Among the many techniques that have emerged in recent years to reduce aircraft fuel burn, the saving of aircraft weight through moisture reduction by utilising CTT Systems's zonal dryer is one of the simplest. The system is lightweight and provides fast return on investment.

Achieving weight & fuel burn reduction through cabin zonal drying

One method of cutting an aircraft's fuel burn is to lower its weight by reducing the condensation formed, and the water and ice that is subsequently carried, in the aircraft cabin during flight. Reducing or elimination this water and ice reduces the aircraft's weight by several hundred kilograms.

Condensation accumulates in the aircraft cabin wall and then freezes in the insulation blankets when the aircraft is at altitude. It is estimated that the amount of water that can be carried in insulation blankets is 250-300kg for a narrowbody, and 350-600kg for a widebody.

CTT Systems

CTT systems of Nykoping Sweden has four main products. Its primary product is the zonal drying system. This system is installed in the crown area of an aircraft, and weighs up to 30kg in a narrowbody, and up to 75kg in a large widebody.

It is used to prevent and minimise condensation forming in the aircraft cabin walls. All or most of the accumulated moisture can be removed by the zonal drying system over a period of about six months following installation. The subsequent weight reduction translates into fuel burn savings, which accumulate to several hundreds of thousands of dollars over an aircraft's operational lifetime.

To date, more than 450 aircraft have been retrofitted with the zonal drying system. A pair of units are fitted in the upper area in the aircraft's crown in an aircraft. The 787, however, is the first type to be fitted with two zonal drying units as a standard specification. More than 100 787s are now in operation with the CTT zonal drying system fitted.

Cabin moisture & ice

"The problem of moisture in the aircraft mainly arises in high-density cabins with a large number of people," explains Peter Landquist, vice president of sales, marketing and customer support at CTT Systems. "Each person in the cabin breathes moisture into the cabin's atmosphere, and this is almost the only source of moisture in the cabin when the aircraft is cruising at altitude. A larger number of people in an economy class cabin breathe out a lot of water vapour.

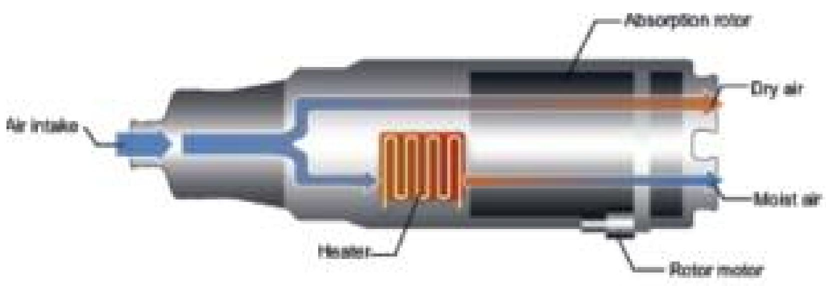
"The problem of moisture production in the cabin wall is explained by the physics of the formation of condensation," continues Landquist. "Condensation will be produced when the air circulating in the cabin wall and fuselage skin area is reduced to a temperature that is equal to the air's dew point. The aircraft cabin wall and underfloor areas are cooler than most other parts of the fuselage and the area inside the cabin. This is because the air circulating outside the aircraft is at temperatures in the region of minus 50 degrees centigrade when the aircraft is cruising at altitude."

The issue is related to the relative humidity (RH) of the air, and its dew point. RH increases with an increased moisture content. The dew point temperature is higher, or warmer, for a higher RH. Thus, the higher the moisture content, the warmer the air temperature at which condensation forms.

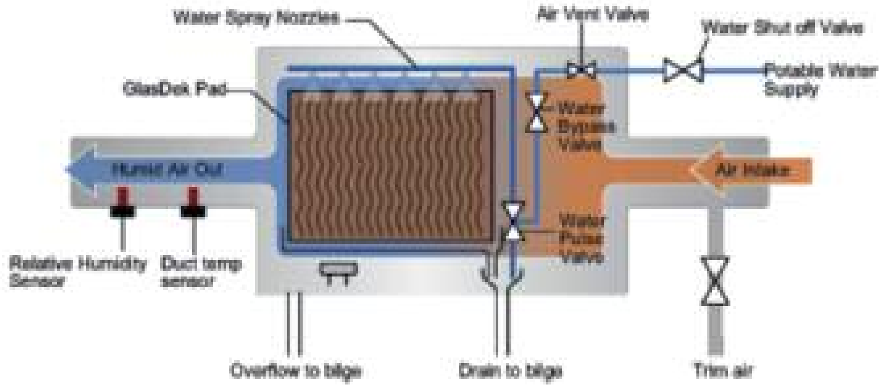
The air in a high-density passenger cabin will have a higher RH than that in a premium cabin, which is configured with more space per passenger. The dew point of air increases with RH. That is, air with an RH of 1% has a dew point of minus 35 degrees centigrade, while air with an RH of 5% has a dew point of minus 18 degrees. Air in a first-class cabin, the flightdeck or a crew rest area is likely to have an RH of 1-5%, so condensation will only form if the air is cooled to these low temperatures.

"The air being pumped into the forward end of the aircraft cabin by the aircraft's pressurisation system will be dry at entry, and its RH increases as it passes through the various sections of the passenger cabin. It is at a temperature close to about 20 degrees centigrade at this point, and so well above the dew point," explains Landquist. "The air then passes both to the rear and sides of the cabin. Some moisture leaves the cabin as air is passed through the rear of the fuselage by the pressurisation outlet ducts. Air that travels to the sides of the cabin is cooled by being close to the fuselage skin. The air gets into the area between the sidewall panels and the outer metal fuselage skin, as well as in the crown area above the ceiling panels and overheads bins. The air in these sections and areas of the fuselage then cools to a lower temperature."

The air in passenger cabins with a higher seating density and more passengers has a higher RH, and so a warmer dew point temperature. Air with an RH of 10% has a dew point of just minus 10 degrees, while air with an RH of 15% and 20% has even higher dew point temperatures of minus five and minus one degree centigrade. An example is an A320 in a high-density seat configuration of 160. Cabin air RH is about 18%. While the RH is still low for passengers compared to air they breathe on the ground, it is still high when the temperature of the aircraft's cabin wall and fuselage skin is taken into consideration. The air's dew point will be a little cooler than minus one degree centigrade, so a lot of condensation will



The main component of CTT System's zonal drying system is the zonal dryer. Each unit weighs about 11kg. The unit dries pressurised air using silica gel crystals.



be produced.

"Air in high-density passenger cabins therefore only needs to be cooled to a relatively warm temperature for condensation to form," explains Landquist. "This is how the problem of condensation and the accumulation of moisture in the cabin walls and insulation blankets arises.

"The problem is made worse by the condensation freezing while the aircraft is cruising at altitude, and the ice building on the inner skin, the insulation blankets, and various structures in and around the fuselage and cabin," continues Landquist. "This way the cold temperature of the outer cabin structure and fuselage skin effectively acts as a humidifier while the aircraft is in flight. The frozen condensation then melts when the aircraft descends into warmer air at lower altitudes. This melting ice can then form 'rain' or mist in the passenger cabin and drip on the passengers, and can cause moisture build-up on aircraft components and structures. The melted ice also accumulates in the aircraft's insulation blankets and lower hold areas. This is the main cause of the aircraft gaining weight, which leads to a long-term fuel burn penalty."

Another issue that results from the accumulation of moisture in the aircraft structure relates to maintenance. "One particular issue is the effect that moisture has on the aircraft's electrical systems and many of its avionic components," says Landquist. "The accumulation of moisture is attributed to the problem of no fault found (NFF) in many avionic components, which results in an excess of rotable component inventory needing to be kept. Moisture is also a cause of corrosion in the aircraft structure, and so increases maintenance costs."

Zonal drying

The technique to minimise the formation of condensation and extracting accumulated moisture is to lower the dew point of the air that is close to the coolest areas of the fuselage. That is, to take the dew point to a larger minus degrees centigrade level. "If the dew point of the air is taken down to close to minus 30 degrees centigrade, then condensation will not form," explains Landquist. "This reduction in the air's dew point is achieved by reducing its RH. This requires a reduction in the air's moisture content.

"Our Zonal Drying system achieves this by blowing in very dry air, generated by two main zonal drying units, into the crown area of the aircraft fuselage. That is, in the upper part of the fuselage barrel," continues Landquist. "This travels along the length of the upper fuselage, above the ceiling panels and in one of the highest parts of the crown, along a perforated pipe known as a piccolo duct. This is made of lightweight glass fibre and silicon. This dry air passes down the side of the fuselage, in the gap between the fuselage skin and the sidewall panels, and close the fuselage wall inside the cabin. This very dry air prevents the moist air from reaching the colder area of the fuselage and the insulation blankets."

The flow of dry air therefore prevents the humid air coming close to the cooler fuselage wall, and so keeps it from reaching its dew point. The moist air therefore gets circulated around the warmer parts of the cabin, and leaves the aircraft through the pressurisation outlet valves.

The dry air, pumped from the zonal drying main duct in the fuselage crown, also draws out moisture from the insulation blankets over the long-term. "This is because the dry air flows between the fuselage skin and sidewall panels, and so will naturally attract the moisture that has accumulated prior to an aircraft being modified," explains Landquist. "This moisture is then circulated around the warmer cabin, and will eventually leave through the pressurisation valves. The zonal drying system can also operate on the ground, and is powered by an auxillary power unit (APU) or a ground power unit (GPU). It can this reduce moisture in the insulation blankets, which is from melted ice."

The heart of the zonal drying system is the zonal drying units. Each zonal dryer weights about 11kg, and they are the same size for all aircraft types. One zonal dryer is used on narrowbodies, and two or three units are used on widebodies. A zonal dryer unit is about 80cm in length, larger units on widebody aircraft are up to about 30cm in diameter. They are electrically powered, and air is fed from the pressurised area in the cabin into the front of the unit. The zonal dryer itself is located either in the crown area, or under the cabin floor.

About 20% of incoming air is heated to about 110 degrees centigrade, before all air is passed through a slowly rotating glass fibre honeycomb rotor, and this is impregnated with silica gel crystals. This means moisture in the air is absorbed by the silica gel crystals, which have been warmed by the hot air. The dry air exits the rotor, and is then routed to the part of the aircraft that needs to be dried via the piccolo duct.

Installation of a complete zonal drying system on a narrowbody includes the two zonal dryers, and the installation of the main piccolo duct and various

The zonal dryer is used as a single unit on narrowbody aircraft, and two are required on widebodies. Each zonal dryer is about 80cm long and 30cm in diameter. The entire zonal drying system weighs up to 70kg in a narrowbody. The system removes several hundred kilograms of moisture from an aircraft cabin.

attachment brackets in the crown of the aircraft. The installation has a list price of about $70,000 per aircraft. It can be installed during a base check, and is estimated to use about 100 man-hours. The whole system weights about 30kg for a narrowbody.

The returns from this are a reduced fuel burn of about 7kg per flight hour (FH) for an aircraft type the size of a 737NG or an A320. This is equal to about 2.3 US Gallons (USG) per hour. Given that narrowbody aircraft have annual utilisations in the region of 3,000FH, this is equal to a fuel burn saving of about 7,000USG per year. Spot fuel prices of about $3 per USG, mean this is an annual saving of $21,000 per aircraft. The system should therefore generate savings that recover its own installation cost in a little over three years of operation.

An ultra large widebody can have up to 1,000kg of accumulated water in the insulation blankets. It is estimated to save up to $255,000 per year on an aircraft the size of the 747-8 or A380. The system can therefore recover the cost of installation in a year or even less than a year when installed on a widebody.

Not only does the zonal drying system have a high return on investment, but it is also one of the fastest and easiest techniques to employ to reduce fuel burn.

Virtually all the saving in fuel burn costs will be direct savings, since the zonal dryer has low maintenance costs. The unit has a mean time between failure of about 20,000FH. Moreover, the zonal drying system will also lead to some savings in component inventory, and airframe maintenance costs due to reduced corrosion and a lower replacement rate of insulation blankets.

Other benefits include improved passenger comfort as a result of the absence of condensation or 'rain'.

To date, CTT's zonal drying system has been available as a retrofit or modification on aircraft. More than 450 aircraft have been modified with the system. The majority of airlines that have selected the system are charter operators and low-cost airlines that both have high seating densities. The zonal drying system has also been installed on a large number of VIP and corporate aircraft.

The zonal drying system is now optional equipment on the 787, and more than 100 are operating with the system.

Cabin humidifier systems

Although apparently contrary to the zonal drying system, CTT also provides humidifier systems for passenger cabins and crew areas. "This is because the air entering the cabin from the pressurisation system is dry and has low humidity," explains Landquist. "Passengers and crew members would like to have a higher moisture level for comfort reasons, because the air in the aircraft is dryer than the air on the ground. This creates a humidity dilemma, with the need to prevent moist air condensing when it reaches the cool fuselage skin. There needs to be a humidity balance. That is, the air near the fuselage skin needs to be kept dry, while certain cabins need to be humidified. A cabin humidifier system on its own would massively increase cabin rain and condensation."

CTT provides humidifying systems for use on the flightdeck, crew rest areas and premium cabins for comfort. CTT recommends that airlines use them together with its Zonal Drying system, however. The humidifier system installed on its own would massively increase cabin 'rain' and condensation, leading to significant weight gain. Humidifiers can, however, be sold on their own for use in cabin crew rest areas.

Various airlines have selected the humidifying systems for rest areas and premium cabins. Lufthansa, for example, has humidifiers installed in the first-class cabin on its A380 fleet, together with a zonal drying system for the whole aircraft.

CTT only sells passenger cabin humidifier systems together with its Zonal Dryer system, and does not sell humidifiers on their own. CTT does, however, sell cabin crew rest area and flightdeck humidifiers separately. The humidifiers use the aircraft's potable water. An example is the humidifying systems on the 777 that use about 3.5 litres per FH to reach an RH of 20-25%.

In addition to the zonal drying system being a standard configuration option on the 787, the A350 is offered with humidification systems on the flightdeck, crew rest areas, and premium passenger cabins as an option. AC