically upwards, downwards or any angle in between. Such heat pipes, however, are expensive and their performance is limited by the pumping power of the wick. A more effective method of ensuring liquid return is to rely on gravity. This means that the warm end of the heat pipe must be below the cool end, if the opposite is the case then liquid will not return to the warm end and the heat pipe will not function.

SPC patented heat pipes for dehumidification are always gravity assisted heat pipes (thermosyphons) with the inter-connection between the pipes assuring gravity return. They are manufactured from copper tubes which are expanded into aluminium fins in the same way that conventional cooling coils are manufactured. As a result heat pipes can be manufactured in the identical size to the cooling coil that they are servicing. One half of the heat pipe will be positioned upstream of the cooling coil and the other half downstream, the two halves joined by connecting pipes. That half of the heat pipe upstream of the cooling coil sees relatively warm air compared to the half downstream and hence heat is transferred, by the heat pipe, from the air prior to it reaching the cooling coil to the air after it has been cooled and dehumidified.

5.2 Performance

As the heat pipe transfers heat internally with great efficiency the overall performance is largely determined by the rate at which heat can be transferred into and out of the air that is flowing over it. As airside heat transfer coefficients are orders of magnitude lower than those associated with the internal boiling and condensing, the external surface area of the heat pipe is finned in order to compensate. The density of the fins can be selected to suit the application along with the number of rows of heat pipes, in the same way that the cooling coil is selected.

As with any type of heat exchanger, an index of heat pipe performance is its effectiveness (or efficiency). This is defined as the amount of heat transferred compared to the theoretical maximum. This maximum would correspond to the lower temperature airstream being raised to the temperature of the warmer airstream and vice versa and would require an infinitely large heat exchanger.

In terms of the dehumidification process, the same mass of air travels through each side of the heat pipe heat exchanger and the formulation for the effectiveness reduces to the degrees of reheat compared to the temperature difference between the entering air (i.e. air on the precool section) and the air off the cooling coil (i.e. air on the reheat section). Note that the degrees of precool will be just equal to the degrees of reheat as the heat absorbed in the former is just equal to that added to the latter.

Heat transferred from air to precool leg of heat pipe =
Heat transferred from reheat leg of heat pipe to air

$$Q_P = \dot{M}_P SH \Delta T_P = Q_R = \dot{M}_R SH \Delta T_R$$

$\dot{M}_P = \dot{M}_R$ = Mass of flow rate of air through AHU

SH = Specific heat of air
ΔT_P = Temperature drop of air flowing across precool
ΔT_R = Temperature rise of air flowing across reheat

As $\dot{M}_P = \dot{M}_R$ and SH is constant then, assuming that there is no moisture condensed on the heat pipe, the above reduces to: $\Delta T_P = \Delta T_R$

Typical values for the effectiveness of dehumidifier heat pipes are 10 to 40%, delivering between 2 and 10°c of reheat. Dehumidifier heat pipes can be manufactured with 1,2 or 3 rows of heat pipes and fin densities up to 12 fins per inch. Chart 1 shows the variation in effectiveness with air velocity for 1,2 and 3 row heat pipes, typical velocities within AHUs would be 2 to 2.5m/s. Chart 2 gives values for the airside resistance associated with the flow across the finned surfaces of the heat pipes. Both charts are based upon fin densities of 12 fins per inch but other spacings can be used to give intermediate performances.

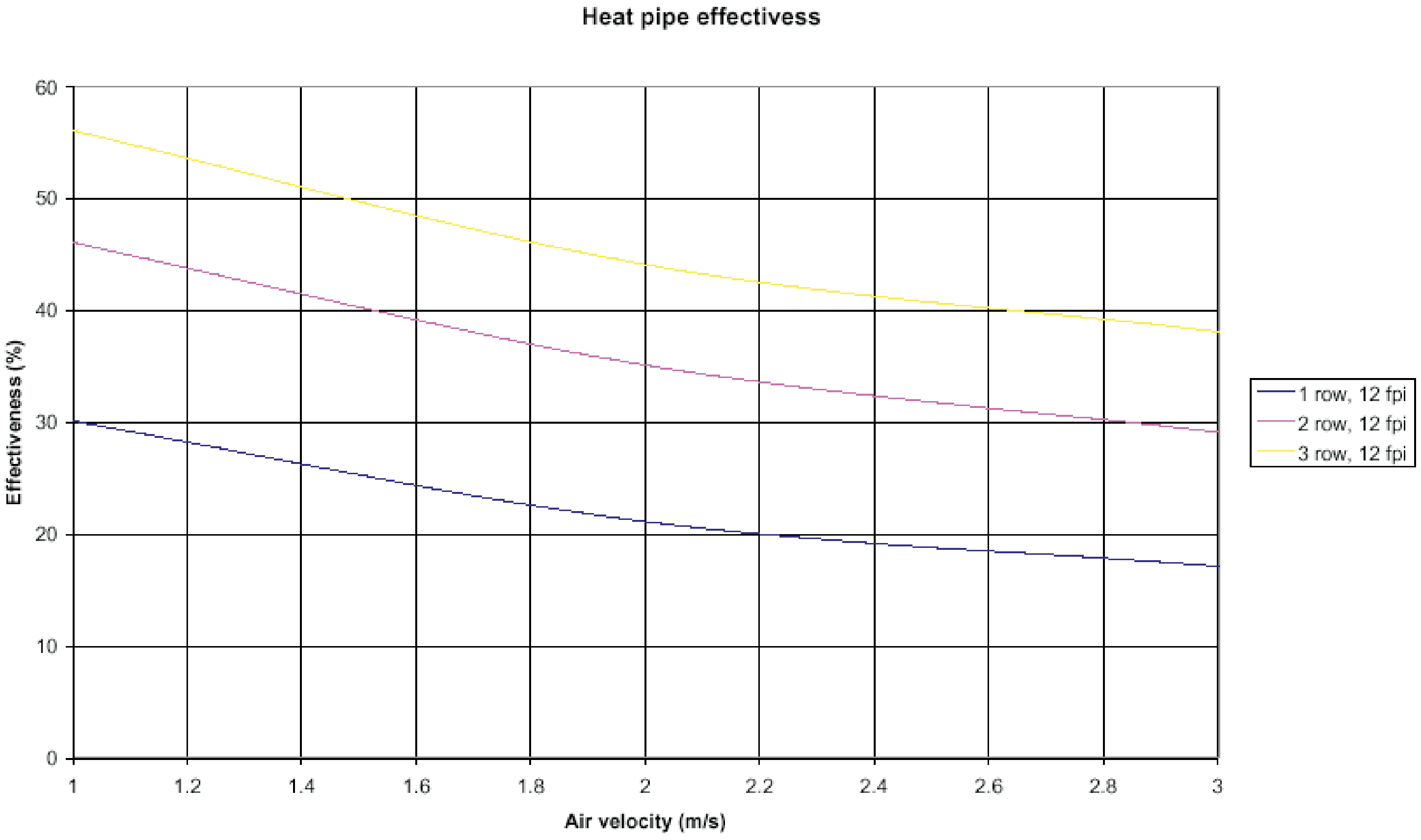


Chart 1 - Typical heat pipe effectiveness against a range of air volumes

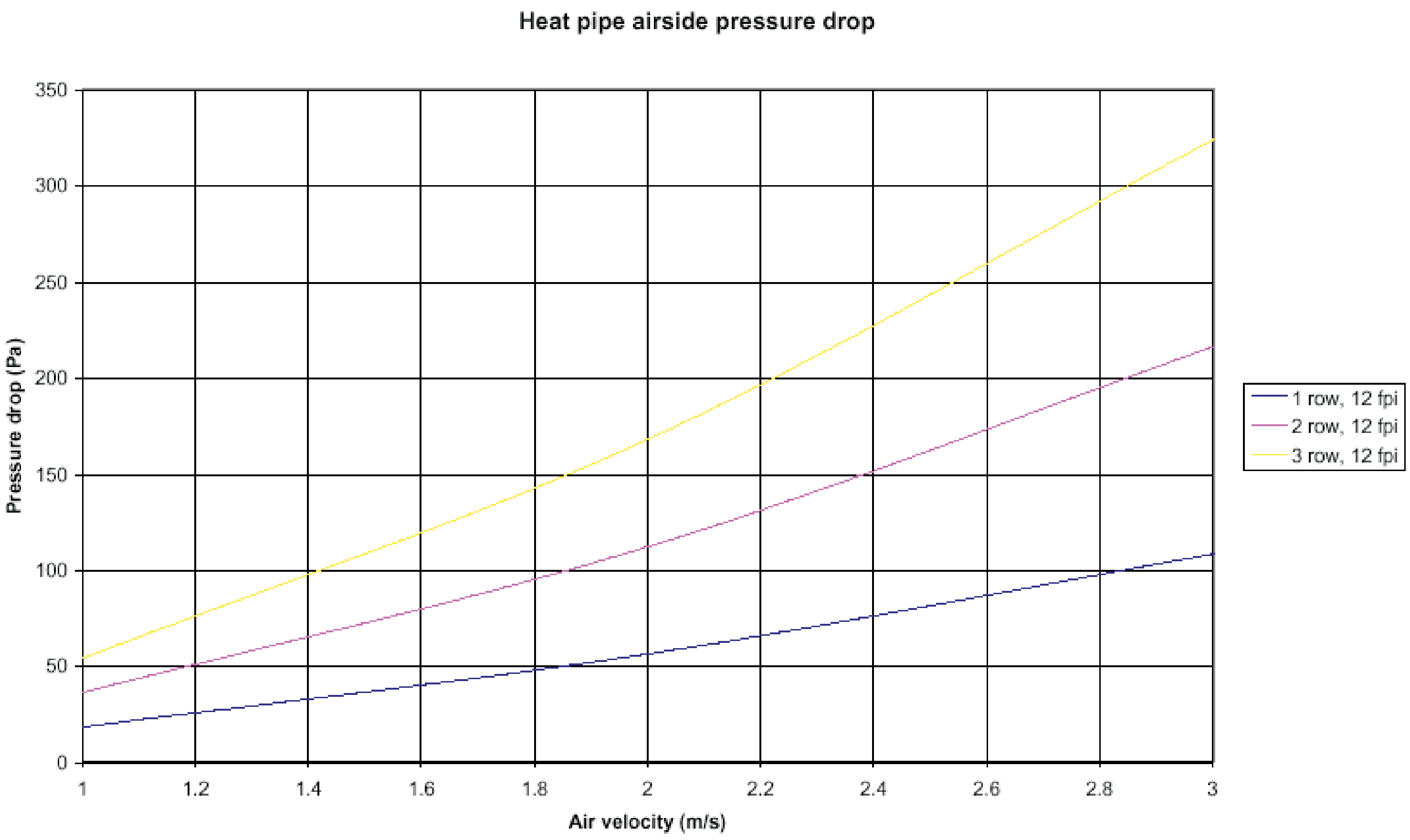


Chart 2 - Typical heat pipe pressure drops against a range of air volumes

5.3 Worked examples

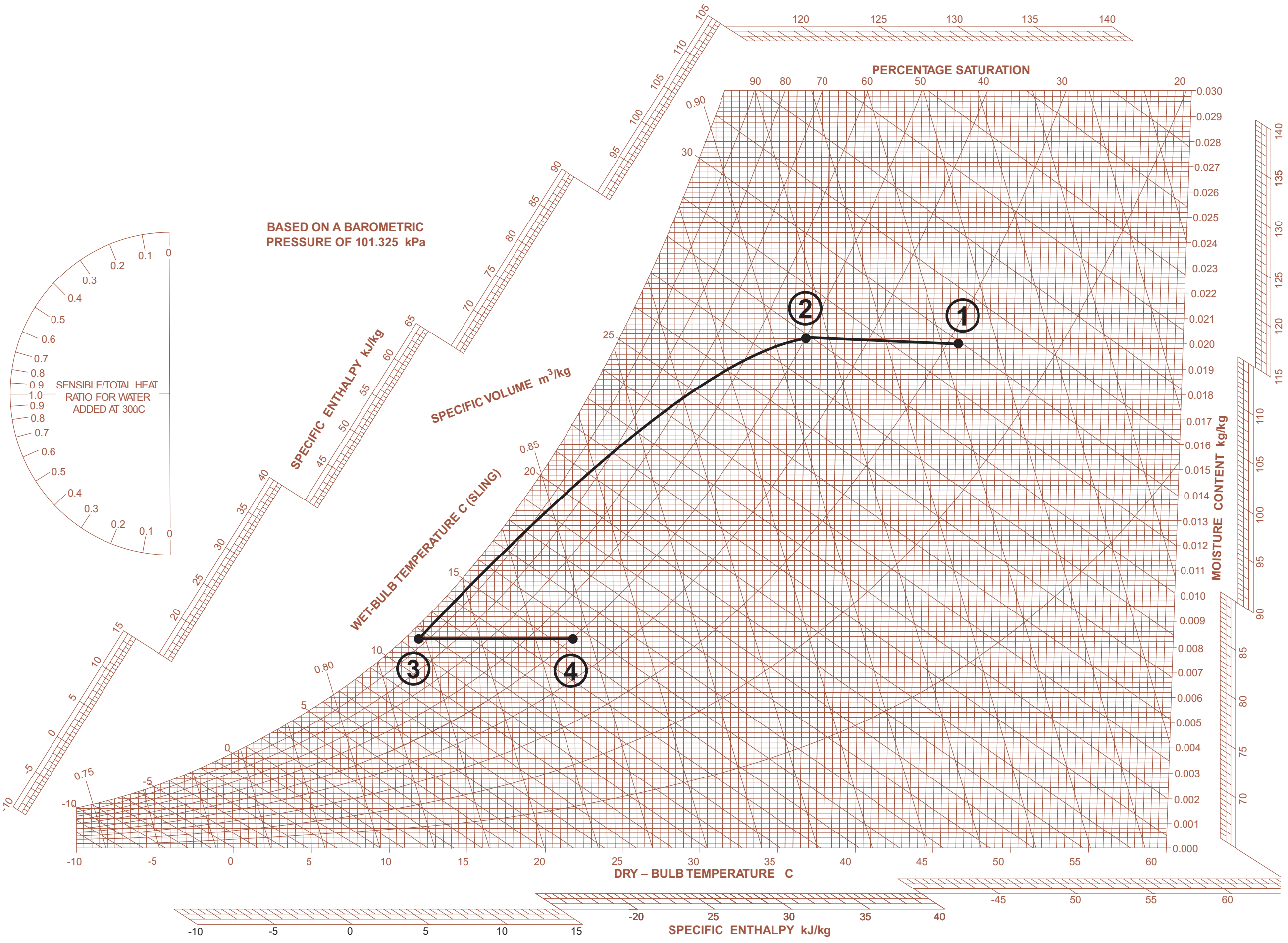
The following processes and intermediate points are shown on the psychrometric charts included below. The points shown represent the outside or mixed air condition, the air condition after the precooling leg of the heat pipe, the air condition after the cooling coil and the condition of the air after the reheat leg of the heat pipe.

5.3.1 Hot and humid climate, 100% outside air make-up unit

Outside air at 46.0/30.0°C dry bulb/wet bulb is to be supplied to a space at a condition of 22.0/15.5°C.

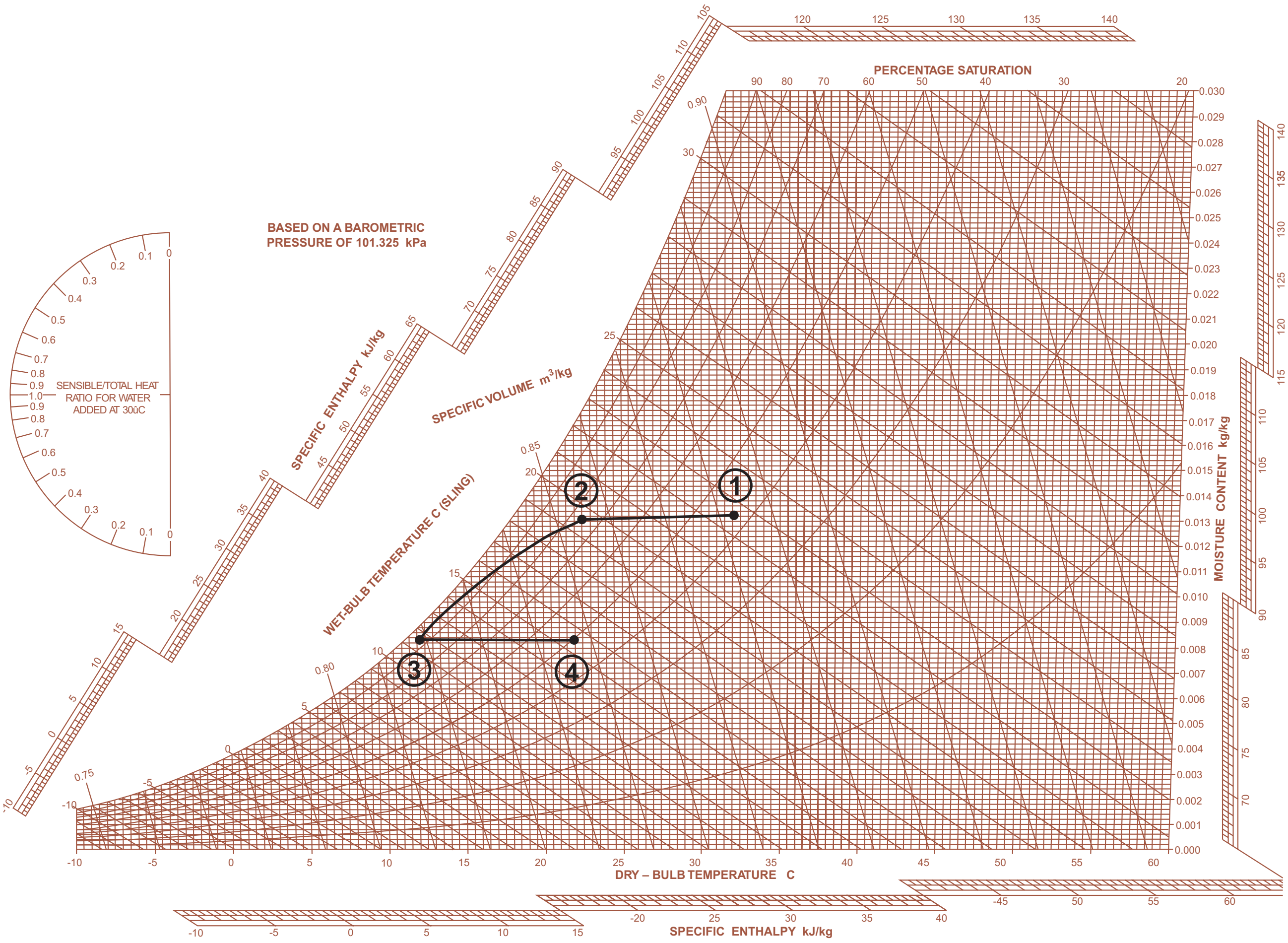
The moisture content of the supply air is 0.0084kg/kg. In order to dehumidify the air to this level it must be cooled to a condition of 12.5/12.0°C by the cooling coil prior to being reheated.

If a heat pipe is being used to enhance the dehumidification process then it will be designed to provide the necessary degrees of reheat against the design conditions. The design reheat is 9.5°C and the heat pipe effectiveness required to provide this will be 9.5/(46.0-12.5)=28.3%, from table 1 a 2 row heat pipe will be capable of providing this effectiveness. The 9.5°C of reheat will be accompanied by 9.5°C of precooling which means that the air onto the cooling coil will be at a condition of 36.5/27.9°C.



5.3.2 Hot and humid climate, 100% outside air make-up unit c/w precooling heat recovery device

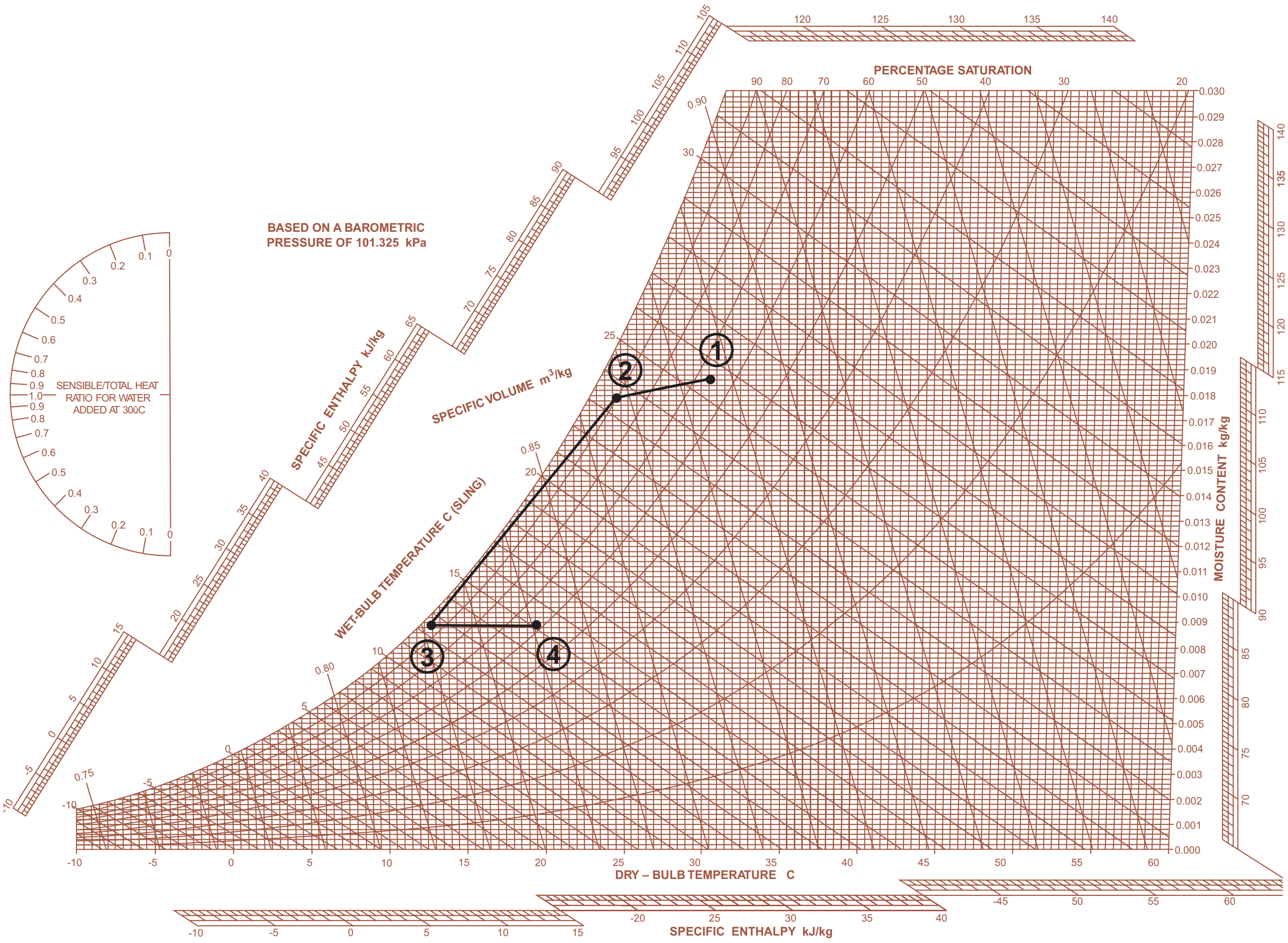
Outside air precooled by heat recovery device to a condition of 32.0/22.5°C, air to be supplied at 22.0/15.5°C.
The moisture content of the supply air is again 0.0084kg/kg and the air off the cooling coil must be at 12.5/12.0°C. Again 9.5°C of reheat are required but as the air off the heat recovery device is now at a lower temperature than the outside air the effectiveness of the heat pipe must increase in order to supply this same reheat. The new effectiveness now required is 9.5/ (32.0-12.5)=48.7%. From table 1 this effectiveness can be achieved using a 3 row heat pipe with a face velocity of 1.6m/s. This velocity is low for typical AHUs and will lead to an excessively large unit. A solution more regularly adopted is to size the heat pipe to give an effectiveness of say 40% and a reheat of 0.4x(32.0-12.5)=7.8°C and allow auxiliary reheat to provide the shortfall (can be electric, LPHW or steam). This would have the added advantage of providing very close control of the supply temperature.



5.3.3 Warm and humid climate, 100% outside air make-up unit

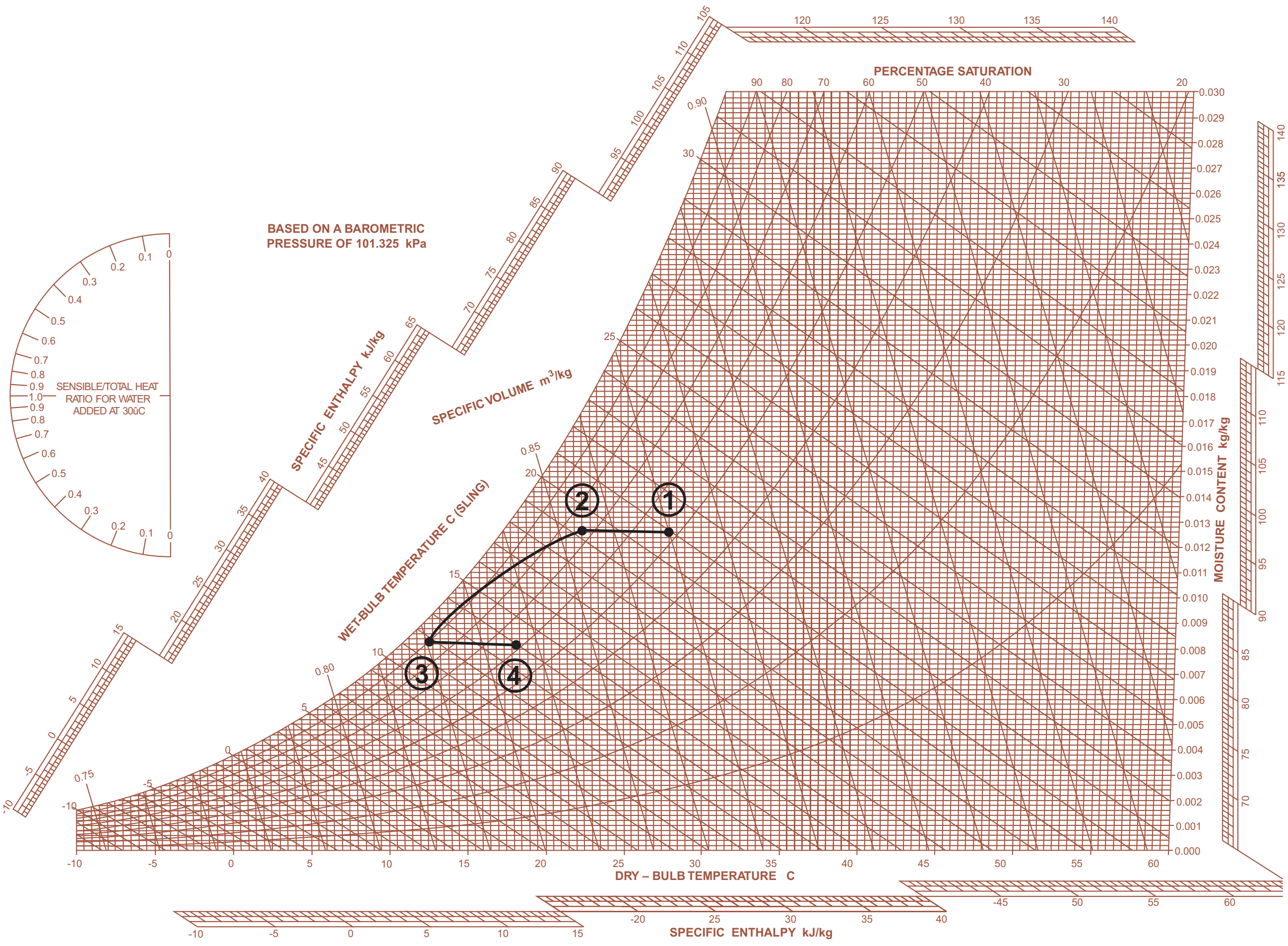
Outside air at 30.5/25.4°C to be supplied at a condition of 20.0/15.3°C.
The moisture content of the supply air is 0.0088kg/kg and the air off the cooling coil must be at a condition of 13.0/12.6°C prior to it being reheated. The degrees of reheat required are (20.0-13.0)=7.0°C and the heat pipe effectiveness required is 7.0/(30.5-13.0)=40%. This can be achieved using a 3 row heat pipe. Note that in this instance the temperature of the heat pipes is such as to below the dewpoint of the outside air. As a result there is some moisture condensed on the precool leg of the heat pipe and the degrees of precooling are less than the degrees of reheating in order to maintain a total enthalpy balance between the two sides of the heat pipe i.e. the precool leg is performing both latent and sensible cooling while the reheat leg provides just sensible heating.

The condition above replicates that experienced during the wet season in Northern India. The outside air is that corresponding to the most common annual condition measured at the New Delhi weather station.



5.3.4 Moderate climate, 100% outside air unit

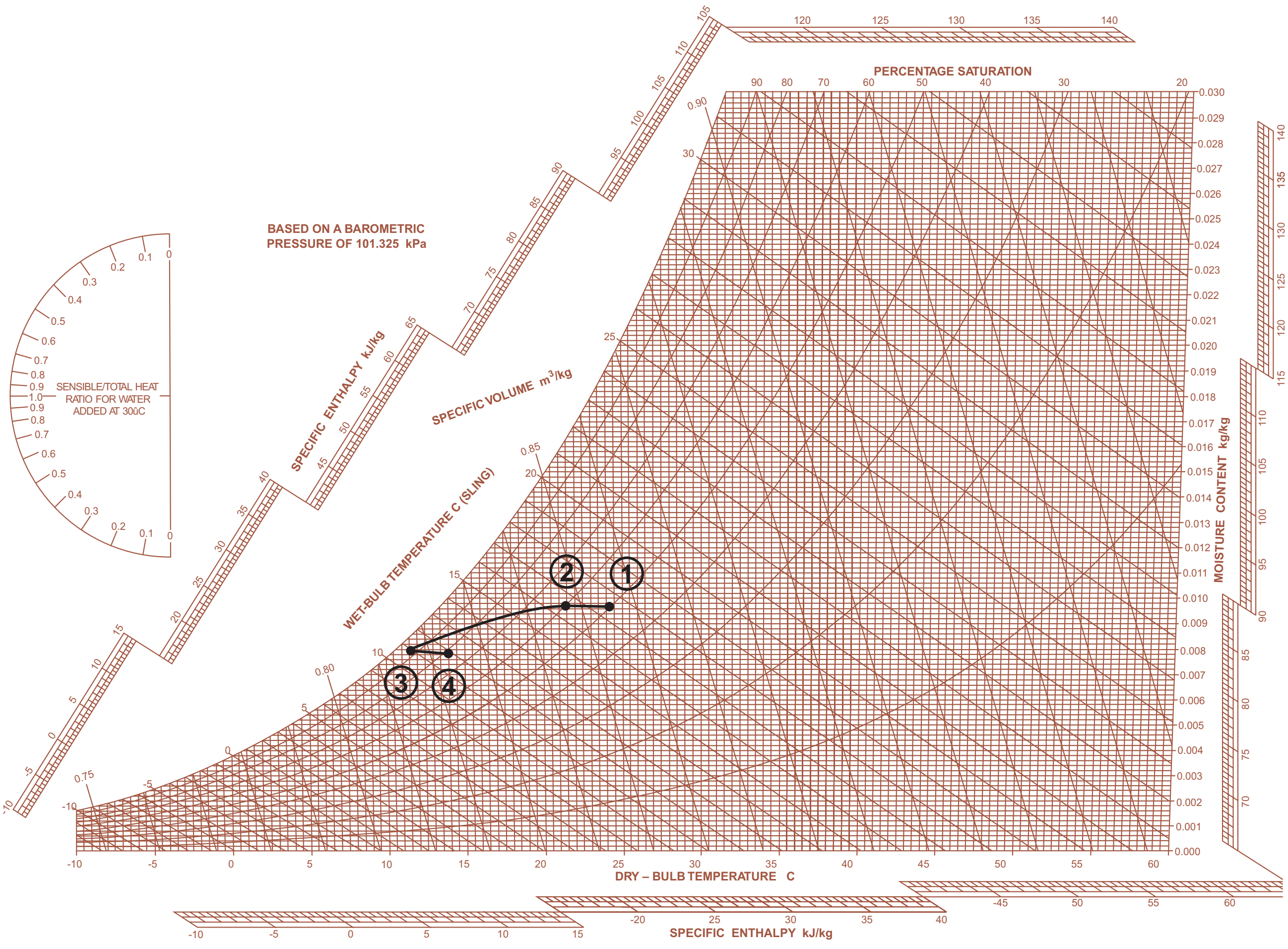
Outside air at 28.0/21.0°C to be supplied at a condition of 18.0/14.0°C
The moisture content of the supply air is 0.0084kg/kg and the air must be cooled by the cooling coil to a condition of 12.5/11.8°C. The degrees of reheat required are (18.0-12.5)=5.5°C and the effectiveness of the heat pipe must be 5.5/(28.0-12.5)=35.4%. This will be achieved with either a 2 row heat pipe or 3 row heat pipe depending upon the velocity of flow through the AHU.
This example is typical of a displacement ventilation system where the supply air needs to be dehumidified in order to prevent condensation on a chilled ceiling and cooled below the room temperature to provide some degree of primary cooling.



5.3.5 Moderate climate, mixed air unit

Outside air at 28.0/21.0°C, return air at 22.0/15.0°C, mixed air at 24.0/17.3°C, air to be supplied at a condition of 14.0/12.0°C.

The moisture content of the supply air is 0.0080kg/kg and the air needs to be cooled to a condition of 11.5/11.0°C. The degrees of reheat required are (14.0-11.5)=2.5°C and the required heat pipe effectiveness is 2.5/(24.0-11.5)=20%. From table 1, a single row heat pipe may be selected.



5.4 Energy savings

The precooling and reheating effects of a heat pipe combine to produce significant energy savings.

The precooling effect reduces the temperature of the air onto the cooling coil and reduces the total duty required of the coil. This in turn reduces the load on the chiller (or compressor in a DX system) and will also reduce the required capacity of the chiller and its initial cost. As the chiller is typically transferring heat from the chilled water to the atmosphere the energy savings associated with the precooling effect of the heat pipe are equal to the amount of energy input to the chiller that would have been needed to achieve the additional heat transfer from the chilled water that is now accounted for by the heat pipe. This means that the energy saving on the chiller is equal to the precool energy saving divided by the coefficient of performance of the chiller (COP), where the COP is equal to the heat transferred out of the chilled water divided by the energy input to the chiller and would typically be equal to around 3.

The reheat effect is a direct energy saving and is equal to the energy which would otherwise need to be added to the airstream in order to increase its temperature. As a result, the reheat energy saving is approximately 3 times the precool energy saving.

While energy savings associated with the introduction of heat pipes are the primary concern when considering new installations, options exist for retrofitting heat pipes in existing installations in order to improve the dehumidification capacity of the system and simultaneously reduce the reheat load. The precooling effect of the heat pipe reduces the temperature of the air onto the cooling coil. This allows a greater portion of the cooling coil surface to be wet and actively condensing moisture i.e. much of the sensible duty of the cooling coil has been performed by the precool leg of the heat pipe, leaving more of the existing cooling coil surface available for removing moisture.

The inclusion of heat pipes in a design only incurs an energy penalty in terms of the additional fan power required to draw the air across the additional fin parcels. As the precool effect of the heat pipe allows the use of a smaller cooling coil and the reheat effect replaces other forms of reheat which would introduce pressure drops the total increase in static resistance of the heat pipe solution compared to a conventional system is low and not as high as the figures shown in the chart of heat pipe pressure drops.

The effectiveness of a particular heat pipe is constant as long as the air volume remains constant. As a result, the degrees of reheat, precool and the energy savings vary with the temperature of the air onto the system (outside air or mixed air). The largest variation in performance is associated with units handling 100% outside air as the air on temperature is not tempered by stable return air.

A bin data analysis of the annual energy savings gives details of the energy that will be saved against the range of outside conditions experienced throughout the year. Bin data lists the range of annual temperatures divided into discrete temperature bands and the number of hours per year that the outside temperature falls within this band is recorded. Table 1 gives an annual energy saving analysis based upon a 100% outside air unit in a warm and humid climate. The analysis is all based on 1kg/s of air being handled and assumes a COP for the chiller of 3. Again the data is based on actual New Delhi conditions as in 5.3.3

For mixed air units handling a mixture of outside and recirculated air, the entering air temperature is relatively constant and an estimate of the annual energy savings is best undertaken based upon the design condition and an estimate of the number of hours per annum that the unit is running.

For the mixed air unit given in the above example 5.3.5 and again assuming that the air being handled is 1kg/s the precool and reheat capacity savings are both equal to 2.5kW. If it is assumed that the plant runs for 3000 hours per year then the annual precool energy saving will be equal to 2500kWh and the annual reheat saving equal to 7500kWh, giving a total annual saving of 10000kWh.

Bin	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Mid-point dry bulb (°C)	9.5	12.5	15.5	18.5	21.5	21.5	24.5	24.5	27.5	27.5	30.5	30.5	33.5	33.5	36.5	
Mean coincident wet bulb (°C)	8.3	10.8	13	14.4	15.4	19.3	17	21.3	18.3	24.2	21.7	25.4	19.3	26.2	25.7	
Hours p.a.	456	730	639	669	752	313	395	213	517	913	365	1125	250	936	487	
Heat pipe effectiveness (%)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	
Air off precool db (°C)	n/a	n/a	n/a	n/a	n/a	19	19.9	20.5	21.7	23	23.5	25	n/a	25.3	27.1	
Air off precool wb (°C)	n/a	n/a	n/a	n/a	n/a	18.1	15.8	19.9	16.3	22.6	19.5	23.6	n/a	24.1	23.3	
Precool saving (kW)	n/a	n/a	n/a	n/a	n/a	3.4	4.6	4.6	5.8	5.8	7.0	7.0	n/a	8.2	9.4	
Air off cooling coil db (°C)	n/a	n/a	n/a	n/a	n/a	13	13	13	13	13	13	13	n/a	13	13	
Air off cooling coil wb (°C)	n/a	n/a	n/a	n/a	n/a	12.6	12.6	12.6	12.6	12.6	12.6	12.6	n/a	12.6	12.6	
Air off reheat db (°C)	n/a	n/a	n/a	n/a	n/a	16.4	17.6	17.6	18.8	18.8	20	20	n/a	21.2	22.4	
Air off reheat wb (°C)	n/a	n/a	n/a	n/a	n/a	14	14.4	14.4	15	15	15.3	15.3	n/a	15.8	16.3	
Reheat saving (kW)	n/a	n/a	n/a	n/a	n/a	3.4	4.6	4.6	5.8	5.8	7.0	7.0	n/a	8.2	9.4	
Precool saving (kWh)	n/a	n/a	n/a	n/a	n/a	354	605	326	999	1763	851	2622	n/a	2556	1524	
Reheat saving (kWh)	n/a	n/a	n/a	n/a	n/a	1064	1817	980	2999	5295	2555	7875	n/a	7675	4578	
Total energy saving (kWh)	n/a	n/a	n/a	n/a	n/a	1419	2422	1306	3997	7059	3406	10497	n/a	10231	6102	46439
Air flow (kg/s)	1.00											Approximate heat pipe cost (£)				1076
												Energy cost (£/kWh)				0.06
												Annual energy cost saving (£)				2786
												Simple payback (years)				0.39

Table 1 - Bin data analysis

Where the coincident wet bulb temperature varies significantly within the dry bulb bin, the bin has been split to properly represent the climate. Cells marked n/a correspond to those where the outside moisture content is below the required space moisture content and hence there is no saving associated with the use of heat pipes.

5.5 Controllability

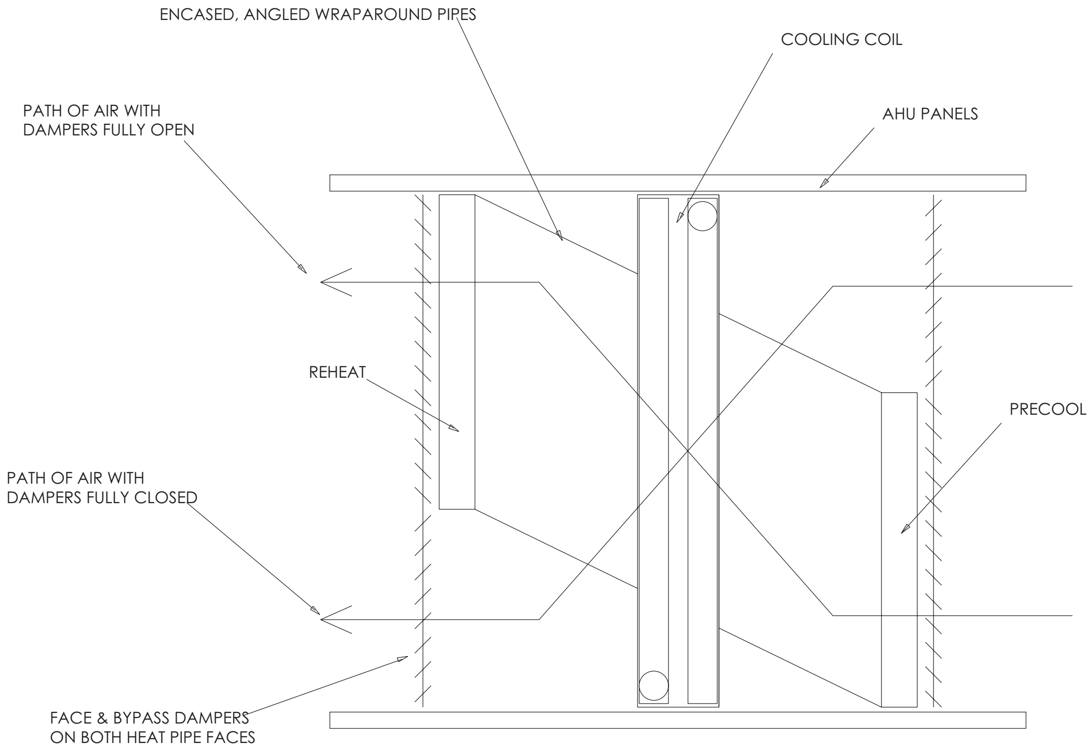
Wrapping a heat pipe around a cooling coil effectively transfers sensible heat from the air around this cooling coil. As the amount of heat transferred varies with the degree of cooling that the cooling coil accomplishes, both the cooling coil and the heat pipe can be considered as a single block with the properties of a cooling coil optimized to remove moisture. The inclusion of the heat pipe modifies the process so as to increase the latent cooling capacity at the expense of the sensible cooling capacity.

As with any conventional cooling coil, increased performance is associated with a decrease in the leaving temperature and the leaving moisture content. When a heat pipe is used, however, the decrease in temperature is less marked and the decrease in moisture content more so. Mixing or diverting valves in the hydronic circuit feeding the cooling coil would normally be used to control the output of the combination of heat pipe and cooling coil in exactly the same manner as a conventional, stand-alone, cooling coil would be controlled.

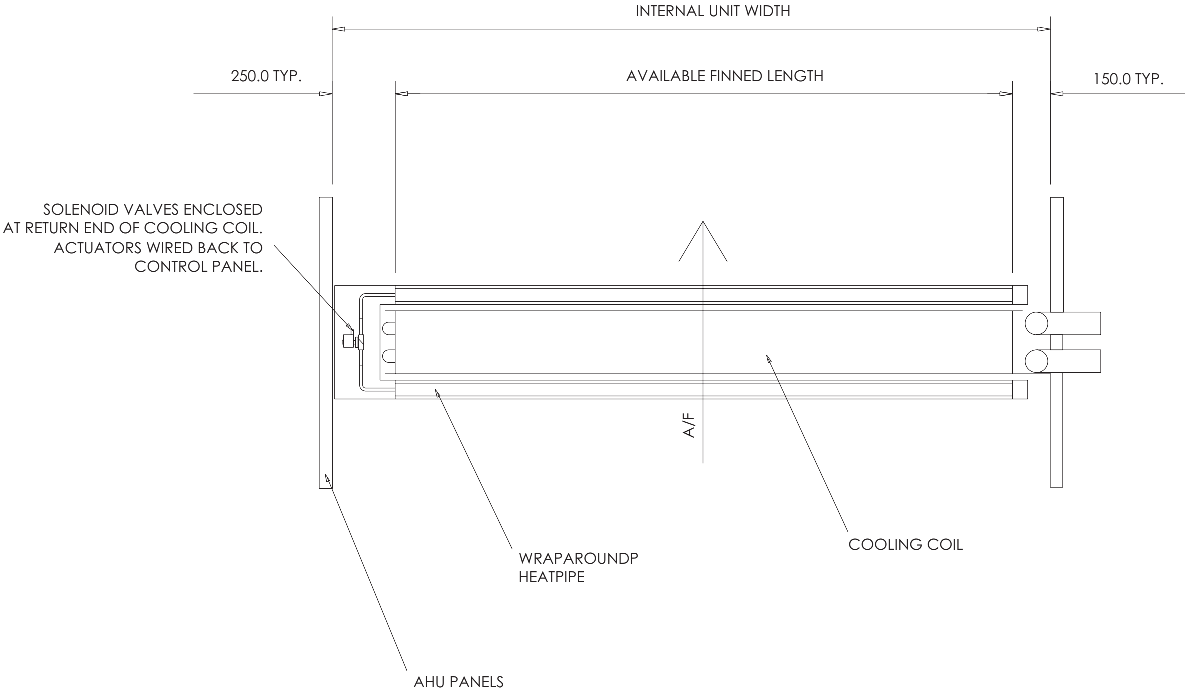
Because the combination of heat pipe and cooling coil is actually made up of two elements this can introduce more exotic control possibilities. It should be borne in mind, however, that these will increase the initial cost and the complexity of the AHU, but can be justified for special applications. Options for increased control are face and bypass dampers on the heat pipe or solenoid valve control of the heat pipes themselves (see page 21).

Both methods of control are aimed at allowing the system to behave, at one extreme, as the heat pipe/cooling coil combination as designed and at the other extreme, eliminating the heat pipe, just as a conventional cooling coil. The control could also, if required, allow intermediate behaviour, as the heat pipe effectiveness reduces from design to zero.

As the introduction of heat pipe control incurs penalties in terms of cost and space within the AHU it should only be considered for extreme applications where the variation in latent and sensible load changes dramatically.



FACE & BYPASS DAMPER CONTROL ARRANGEMENT



SOLENOID VALVE CONTROL ARRANGEMENT

5.6 Practical issues

Heat pipes are regularly installed in central air handling units where the dehumidification process occurs. There are two options for the supply of heat pipes for inclusion in AHUs; they can be supplied as so-called ‘horseshoe’ units for fitting around a cooling coil supplied separately or a so-called ‘combi’ unit can be supplied which consists of a cooling coil and wrap-around heat pipe in a common casing.

‘Combi’ heat pipe

Six row chilled water coil inside two row heat pipe.
This case is complete with an integral drainpan.

The combi unit affords the simplest method of installation as it requires no more than the standard procedure for fitting a conventional cooling coil to be followed i.e. blanking off around the casing to ensure that there is no air bypass around the fin block. Combi units can be manufactured from a range of casing materials, the most common being galvanized steel and stainless steel and, if there is no drainpan fitted in the base of the AHU, the combi can be supplied with an integral drainpan. A range of fin materials is available; aluminium, copper, vinyl coated aluminium and tinned copper, in fact, the same range of materials as would be available for a conventional cooling coil.

Horseshoe units are supplied whenever the heat pipe needs to be separate from the main cooling coil or the cooling coil is manufactured by others. When installed in the AHU the heat pipe wraps around the return bend end of the cooling coil leaving the opposite end open for the flow and return connections to penetrate the panel of the AHU. Provision must be made for this wrap around section behind the bends of the cooling coil with this section typically taking up 60mm of the width of the AHU.

The base of the horseshoe heat pipe forms a channel section and can be slid in and out of the AHU. These units are shipped with transit plates to increase the stiffness of the assembly during delivery and installation. These must be removed after fitting within the AHU so that the cooling coil can be slid inside the two legs.

The choice of materials is as broad as it is for the combi unit although drainpans cannot be incorporated into the narrow casing of horseshoe heat pipes and overall catchment should be secured beneath the entire assembly within the base of the AHU.

A further requirement for fitting horseshoe heat pipes is that the internal AHU area around both the heat pipe and the cooling coil be blanked off. Not only must air not be allowed to bypass around or over the precool and reheat legs of the heat pipe it must not be allowed to bypass around or over the cooling coil between the heat pipe legs.

Any bypass around either the heat pipe or cooling coil will lead to a reduction in the rated performance of the combination. In order to minimize the blanking requirements the finned area of the horseshoe heat pipe will typically be sized to match the finned area of the cooling coil and the distance between the heat pipe legs sized to just clear the casing of the cooling coil. 10mm clearance is typical.

Other than central AHU plant, dehumidifier heat pipes can find application in a variety of other equipment. For example they have been incorporated in PAC units where they are typically installed straddling the supply and return ducts to and from the DX coil within the unit itself. These heat pipes are straight but mimic the behaviour of the horseshoe heat pipe with the air being turned through 180° by the supply fan rather than the heat pipe being turned through 180°C.

SPC also supply a range of stand-alone dehumidifier units incorporating wrap around heat pipes. These are so-called heat pump dehumidifiers incorporating a complete refrigeration circuit with heat pipes wrapped around the evaporator coil to optimize moisture removal. This gives the highest rate of moisture removal per unit of energy consumed of any heat pump type dehumidifier available on the market.

‘Horseshoe’ heat pipe

View from coil connection end showing two rows of heat pipes. Wrap-around pipes encased at opposite end. Cooling coil slides between the two heat pipe legs. Bars shown are transit plates and must be removed before fitting the coil.

6. Conclusions

For comfort air conditioning applications the method of dehumidification of choice is condensation dehumidification. This involves overcooling air to strip out moisture on the fin surfaces of a cooling/dehumidifying coil. The traditional process is wasteful of energy due to both the overcooling and reheating that are involved in producing the required supply condition.

By wrapping a heat pipe around a cooling coil the process can be achieved in a single stage with no wasted energy. This is achieved by the heat pipe transferring heat around the cooling coil to give a precool and reheat effect without input of any wasted energy.

Heat pipes have, in common with other heat exchangers, a quantifiable performance index called effectiveness. This index allows prediction of the performance of a given heat pipe across a range of air conditions. This property is used, as in the worked examples shown above, to calculate supply conditions from the dehumidification system.

The worked examples have been chosen to be illustrative of common applications into which heat pipes have been incorporated but this selection of examples could be widened to include any set of environmental conditions of interest. Selection software is available to assist engineers in the choice of heat pipes based upon the location’s prevalent conditions.

Bin data analysis has been described and used to give as accurate as possible an estimate of the annual energy savings that can be accrued through adoption of the heat pipe dehumidification principle.

While the combination of cooling coil and heat pipe can be considered a special case of a cooling coil, the fact that they are not physically linked allows the possibility of more specialized control options than are available simply with a cooling coil. These control options can, if circumstances demand, be included within either the heat pipes themselves or the AHU. Caution should be exercised, however, as their incorporation adds significantly to the size and initial cost of the installation.

The optimal route to heat pipe installation is to specify a combi unit where the heat pipe and cooling coil are incorporated in a common casing. Often this is not an option and the heat pipe is supplied separately to the cooling coil. Fortunately heat pipes consist of bundles of copper tubes expanded into aluminium or copper fins just as the cooling coil is constructed and sizes/materials can be matched.

SPC

S & P Coil Products Ltd
SPC House, Evington Valley Road, Leicester, LE5 5LU
tel: (0116) 249 0044 fax: (0116) 249 0033
email: spc@spcoils.co.uk web: www.spcoils.co.uk

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