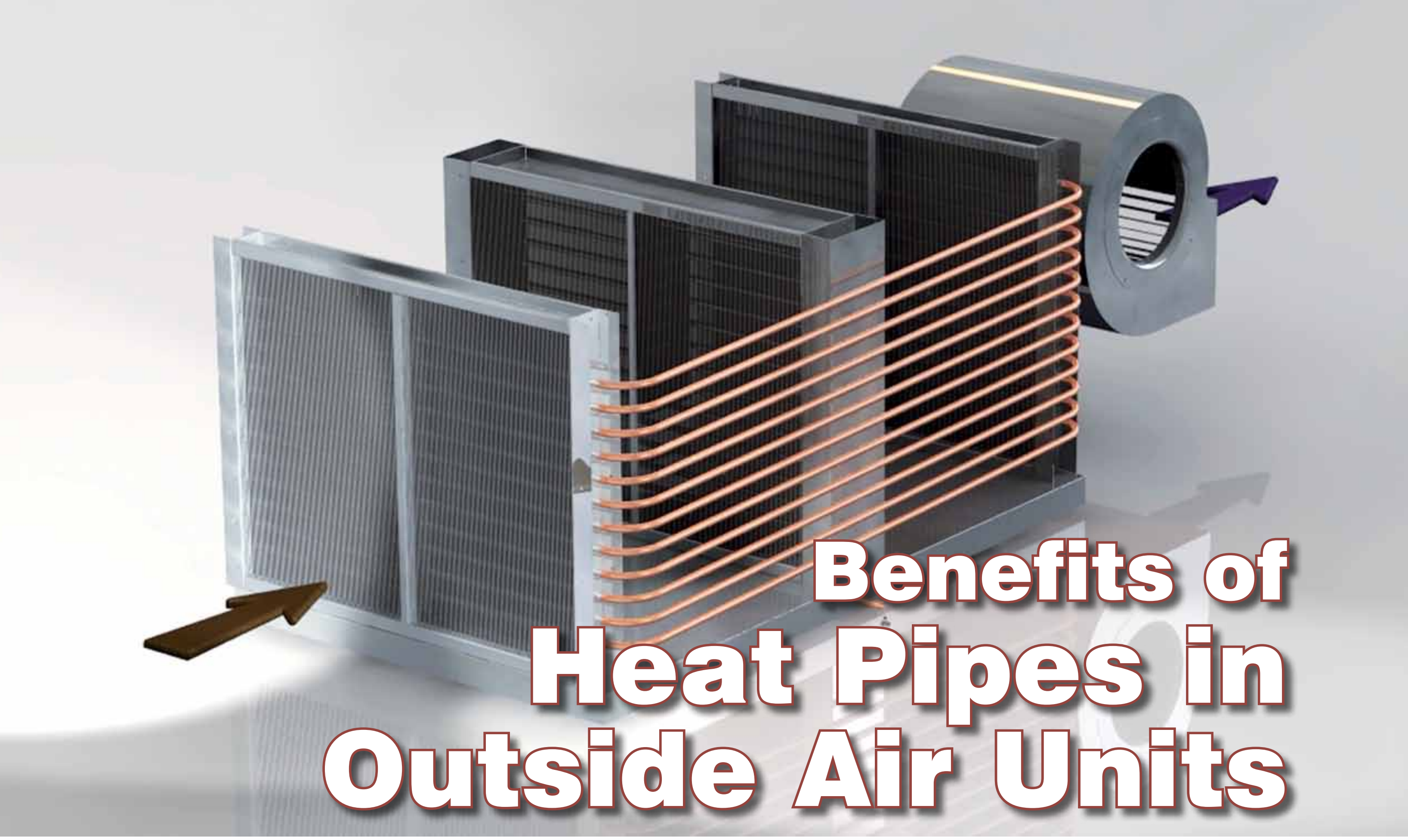

Benefits of Heat Pipes in Outside Air Units

By Sudeep Sethi
Regional Director, S & P Coil Products Ltd.
Dubai

and

Richard Meskimmon
Technical Manager, S & P Coil Products Ltd.
U.K.

In recent years the market for heat pipe technology in India has increased dramatically as heat pipes have finally become recognized as playing a vital role in the energy efficient treatment of ventilation air and particularly their suitability to the conditions pertaining in the Indian sub-continent.

How Heat Pipes Work

Heat pipes are the most effective passive method of transferring heat available today. In their simplest form, a sealed tube is evacuated and charged with a working fluid. In the case of heat pipes for HVAC purposes, refrigerants such as R134A are currently used. Heat transfer occurs without the need for energy input.

Figure 1 shows the basic structure of a heat pipe and identifies the major steps in the heat pipe process. Heat is absorbed from the incoming warm air stream in the evaporator section, boiling the refrigerant. Due to its elevated vapour pressure, the vapour moves rapidly to the cooler condenser section of the heat pipe, carrying with it the absorbed heat. As the vapour reaches the condensing area of the heat pipe, heat is released to the cooler air and the vapour condenses. The liquid returns by gravity to complete the cycle. The entire heat transfer process occurs with a very small temperature difference along the pipe.

Heat pipes can not only be used to recover waste heat but, more valuably, are able to reduce the energy costs associated with the generation of treated and dehumidified outside air for use in the ventilation of commercial and industrial premises. So-called 'wraparound' heat pipes operate in conjunction with the main cooling coil in the primary air treatment unit to reduce the energy penalty associated with the removal of heavy moisture concentrations within the humid outside air.

The primary role of the centralized outside air unit is to remove moisture from the incoming air and generate neutral air

---

About the Authors

Sudeep Sethi is a mechanical engineer from the YMCA Institute of Engineering, Faridabad with an MBA from University of Strathclyde, Glasgow. He has 18 years experience in HVAC of which 12 years are with S&P Coil Products and 6 years with Blue Star Ltd., Delhi. He is responsible for the regional office in Dubai, the factory in Sharjah and covers the territory of Middle East and South Asia.

Richard Meskimmon has spent the last 20 years in the HVAC industry with S&P Coil Products Ltd. After graduating with a honours degree in mechanical engineering from the University of Leicester, he spent 5 years working within the design team at S&P Coil Products Ltd., responsible for design of heat exchangers and specialist applications. Since becoming technical manager, he has been responsible for the development of heat pipe technology and has designed applications world-wide.

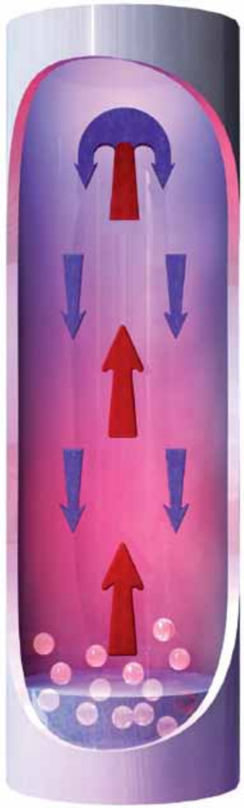

Figure 1: Basic heat pipe structure

at a temperature suitable for direct supply to the occupied spaces. The adoption of heat pipes in these designs radically reduces the running costs while adding little to the initial cost of the project and achieving rapid payback times.

In order to generate ventilation air at a moisture content and temperature which is suitable for direct supply, the conventional technique involves overcooling of the air in order to strip out the necessary moisture and then reheating the air to a suitable supply temperature. Typically, the air would be supplied at a temperature of around 18°C and a moisture content of around 8g/kg. This air is at or just below the conditioned space temperature and hence will provide some primary cooling. The moisture content of the ventilation air will be lower than that within the conditioned space and hence will be capable of absorbing any internal moisture gains from occupants or other processes.

The conventional ventilation process is wasteful of energy as a result of the need to overcool air and then reheat it. If a heat pipe is wrapped around the cooling coil its effect is to precool the outside air prior to it reaching the cooling coil and then reheat the air after it has been overcooled. Both the precooling and reheating effects of the heat pipe are achieved completely passively with no energy or cost penalty. In essence, the heat pipe reduces the load on the cooling coil which offsets the energy penalty associated with overcooling, and also removes the need for expensive reheat (electrical or otherwise) and its associated equipment.

Heat pipe devices contain no moving parts and are completely passive. They are designed to suit each particular application and are simply fitted inside the air handling unit along with the primary cooling coil. Unlike other heat transfer devices, heat pipe maintenance is easily undertaken as it only involves a seasonal cleaning of the external surfaces and does not demand the attention of a skilled maintenance team. Heat pipes are typically manufactured from an array of copper tubes expanded into aluminium fins using the same techniques as used for conventional coil manufacture. A range of alternative materials are available inline with those used in the coil manufacturing processes. The tubes are then 'laced' together to form patented loops with each heat pipe being made up of a significant quantity of such loops. The final manufacturing process involves the charging of the heat pipes with the required working fluid. Because the heat pipe consists of multiple loops it is not subject to complete failure should leaks occur as only the affected individual loop will lose its charge.

Figure 2: Typical wraparound heat pipe installation

Figure 2 shows a complete air treatment section of an air handling unit and demonstrates how the heat pipe slides in and out of the section on rails in the identical fashion to the cooling coil shown inside it. *Figure 3* shows a typical wraparound heat pipe in the factory; the two 'legs' of the heat pipe will be fitted around the main cooling coil.

Case Study

In order to demonstrate the energy savings that are likely to be achieved via the introduction of heat pipes, an actual installation (international hotel in Delhi) was chosen as a test site to monitor the actual air conditions attained in the air treatment section of an outside air AHU equipped with heat pipes wrapped around the primary cooling coil. Temperatures were monitored in the relevant positions upstream and downstream of the heat pipe and cooling coil over the course of a number of days. Three dataloggers were set-up and simultaneously started, measuring the temperature of the outside air, the temperature of the air on the leaving face of the cooling coil and the temperature of the supply air downstream from the reheat leg of the heat pipe.

Figure 3 shows details of the heat pipe and cooling coil arrangement along with the positions of the dataloggers. Position 1 measures the outside air temperature, position 2 the temperature off the precool leg of the heat pipe, position 3 the off cooling coil temperature and position 4 the supply air temperature. Note that

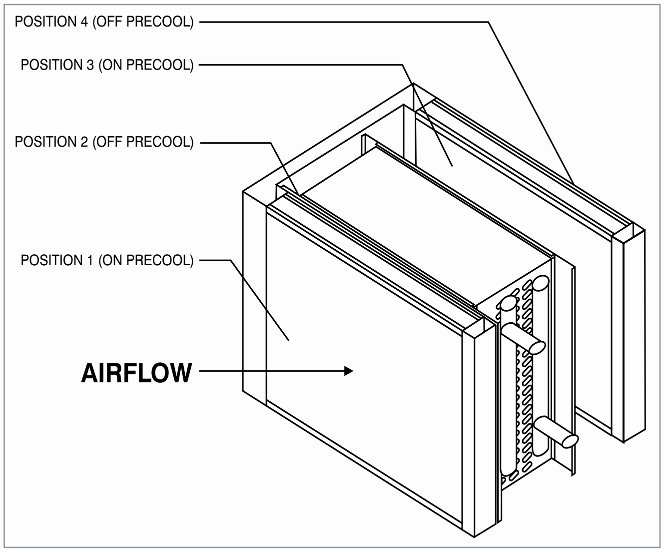

Figure 3: Heat pipe / cooling coil arrangement with positions of dataloggers

there is no room to position a datalogger in position 2 and hence the temperature shown at this position is, by necessity, implied rather than measured. The implied temperature can easily be calculated bearing in mind that the degrees of precooling are always just equal to the degrees of reheating. The degrees of reheating are calculated by subtracting the temperature measured at position 3 from that measured at position 4.

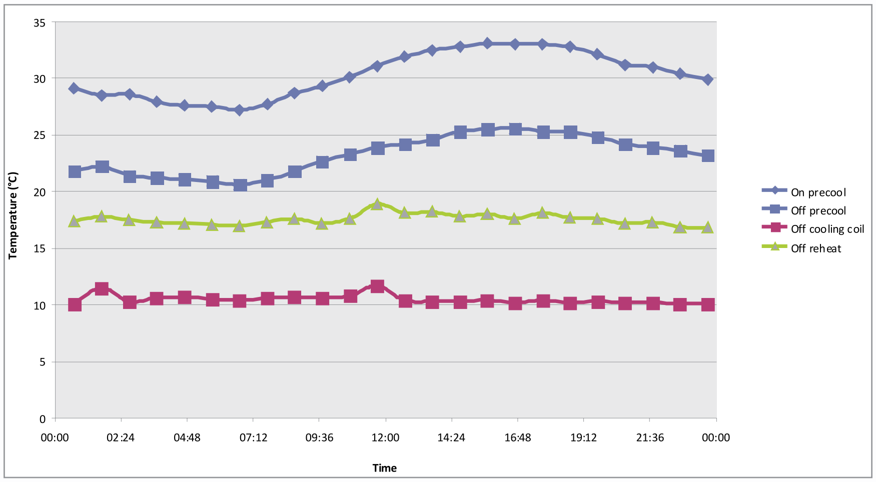

Figure 4 – Temperature conditions throughout the day

Results

Table 1 shows the actual recorded data, downloaded from the three dataloggers plus the implied reading for position 2. The final column of the table labeled 'energy saving' is equal to the reduction in load on the cooling coil and hence on the chiller. This value is also simultaneously equal to the reheat saving as a result of allowing the heat pipe to provide this rather than conventional energy consumptive equipment.

There are two areas of energy saving and the mean daily value is calculated from the hourly data as 31.2kW. That is, there is an average reheat saving of 32.1kW which is a direct energy saving, replacing electric (or other) reheat. There is also an average load saving of 32.1kW on the chiller and assuming that the chiller runs at a COP of 3, this can be converted to a chiller energy input rate saving of 32.1/3 = 10.7kW. The total, average rate of energy saving is 42.8kW. This energy saving is based on the design air volume throughput for the unit of 8000cfm or 3.78m^3/s.

Table 1: Recorded data

Time	Temperature (°C)				
	Sensor 1	Sensor 2*	Sensor 3	Sensor 4	Energy saving (kW)
00:41	29.1	21.8	10.1	17.4	33.1
01:41	28.5	22.2	11.5	17.8	28.6
02:41	28.6	21.4	10.3	17.5	32.7
03:41	27.9	21.2	10.6	17.3	30.4
04:41	27.6	21.1	10.7	17.2	29.5
05:41	27.5	20.9	10.5	17.1	29.9
06:41	27.2	20.6	10.4	17	29.9
07:41	27.7	21	10.6	17.3	30.4
08:41	28.7	21.8	10.7	17.6	31.3
09:41	29.3	22.7	10.6	17.2	29.9
10:41	30.1	23.3	10.8	17.6	30.8
11:41	31.1	23.9	11.7	18.9	32.7
12:41	31.9	24.2	10.4	18.1	34.9
13:41	32.5	24.6	10.3	18.2	35.8
14:41	32.8	25.3	10.3	17.8	34.0
15:41	33.1	25.5	10.4	18	34.5
16:41	33	25.6	10.2	17.6	33.6
17:41	33	25.3	10.4	18.1	34.9
18:41	32.8	25.3	10.2	17.7	34.0
19:41	32.1	24.8	10.3	17.6	33.1
20:41	31.2	24.2	10.2	17.2	31.8
21:41	31	23.9	10.2	17.3	32.2
22:41	30.4	23.6	10.1	16.9	30.8
23:41	29.9	23.2	10.1	16.8	30.4

* The values for sensor 2 are calculated from the amount of reheat generated at the leaving leg of the wrap around heat pipe. As the precool leg will be in 100% sensible operation, the temperature delta observed will be the same as on the reheat leg.

Conclusions

Figure 4 shows, graphically, the temperature conditions throughout the day for the air treatment section of the FAHU. The reheat and precool achieved by the heat pipes shows some variation; this is a result of the variation in the outside air temperature while the air off cooling coil temperature is held largely constant. The heat pipe is a constant-effectiveness device, so the higher the temperature difference across its two legs the higher the rate of heat transfer and the greater the degrees of precooling and reheating.

At the calculated rate of energy saving above, 42.8kW, the energy saved per day as a result of the inclusion of the heat pipe will be 1027kWh. While this energy saving will not be typical of every day of the year, it does demonstrate the quantity of savings that will be accrued from even such a modestly sized system. During the heating period of the winter the heat pipe is likely to be inoperative as it will only function if the cooling coil is receiving a supply of chilled water. Similarly, during mid seasons the savings will be diluted due to the reduced temperature differences across the heat pipe. A good estimate of the annual savings can be quantified by assuming that the system operates at the conditions as measured for 3000 hours per year and that it is inoperative for the remaining hours. This gives a total annual energy saving of 128400kWh and can, in turn, be converted to an annual cost saving simply by multiplying by the cost of electricity. While this calculation technique is approximate it has been shown to give good correlation with a year round detailed analysis. The payback period for such a heat pipe will be much shorter than one year.