This application note will highlight the primary sources of moisture in industrial facilities. Different methods of solving moisture problems are outlined along with formulas for estimating the moisture content. A questionnaire is incorporated to obtain the minimum information required for proper sizing of dehumidification equipment.

**Methods of Drying Air**

There are several methods of drying air. Each method has advantages and disadvantages. The common types are:

- Make-up air method
- Compression
- Refrigerated dehumidification
- Desiccant dehumidification

The first method uses the principle of dilution, removing a portion of the moisture laden air from a space and replacing it with drier air. The net result is a lower average moisture content. This method is relatively inexpensive to install, but relies on the fact that drier air is available. Since the most common source is outside make up air, this method is difficult to apply in summer months and expensive to operate in winter due to heating costs.
Sources of Moisture

There are many sources of moisture in a facility. A list of the Common ones follows:

- Infiltration
- Permeation
- Ventilation and make-up air
- Door and window openings
- People
- Processes
- Product

Infiltration and permeation are often considered the same thing. Infiltration is the movement of water vapor through cracks, joints and seals. Permeation is the migration of water vapor through materials such as brick and wood. One of the physical laws of nature states that all conditions must be balanced. In the case of water vapor the partial pressure of the water vapor must be the same on either side of a barrier. For this reason water vapor will migrate through brick walls to get to the less humid side. The rate of migration in an unbalanced situation exceeds the rate of air through cracks and seals and will in effect find a path to attempt to balance partial pressures.

Moisture load in a space due to infiltration and permeation is not easily measured. Factors such as the actual moisture deviation, materials of construction, vapor barrier and room size all have an effect on the vapor migration. Desert Aire has used some basic models to make assumptions to estimate moisture infiltration and permeation.

The Combined infiltration and permeation load can be approximated from the following equation:

\[ \text{Lb/HR Moisture} = \frac{V \times AC \times GR \times MF \times CF}{7000 \times 13.5} \]

Where
- \( V \) = Volume of room to be conditioned (cu. ft.)
- \( AC \) = Air change factor from Table 1
- \( GR \) = The deviation from the outside to the desired conditions (grains/LB)
- \( MF \) = Migration factor is \( \frac{2GR}{30} \) (min. value = 1.0)
- \( CF \) = Construction factor from table 4
- 13.5 = Conversion factor for CU. Ft./LB.
- 7000 = Conversion factor for GR/LB

According to ASHRAE, the median number of air changes per hour is 0.5. The actual number of air changes is influenced by several factors, the most dominate being the size of the room. The larger the room the longer it takes to convert one volume. The following table compensates for the reduction in infiltration/permeation on larger or smaller volumes.

<table>
<thead>
<tr>
<th>VOLUME (CU FT.)</th>
<th>AC</th>
<th>VOLUME</th>
<th>AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less Than 10,000</td>
<td>0.65/HR</td>
<td>40,001-60,000</td>
<td>.45</td>
</tr>
<tr>
<td>10,001-20,000</td>
<td>0.60</td>
<td>60,001-100,000</td>
<td>.40</td>
</tr>
<tr>
<td>20,001-30,000</td>
<td>0.55</td>
<td>100,000-200,000</td>
<td>.35</td>
</tr>
<tr>
<td>30,001-40,000</td>
<td>0.50</td>
<td>Greater than-200,000</td>
<td>.30</td>
</tr>
</tbody>
</table>

Table 1 - Air Changes for Specific Volumes

The rate of infiltration is a function of the magnitude of imbalance between the outside absolute humidity and that inside the conditioned space. The greater the difference, the greater the driving force to make the vapor pressures equal. The migration factor compensates for this influence.

The GR (grain/lb) deviation must be obtained from the Psychrometric chart. By locating the outside and inside conditions on the chart an absolute humidity in grains/lb can be obtained. The formula uses the difference in grain/lb between these two conditions. Refer to Table 2 and 3 for humidity values for specific locations and inside design conditions. For other values the Psychrometric chart must be utilized. Please refer to Desert Aire Technical Bulletin Number 3 if assistance is required to read the chart.
Another primary factor is the amount of moisture that is allowed to permeate through the walls, floor and roof. The construction factor takes into account the effect good vapor barriers and construction materials will have on the moisture migration. Table 4 gives factors for common construction materials. This factor will vary between 0.3 and 1.0. A composite wall must be modeled and a factor estimated.

Another source of moisture is the opening of other openings such as conveyor passages. In these cases, the amount of moisture is directly proportional to the frequency of the opening, the difference in indoor and outdoor moisture content and the wind velocity at the opening. The wind velocity will be the most difficult to take into account since it will vary depending on the location of the opening with respect to the wind source. Local weather stations can provide details on the normal prevailing direction and speed. However, a guideline is 12 CFM of outside air per square feet of opening. The amount of air can be estimated by the following formula.

\[
\text{LB/HR} = \frac{\text{AREA} \times \text{OPEN} \times \text{cGR} \times 12}{7000 \times 13.5}
\]

Where:
- AREA = Surface area of opening (Sq. Ft.)
- OPEN = Minutes area is open per hour
- AG = The deviation from the outside to the desired conditions (grains/LB)
- 12 = Estimated ingress of moisture (CFM/Sq.Ft.)
- 13.5 = Conversion factor for CU. FT./LB
- 7000 = Conversion factor for GR/LB

When this equation is used for a fixed opening such as a window, the minutes open/hr will equal 60.

### Table 2 - Grains/LB at specific temperature and RH

*Below refrigerant dehumidification capability

<table>
<thead>
<tr>
<th>RELATIVE HUMIDITY</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRY BULB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>25*</td>
<td>32*</td>
<td>40*</td>
<td>45*</td>
</tr>
<tr>
<td>60</td>
<td>31*</td>
<td>39*</td>
<td>46*</td>
<td>54*</td>
</tr>
<tr>
<td>65</td>
<td>37*</td>
<td>46*</td>
<td>55*</td>
<td>65*</td>
</tr>
<tr>
<td>70</td>
<td>42</td>
<td>55</td>
<td>66</td>
<td>78</td>
</tr>
<tr>
<td>75</td>
<td>53</td>
<td>66</td>
<td>78</td>
<td>91</td>
</tr>
<tr>
<td>80</td>
<td>62</td>
<td>77</td>
<td>93</td>
<td>108</td>
</tr>
<tr>
<td>85</td>
<td>72</td>
<td>91</td>
<td>109</td>
<td>128</td>
</tr>
<tr>
<td>90</td>
<td>85</td>
<td>108</td>
<td>128</td>
<td>152</td>
</tr>
</tbody>
</table>

### Table 3 - Geographic Outdoor Design Criteria (ASHRAE FUNDAMENTALS 1%)
The three “P’s”, product, process and people must also be included in the moisture evaluation. If the product has an affinity for water, then it may also release the water in the conditioned room. For example, wet wood brought into a conditioned warehouse will release the water at a specific rate. This can be determined by measuring the products weight loss over time.

The process itself may generate moisture. If there are open water tanks or cooking vessels, they will add moisture. A model must be developed for each process.

In the case of, open water tanks, the evaporation rate can be calculated with the following equation.

\[
\text{LB/HR} = 0.1 \times \text{AREA} \times (\text{VP}_{\text{H}_2\text{O}} - \text{VP}_{\text{AIR}})
\]

Where:

- Area = Surface area of water (square feet).
- \(\text{VP}_{\text{H}_2\text{O}}\) = Vapor pressure of water at water temperature
- \(\text{VP}_{\text{AIR}}\) = Vapor pressure of air at its corresponding dew point.

The above equation assumes 10 to 30 FPM air velocity in room. Vapor pressures can be obtained from technical publications. Consult Desert Aire if you need assistance. Finally people give off moisture. This is a function of the number of people and their activity: a worker lifting boxes will generate 4 to 8 times the moisture of a worker at a lab bench. ASHRAE’S data on the amount of water added per person is reproduced in table 5.

<table>
<thead>
<tr>
<th>WORK TYPE</th>
<th>EVAP. RATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seated in theater</td>
<td>0.10 Lb/Persons/HR</td>
</tr>
<tr>
<td>Office work, light work</td>
<td>0.200</td>
</tr>
<tr>
<td>Medium factory work</td>
<td>0.475</td>
</tr>
<tr>
<td>Heavy factory work</td>
<td>0.965</td>
</tr>
<tr>
<td>Athletics</td>
<td>1.095</td>
</tr>
</tbody>
</table>

Table 5 - Evaporation Rates of People

If the facility is using fresh outside make-up air for ventilation as required by some building codes, then this air can contribute to the moisture load. This is especially important in the summer months when high humidity is common. As with the calculation for infiltration the difference in absolute humidity must be used, along with the volume of make-up air being brought in by the air handling system. The formula for calculating moisture load is:

\[
\text{LB/HR Moisture} = \frac{\text{CFM} \times \text{GR} \times 60}{7000 \times 13.5}
\]

- **CFM** = Volume of outside air introduced
- **GR** = The deviation from the outside to the desired conditions (grains/LB)
- 60 = Conversion factor for min/hr
- 13.5 = Conversion factor for CU.FT./LB
- 7000 = Conversion factor for GR/LB

To properly select and size a dehumidification system to condition a facility requires careful planning. The engineer or facility operator must specify the operating conditions that must be maintained. Then he must evaluate all of the potential sources of water and the outside ambient conditions. This information can then be used to size the system. The enclosed worksheet is provided to organize the collection of minimum information required for selection and sizing. The formulas will provide an approximation of the moisture load. An engineer should be consulted to confirm that the assumptions are appropriate for the application.