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SPECIAL REPORT:

Psychrometrics for Builders and Designers

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SPECIAL REPORT:

Psychrometrics for Builders and Designers

With the advent of more-sophisticated envelope design for houses, it has become increasingly important for residential designers and builders to understand psychrometrics — the behavior of moist air under various temperature and humidity conditions.

One basic tool is the "psychrometric chart." A full psychrometric chart includes hundreds of lines that describe the physical properties of air over a broad range of temperatures. Most people get dizzy just looking at a complete chart and to master its use is a challenge even for many engineers. Figure 1 is a simplified version of the psychrometric chart. The horizontal axis represents dry-bulb air temperature (dry-bulb temperature is what we're all used to, measured with an ordinary thermometer). The curved lines represent relative humidity.

In this report we will show how this simplified chart can be used by designers and builders to address several practical moisture-related design issues.

Predicting Moisture Condensation With the Psychrometric Chart

Some common questions

1. During summer, will condensation occur on an uninsulated basement floor in a warm climate if the basement is ventilated with outdoor air?

2. During winter, will condensation occur on ventilation intake ducts located in a heated basement?

3. Under what conditions will condensation occur on cold water pipes?

4. If a wall is insulated with R-19 fiberglass batts plus R-7 exterior foilfaced foam sheathing, will condensation occur on the inner foil face of the sheathing?

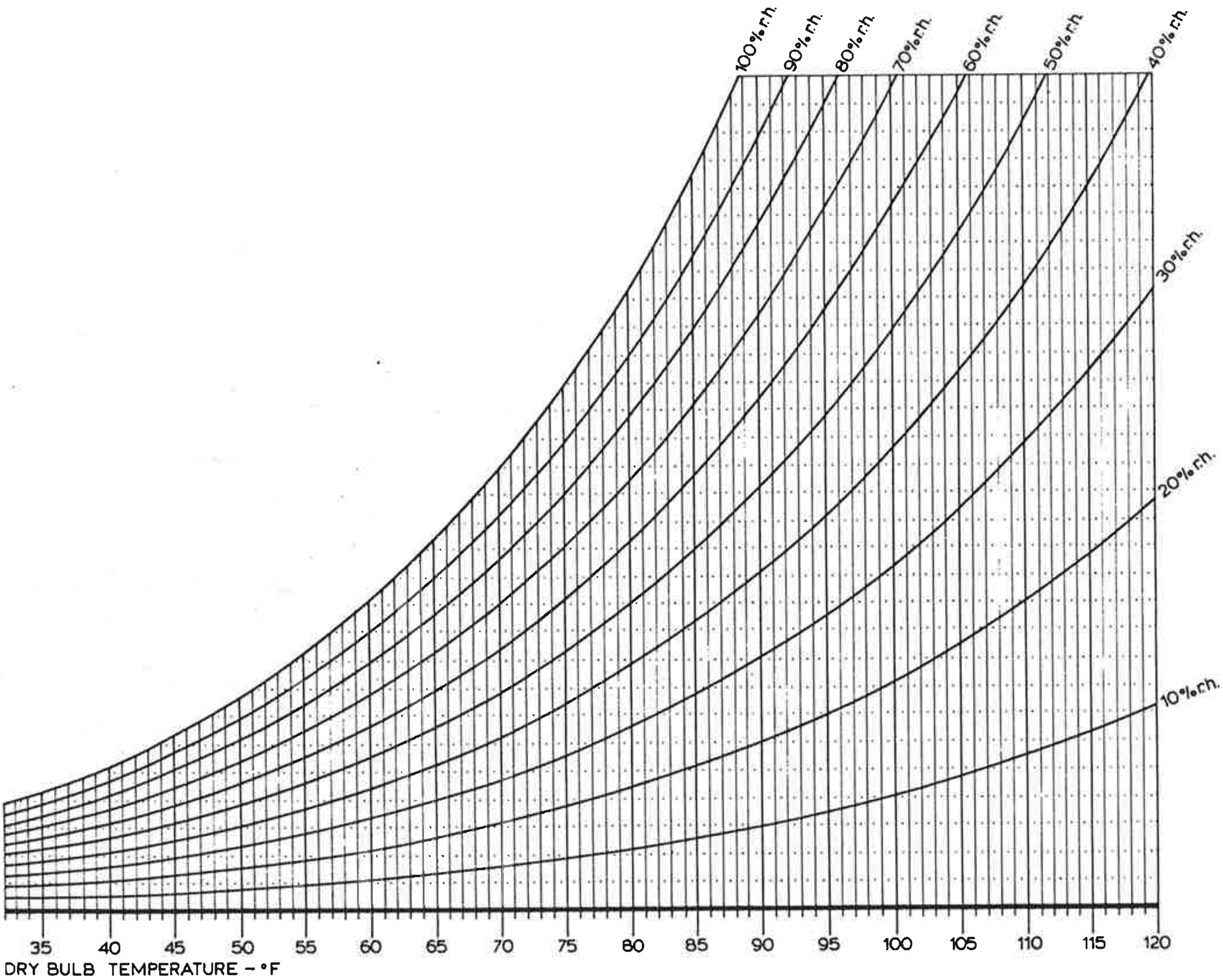


Figure 1 — A Simplified Psychrometric Chart

Finding the answers

To predict whether or not moisture condensation will occur on a certain surface, one needs to know three things:

1. The temperature of the air.

2. The relative humidity of the air.

3. The temperature of the surface in question.

Moisture condensation occurs when air is cooled below a certain critical temperature called the "dew point temperature."

If the temperature of a surface is below the dew point temperature of the air, condensation will occur.

If we know the temperature and relative humidity, it is easy to determine the dew point temperature of an air mass by using the psychrometric chart. The following four examples show how to use the chart to determine dew point temperature and to predict condensation conditions. The first three examples deal with surface condensation on basement floors, ventilation ducts, and cold water pipes. Example 4 is a slightly more complex situation in which we look at the possibility of concealed condensation inside a wall section.

Example 1: Condensation on basement floors

In warm climates, some designers intentionally avoid sub-slab insulation under basement floors to derive some benefit from ground-coupled cooling. But sometimes those slabs get wet and although the first suspected culprit is groundwater, moisture condensation from interior air may actually be the source. In those cases, it may be advisable to insulate the slab to prevent surface condensation.

As an example, let's look at Houston, Texas, where summer design conditions are about 92°F and 50% relative humidity. If a basement in Houston is ventilated with outdoor air during the summer, is condensation likely to occur on the uninsulated basement floor? (The average ground temperature at 2- to 12-foot depth is about 79°F in summer.)

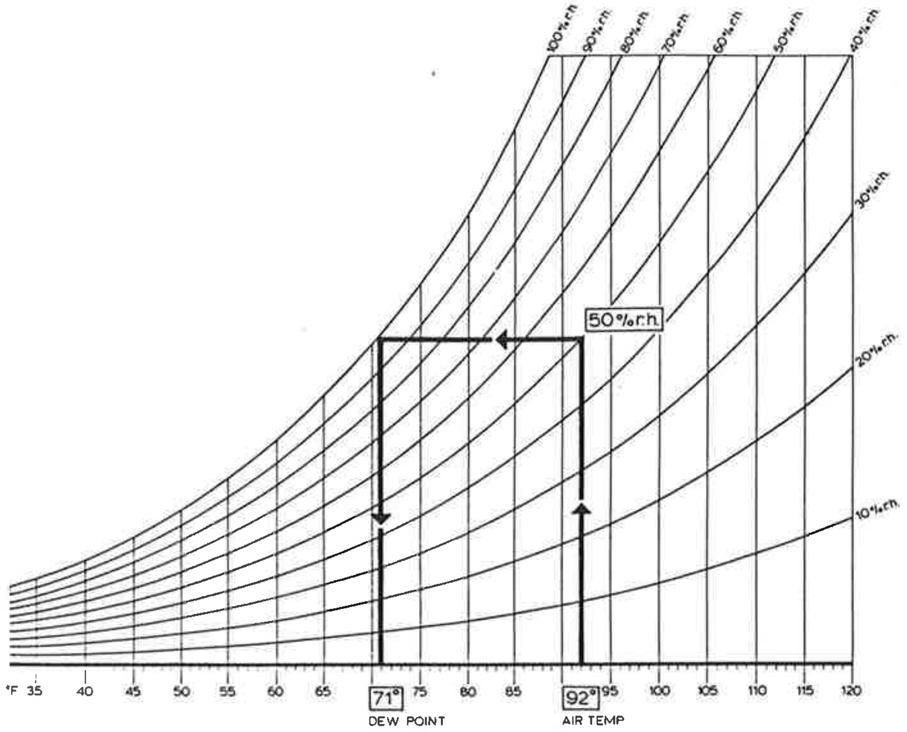


Figure 2 — Finding the Dew Point Temperature of Air at 92°F and 50% RH.

Solution (Figure 2)

To answer the question, we use the psychrometric chart to determine the dew point temperature of the air. If the surface temperature of the floor is below the dew point temperature of the air, condensation will occur.

Here's how to use the chart:

1. Find 92°F on the horizontal axis.

2. Follow the line vertically up to the intersection of the curved line marked 50% RH.

3. Proceed horizontally to the left to the intersection with the curved line marked 100% RH.

4. Finally, proceed vertically down to the horizontal axis and read the dew point temperature — about 71°F.

In this instance, the dew point temperature of the air is 71°F. Since the average ground temperature in summer, about 79°F, is not below the 71°F dew point temperature, *condensation should not occur.*

Example 2: Condensation on ventilation ducts

If fresh air intake ducts for a ventilation system are located in a heated basement, will moisture condense on the outer surface? If so, what should be done?

Solution (Figure 3)

To answer the question, we first determine the dew point temperature of the indoor air using the psychrometric chart. Next we estimate typical duct surface temperatures to see if they fall below the air dew point temperature.

Let's assume the indoor air is at 70°F and 40% RH. The method for determining dewpoint temperature is the same as in Example 1.

1. Using the chart, find 70°F on the horizontal axis.

2. Proceed vertically to the curved line marked 40% RH.

3. Proceed horizontally to the lift to the intersection with the curved line marked 100% RH.

4. Finally, proceed downward and read the dew point temperature — 44°F — on the horizontal axis.

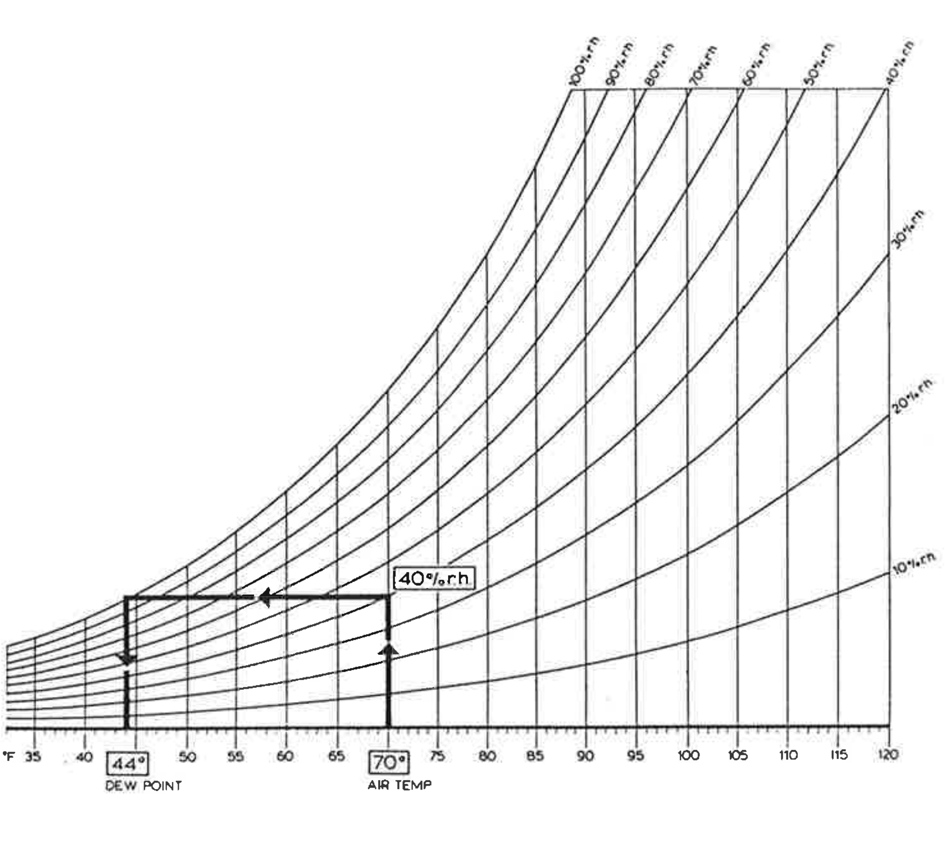


Figure 3 — Finding the Dewpoint Temperature of Air at 78°F and 40% RH.

Under these indoor conditions, condensation will occur on any surface whose temperature is below 44°F. If winter outdoor air temperatures are often below 44°F for extended periods of time, then condensation on the duct surface will definitely be a problem.

To alleviate the problem, the fresh air intake duct should be insulated.

Example 3: Condensation on cold water pipes

Suppose one of your customers discovers water in the plumbing wall behind the bathroom. He suspects a plumbing leak, but there doesn't seem to be enough water for that. He is any elderly man and keeps the house at about 78°F. When you visit the house, you measure the relative humidity at 50%. Could the problem be condensation on the cold water pipes? The house uses well water from a deep well. The water temperature is about 45°F.

Solution (Figure 4)

Using the psychrometric chart (Figure 4), we see that the dew point temperature of air at 78°F and 50% RH is 58°F. Since the cold water temperature is below that (45°F), condensation is probably occurring on the pipes. To remedy the situation, either the relative humidity of the house should be reduced and/or the cold water pipes should be insulated.

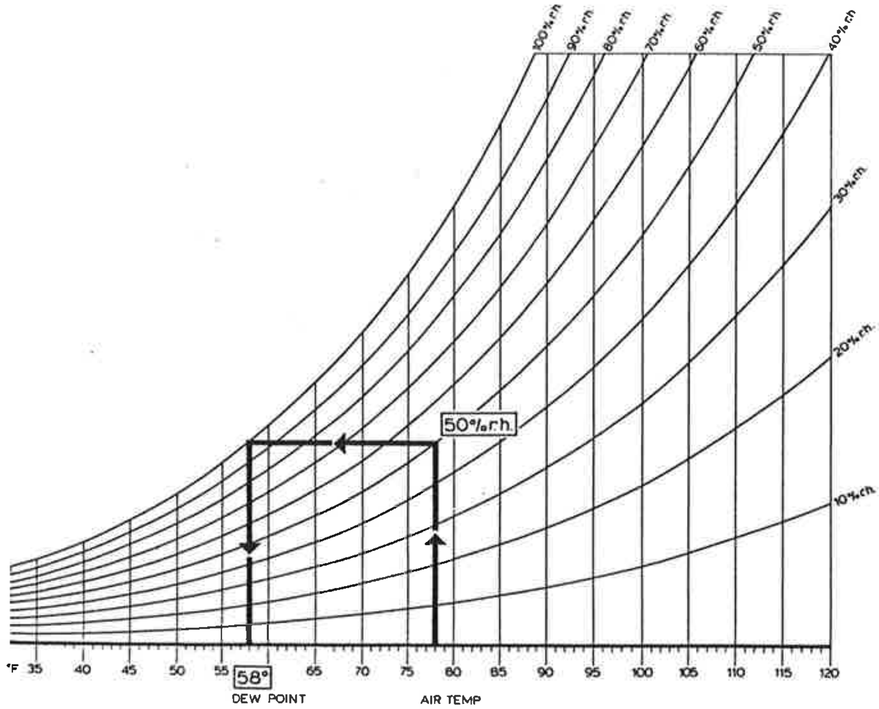


Figure 4 — Finding the Dew Point Temperature of Air at 78°F and 50% RH.

Example 4: Concealed condensation in an insulated wall

Suppose you have designed a wall with 6-inch (R-19) fiberglass batts plus foil-faced exterior sheathing (R-7). Since the foil-faced sheathing creates a vapor barrier on the cold side of the fiberglass insulation, there is some concern that condensation might occur on the foil if moist indoor air leaks into the wall cavity. (No condensation will occur if the temperature of the foil is above the dew point of the air.) Under average winter conditions, say 35°F outdoor air temperature, will the temperature of the foil facing be above or below the dew point temperature of the indoor air?

Solution

This example is slightly more complex because you need to calculate the temperature of the foil. Since there is insulation on both sides (foam on the outside, fiberglass on the inside), the foil temperature will be somewhere between the indoor and outdoor air temperatures.

The following simple procedure can be used to calculate the temperature at any point (P) inside a wall (see Figure 5).

1. Calculate the total R-value of the wall. Call this R1.

2. Calculate the R-value of the wall from the inside air to the point (P) that you are interested in. Call this R2.

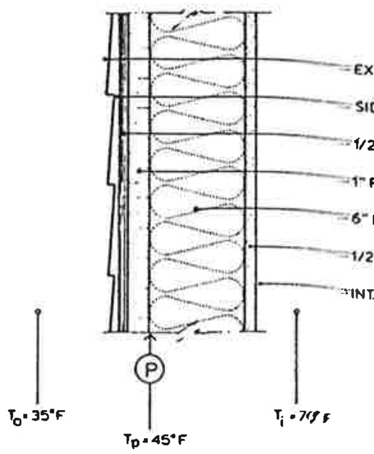
3. Ti = Indoor temperature.

To = Outdoor temperature.

4. Tp = Temperature at point P.

To find Tp, use the following equation:

Tp = Ti - ((Ti-To) x (R2/R1))



	R1	R2
EXT. AIR FILM	0.17	-
SIDING	0.80	-
1/2" PLYWOOD	0.62	-
1" FOAM	7.00	-
6" FIBERGLASS	19.00	19.00
1/2" GYP. BD.	0.45	0.45
INT. AIR FILM	0.68	0.68
TOTAL	28.72	20.13

Figure 5 — Finding the Temperature at a Point P in a Wall

For this example, we need to find the temperature of the foil when the indoor temperature (Ti) is 70°F and the outdoor temperature (To) is 35°F. The R-values are taken from Figure 5.

1. R1 = 28.72

2. R2 = 20.13

3. Ti = 70°F
   To = 35°F

4. Tp = 70 - ((70-35) x 20.13/28.72) = 45°F

Thus the temperature of the foil surface will be 45°F when the outdoor air is 35°F and the indoor air is 70°F.

In Example 2, we found that the dewpoint temperature of air at 70°F and 40% RH is about 44°F (Figure 3) — slightly below the 45°F foil temperature. Thus no condensation should occur under these temperature conditions. It is, however, a borderline case; if the outdoor air temperature were to drop, condensation might occur.

You can perform this calculation for any wall design and temperature regime. Keep in mind that it cannot exactly predict when condensation will occur because of complicating factors such as parallel heat flow through studs, insulation imperfections, air leaks, etc. Also, keep in mind that moisture condensation in walls with exterior sheathing is quite complex and not fully understood. In many cases, no evidence of condensation is found even though calculations show that it should occur. But the calculations are good insurance. If they show that condensation will not occur under average winter conditions, then one can confidently assume that no moisture problems from condensation will occur.

Understanding "Dry Winter Air"

At a seminar in Cleveland, Ohio, one builder in the audience asked why outdoor air could be used to lower the humidity in a house even though the outdoor air may have a relative humidity as high as 70% and the indoor air may have a lower relative humidity of, say, only 50%.

The explanation is actually quite simple. Relative humidity is a measure of "percent saturation" of water vapor in air. Cold air can hold less water vapor than warm air. For example, air at 35°F can hold a maximum of 0.0043 pounds of moisture per pound of dry air at saturation. If outdoor air at 35°F has, say, 70% of that amount of moisture (0.0030 pounds per pound dry air), we say it is 70% saturated and has a relative humidity of 70% (see Figure 6). Now suppose we bring outdoor air at 35°F and 70% RH into a house and heat it to 70°F.

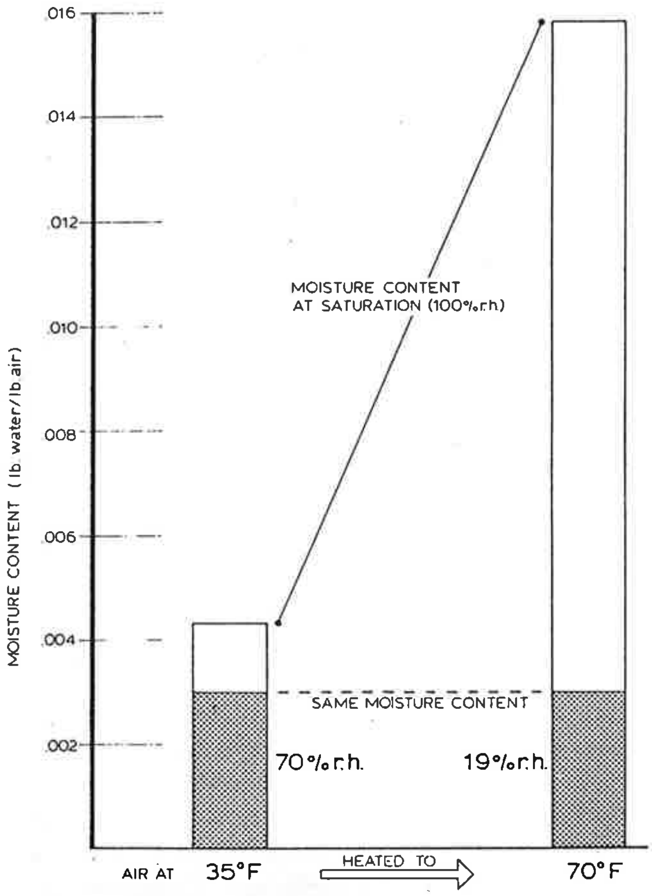


Figure 6 — Graph Showing the Change in Relative Humidity of Air at 35°F and 70% RH When Heated to 70°F With no Moisture Added or Removed

Let's assume ***no moisture is added or removed from the air.*** At 70°F, air can hold 3.4 times as much moisture as air at 35°F (0.0158 pound per pound dry air). Thus, even though this air was nearly saturated when it was outside (70% RH), it is nowhere near saturated when it is brought indoors and heated. In fact, the relative humidity is now only 19% (see Figure 6).

The change in relative humidity when dry winter air is brought into a house is easy to determine using the psychrometric chart. Here's a quick example:

Example 5

If outdoor air has a temperature of 40°F and a relative humidity of 60%, what will be its relative humidity if it is brought into a house and heated to 75°F?

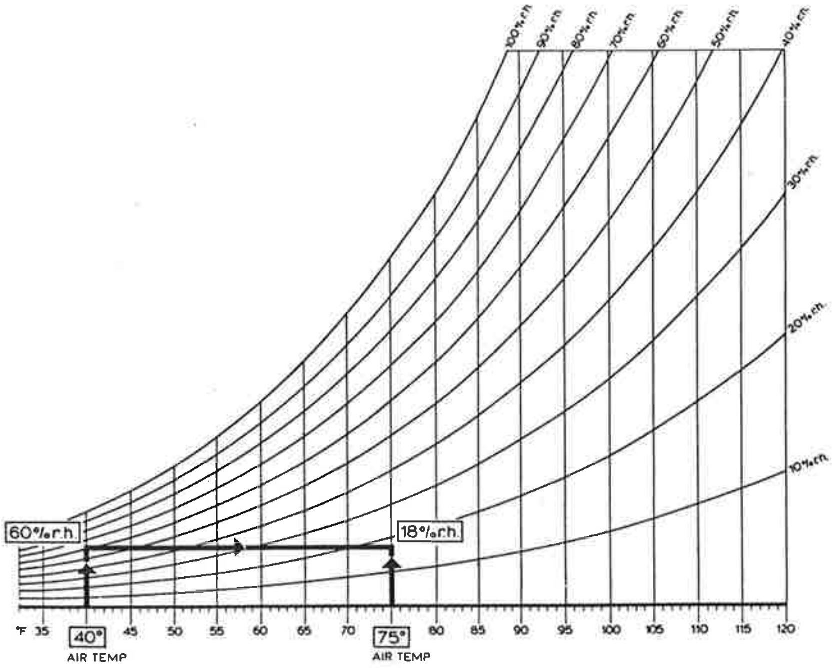


Figure 7 — Finding the relative humidity of air at 40°F and 60% rh when heated to 75°F.

Solution (Figure 7)

1. Find 40°F on the horizontal axis.

2. Proceed vertically to the intersection of the curved line marked 60% RH.

3. Proceed horizontally to the right to the intersection with the vertical line marked 75°F.

4. The relative humidity of the air is read from the curved lines. In this case, it is between 10% and 20%, about 18%.

In this situation, if no moisture was added to the air from indoor sources, the indoor relative humidity would be 18%. Of course, if the house is occupied, quite a bit of moisture is given off from occupant activity and the actual indoor relative humidity will be somewhat higher, depending upon the rate of indoor moisture generation and outdoor air leakage and ventilation.