Condition Air into the Human Comfort Zone

Introduction

Humans generally feel comfortable between temperatures of 22°C to 27°C and a relative humidity of 40% to 60%.

In this application, air at 35°C and 60% relative humidity will be conditioned into the human comfort zone, with the thermodynamic process plotted on a psychrometric chart. To do this, we will

- first cool the air to 14°C (this removes some of the water from the air),
- and then heat the air to 24°C.

Additionally, we will calculate

- the heat and mass of water removed in the cooling phase,
- and the heat added in the heating phase.

Plot the Comfort Zone on the Psychrometric Chart

```
> restart :
  with( ThermophysicalData ) : with( plots ) : with( Units[Standard] ) :
```

Functions for the lower and upper bounds of the human comfort zone.

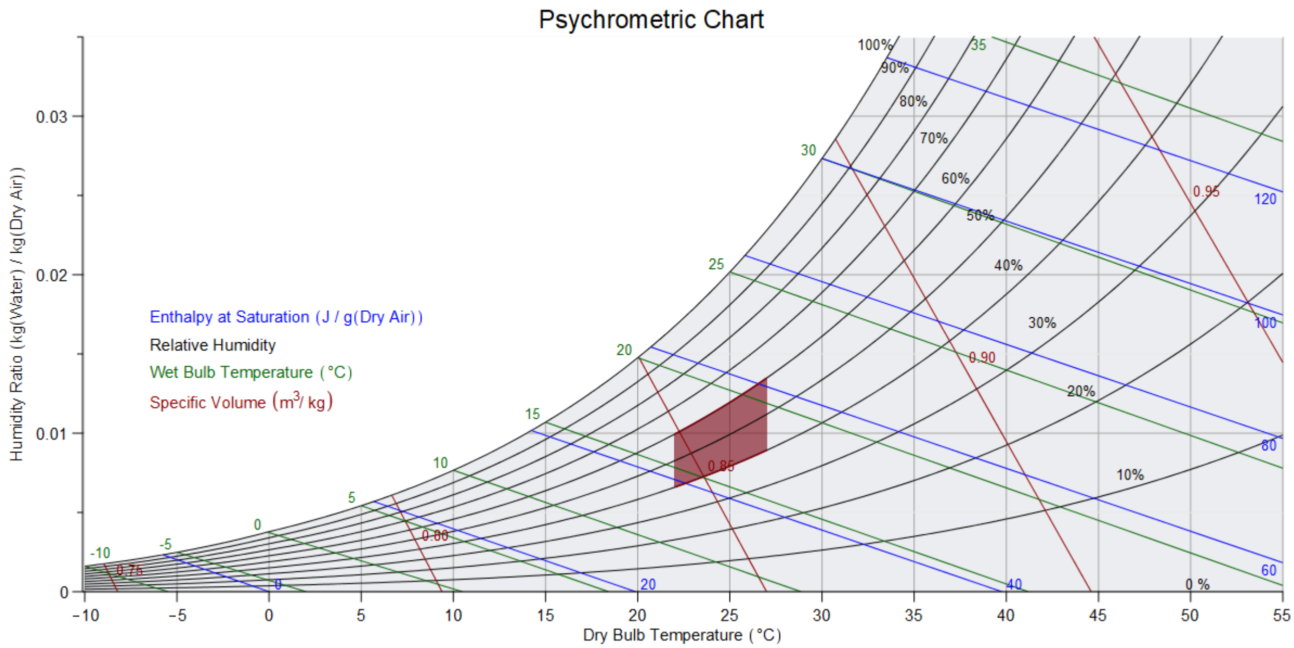
```
> lower := T→Property( humidityratio, HumidAir, P = 101325, Tdb = T, R = 0.4 ) :
> upper := T→Property( humidityratio, HumidAir, P = 101325, Tdb = T, R = 0.6 ) :
```

Shade the human comfort zone between 22°C and 27°C.

```
> comfortZone := shadebetween( lower, upper, 273.15 + 22 ..273.15 + 27 ) :
```

Plot the human comfort zone on a psychrometric chart.

```
> display( PsychrometricChart( ), comfortZone )
```



Plotting the Thermodynamic Cycle

Initially the air is at a temperature of 35 °C at a relative humidity of 60%

> $T_1 := 35\,\mathrm{degC} + 273.15\,\mathrm{K}$:

> $hr_1 :=$ Property(humidityratio, HumidAir, Tdb = T_1, "P" = 101325Pa, "R" = 0.6)

$$hr_1 := 0.02154666081 \quad \textbf{(3.1)}$$

Then, we cool the air, and calculate the temperature at saturation (that is, the temperature at which the relative humidity is 1).

> $T_2 :=$ Property(Tdb, HumidAir, R = 1, P = 101325Pa, humidityratio = hr_1)

$$T_2 := 299.2227624\ \mathrm{K} \quad \textbf{(3.2)}$$

> $hr_2 := hr_1$:

We continue cooling along the saturation line until we reach 14 °C (in this process, water condenses out of the air).

> $T_3 := 14\,\mathrm{degC} + 273.15\,\mathrm{K}$:

> $hr_3 :=$ Property(humidityratio, HumidAir, Tdb = T_3, P = 101325Pa, R = 1)

$$hr_3 := 0.01001332280 \quad \textbf{(3.3)}$$

Now we heat the air until it reaches 24 °C.

> $T_4 := 273.15\,\mathrm{K} + 24\,\mathrm{degC}$:

> $hr_4 := hr_3$:

Hence the entire thermodynamic cycle can then be plotted.

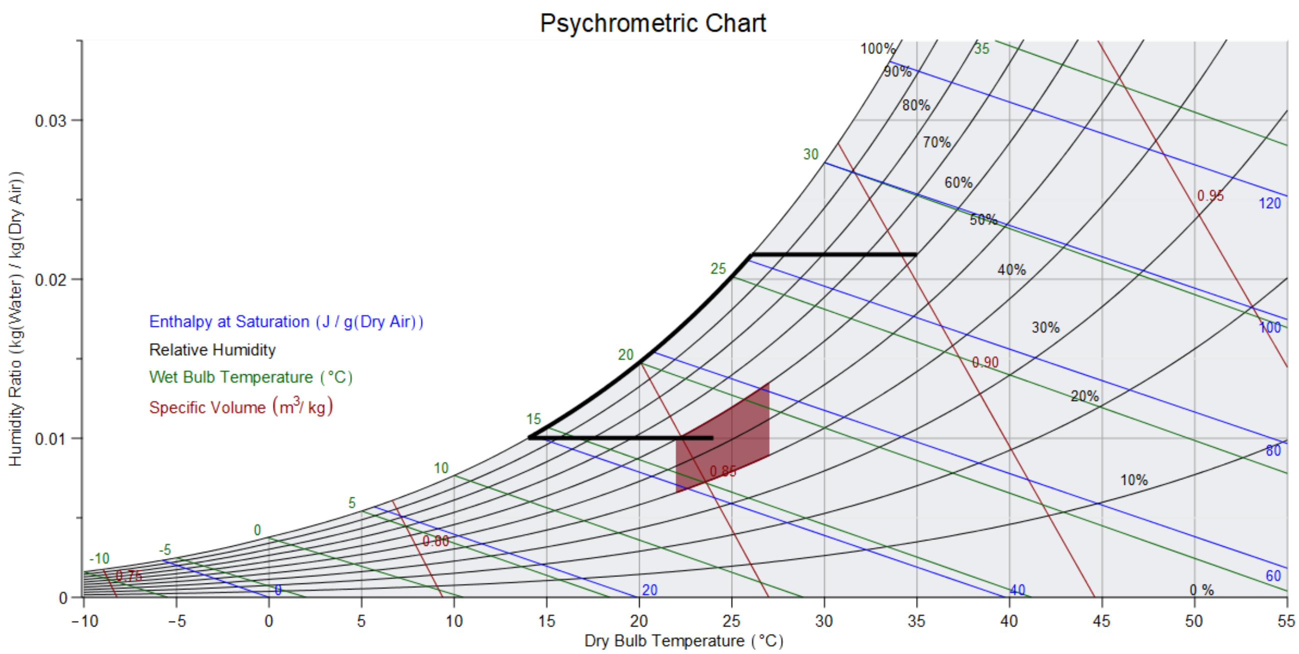
> route1 := pointplot(convert~([[T_1, hr_1], [T_2, hr_2]], unit_free), connect = true, thickness

$= 4)$:

route2 := pointplot($convert^{\sim}([[T_3, hr_3], [T_4, hr_4]]$, unit_free), connect = true, thickness $= 4)$:

> satLine := plot(Property("humidityratio", HumidAir, Tdb = T, P = 101325, R = 1), T = $T_2 .. T_3$, color = black, thickness = 4) :

> display(PsychrometricChart( ), comfortZone, route1, route2, satLine)



Heat Changes and Water Removed over the Thermodynamic Cycle

Water removed in the cooling process (in kg water per kg dry air)

> $hr_2 - hr_3$

$$0.01153333801 \qquad (4.1)$$

Heat removed in the cooling process (in J kg^{-1})

> h_1 := Property(enthalpyperdryair, HumidAir, Tdb = T_1, P = 101325, R = 0.6) :

> h_3 := Property(enthalpyperdryair, HumidAir, Tdb = T_3, P = 101325, R = 1) :

> $h_1 - h_3$

$$51101.11785 \frac{\mathrm{J}}{\mathrm{kg}} \qquad (4.2)$$

Heat added in the heating process (in J kg^{-1})

> h_4 := Property(enthalpyperdryair, HumidAir, Tdb = T_4, P = 101325, R = 0.5) :

> $h_4 - h_3$

(4.3)

$$8537.89452 \frac{\mathrm{J}}{\mathrm{kg}} \tag{4.3}$$