DRIYING CURVES OF A NON-POUROUS SOLID

OBJECTIVE

Determine the drying behavior of a non-porous solid and calculate the heat and mass transfer coefficients during the constant-rate drying period. Determine how your drying curve plots correspond to the plots shown in Figure 1 below. Determine how the sand temperature relates to the air temperature and the wet bulb temperature of the air above the sand.

INTRODUCTION

The term "drying" is a relative one, and simply means that there is a further reduction in the moisture content from some initial level provided by mechanical dewatering to some acceptable lower level. For example, a moisture content of 10-20% by volume would normally allow particles to flow freely, yet suppress dust formation. The necessity for drying may be to make a product suitable for sale (e.g. paint pigments), or for subsequent processing (e.g. in pyrometallurgical operations).

When a solid dries, two fundamental and simultaneous processes occur: (1) heat is transferred to evaporate liquid; (2) mass is transferred as a liquid or vapor within the solid and as a vapor from the surface. These factors governing the rates of these processes determine the drying rate. Commercial drying operations may utilize heat transfer by convection, conduction, radiation, or a combination of these. Industrial dryers differ fundamentally by the methods of heat transfer employed. However, irrespective of the mode of heat transfer, heat must flow to the outer surface and then into the interior of the solid.

Careful consideration of many factors is necessary in the final selection of the most suitable type of dryer for a particular application. Some of these factors are:

- Properties of the material being handled
- Drying characteristics of the material
- Flow of the material to and from the dryer
- Product qualities
- Recovery problems
- Facilities available at the site of the proposed installation.
When a solid is dried experimentally, data are usually obtained relating moisture content to time. Consider the drying of a non-porous, insoluble material such as sand in a tray. The surface of the sand is exposed to a drying medium such as hot dry air passing over the surface. Figure 1. shows a typical drying curve.

Immediately after contact between the wet solid and the drying medium, the solid temperature adjusts until it reaches a steady state. The solid temperature and the rate of drying may increase or decrease to reach the steady state condition (AB). At steady state, the temperature of the wet solid surface is the wet bulb temperature of the drying medium. Temperatures within the drying solid also tend to equal the wet bulb temperature of the gas, but the lag in movement of mass and heat result in some deviation. Once the stock temperatures reach the wet bulb temperature of the gas, they are quite stable and the drying rate also remains constant. This is the constant rate drying period (BC) which ends when the solid reaches the critical moisture content. Beyond this point the surface temperature rises and the drying rate falls off rapidly (CD). Not always distinguishable, there may be another change in drying rate (DXE). If this occurs, it is referred to as the second falling rate period. The falling rate periods can take a far longer time than the constant rate period even though the moisture removal may be less. The drying rate approaches zero at some equilibrium moisture content (XE) which is the lowest moisture content obtainable with the solid under the drying conditions used.

Figure 1. Typical Drying Curve.
REFERENCES


EQUIPMENT

1. Tray drier
2. Stop watch
3. Humidity meter
4. Velometer
5. Polyethylene bucket
6. Large spatula
7. 500 mL graduated cylinder
8. Digital thermometer

CHEMICALS/MATERIALS

1. Sand.

EXPERIMENTAL PROCEDURE

The temperature of the sand will be recorded using the thermocouple taped to the bottom pan. Be careful when filling this pan so as not to disturb the thermocouple. The Digital thermometer should be placed on the top of the balance and connected to the thermocouple before the balance is turned on so it will zeroed out.

The equipment set up for the laboratory experiment is shown in Figure 2. Distribute about 2800 gms of wet sand between all four trays. The initial moisture content should be ≥ 10%. Weigh the dry sand before adding water. The sand should be removed from the container and drained of excess “free water” before being loaded evenly and smoothly into the drying trays. Take care to avoid any spillage. The total weight of the wet sand should be noted before drying commences. Measure the surface area of the sand exposed to air; that is, the area across which the water is transferred.
At some arbitrary time \((t=0)\), switch on and set the fan speed control to mid-position \((5)\) and the heater power control to a setting of \(9\), letting them remain constant throughout the experiment. Record the total weight of sand in the trays at regular time intervals until drying is complete. Record the temperature of the sand at the same intervals you record the humidity measurements. Record relative humidity and temperature measurements of the air stream before and after the drying trays at appropriate time intervals. Humidity measurements of the air stream before the drying trays should be taken every third or fourth time the measurement after the air stream is taken. Record the air flow rate at appropriate time intervals.

**Figure 2.** Tray Drier

**SAFETY NOTES**

1. Personal protective equipment shall include safety glasses with side shields and thermal mitts. Thermal mitts shall be worn whenever items at temperatures above ambient are handled. The trays when removed from the drier are at an elevated temperature.

**WASTE DISPOSAL PROCEDURES**

There should be no waste from this experiment. The sand will be reused.

07/2012
**Department of Chemical Engineering**  
Stockroom Checkout slip

Drying Curves of a Non-porous Solid Experiment  
ChE 3211

Name: ____________________________  
(print name)  
Date: ____________________________

Lab No.:  Lab 1  Tuesday  12:00 - 4:50 PM  
Lab: Thursday  12:00 - 4:50 PM

Lab No.:  Lab 3  Tuesday and Thursday morning (9:30 - 11:50 AM)  
(circle one)

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Out</th>
<th>In</th>
<th>Equipment</th>
<th>Out</th>
<th>In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity meter</td>
<td></td>
<td></td>
<td>Stopwatch</td>
<td></td>
<td></td>
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<tr>
<td>Velometer</td>
<td></td>
<td></td>
<td>Large spatula</td>
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<td>Digital thermometer</td>
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<td>500 mL graduated cyl.</td>
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Name: ____________________________  
(Signature)
Instructions for the Fortran Program

PSYCHRO

There is a compiled fortran program on the computers in Engr 270 available for calculating selected psychrometric parameters from combinations of the input parameters — wet and dry-bulb temperatures, dew point, and relative humidity.

The program PSYCHRO will calculate psychrometric parameters by entering a single set of data (example: dry bulb (°C) and % relative humidity). It will calculate the other parameters and print them to the screen. It will then ask whether you want to do another calculation. If you select yes, you will have to enter another set of data.

The program is a compiled fortran program and can be accessed on the computers in Engr 270 by double clicking on the shortcut PSYCHRO. If the shortcut is not shown on the desktop the fortran compiled file “psychro.exe” can be found in C:\lab programs. Answer the questions asked by the program and input the data when asked. The two data points can be input with a space between them or you can enter the dry bulb temperature, press <Enter> and then enter the relative humidity and press <Enter>.

A sample output from this program is shown below.

DATA used in the example

Dry bulb temperature = 30 °C
Percent Relative Humidity = 55 percent.

INSTRUCTIONS

1. Start program. (See instructions above for location of the program.)

2. Select number 3 on the screen (Dry bulb temperature and relative humidity) Press “Enter”

3. Enter 30,55 Press “Enter”

4. Example of output

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<thead>
<tr>
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<th>Value</th>
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<tbody>
<tr>
<td>DRY-BULB TEMPERATURE</td>
<td>30.00 DEGREES C</td>
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<tr>
<td>WET-BULB TEMPERATURE</td>
<td>22.92 DEGREES C</td>
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<tr>
<td>DEW POINT TEMPERATURE</td>
<td>19.95 DEGREES C</td>
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<td>RELATIVE HUMIDITY</td>
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