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## Calculating Bushels

The information in this handout can be used to estimate the number of bushels of grain contained in various sizes and shapes of vehicles or storage structures. There are two different ways of calculating bushels; one method uses grain volume and the other uses grain weight.

A bushel by volume is defined as a certain number of cubic feet of grain. (Technically a volume bushel is 1.244 cubic feet, but the value of 1.25 cubic feet is normally used.) To estimate the number of bushels by volume in a vehicle, pile, or storage structure, you determine the volume of grain and then use a standard volume factor to calculate bushels.

A bushel by weight is defined as a certain number of pounds of grain, and each type of grain has a different standard bushel weight. (See table 2.) Grain is generally bought and sold by weight. To calculate bushels by weight, you actually weigh the grain, divide total weight by the standard weight per bushel for that type of grain, measure grain moisture, and finally adjust the number of bushels to the number that you would have at the moisture value specified by the buyer.

Test weight is the weight of grain per unit of volume and is usually expressed as pounds per volume bushel. This value can be used to estimate bushels by weight from bushels by volume. In the rare case that grain test weight (lb/vol bu) equals the standard bushel weight (lb/weight bu), bushels calculated by volume will equal bushels determined by weight. In most cases, however, bushels estimated by volume differ slightly from bushels calculated by weight. Volume calculations can be used to get a reasonable estimate of the number of bushels, but it is always more accurate to weigh grain and measure its moisture content and calculate bushels by weight.

### Bushels by Volume

**1 volume bushel (vol bu) = 1.25 cubic feet (cu ft) of shelled grain, or  
1 cu ft of shelled grain = 0.8 vol bu**

**1 volume bushel (vol bu) = 2.5 cubic feet (cu ft) of ear corn, or  
1 cu ft of ear corn = 0.4 vol bu**

To determine bushels of shelled grain by volume, calculate grain volume in cubic feet, and divide by 1.25 or multiply by 0.8.

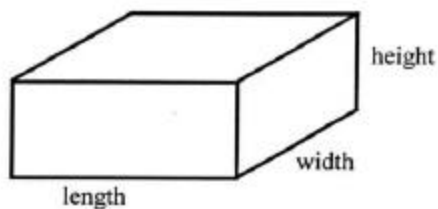
Most storage structures can be visualized as some simple geometric shape, or combination of shapes. You can estimate storage volume by totaling the volumes for each separate shape.

## Piles with Level Surfaces

### Rectangular bins or buildings

To calculate the volume of a rectangular-shaped pile with a level top surface,

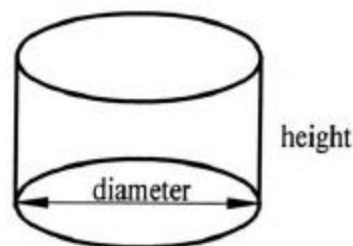
$$\text{volume} = \text{length} \times \text{width} \times \text{height}$$



### Cylindrical bins or cribs

To calculate the volume of a round bin or crib with a level top surface,

$$\begin{aligned} \text{volume} &= [(\pi \times \text{diameter squared}) \div 4] \times \text{height} \\ &= [(3.14 \times \text{diameter} \times \text{diameter}) \div 4] \times \text{height} \\ &= 0.785 \times \text{diameter} \times \text{diameter} \times \text{height} \end{aligned}$$



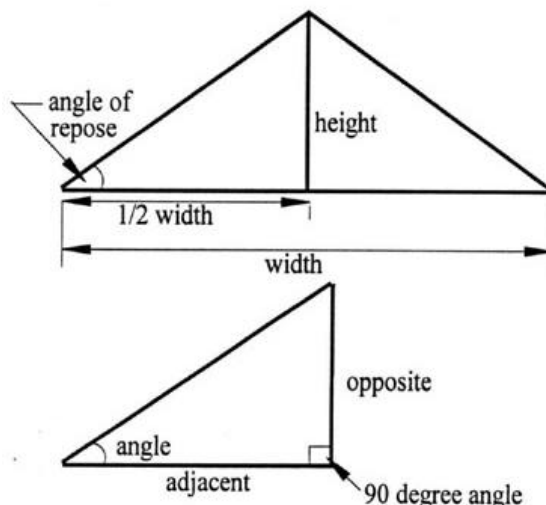
## Piles with Sloped Surfaces

### Angle of repose

The angle of repose, or angle with a horizontal surface formed when free-flowing grain comes to rest, can be used to estimate the height or width of grain piles. Angle of repose depends on things like size and shape of kernels, moisture content, fines and foreign material content, presence of mold, and filling or emptying method, and can vary greatly. For example, the angle of repose for dry corn can range from 15 to 26 degrees. The following values are average expected angles of repose for several different dry grains. (Values come from Table 4-1 in the MidWest Plan Service's *Grain Drying, Storage, and Handling Handbook, MWPS-13*.)

Table 1. Expected angle of repose for various crops.

Crop	Angle (degrees)	Tangent
Barley	28	0.53
Shelled corn	23	0.42
Oats	28	0.53
Soybeans	25	0.47
Sunflowers	27	0.51
Wheat	25	0.47



The tangent of an angle (abbreviated tan) is the ratio of the length of the side of a right triangle (triangle that contains one 90-degree angle) that is opposite the angle to the length of the side of the triangle that is adjacent to the angle. This means that for grain dropped into a pile from an overhead spout, the tangent of the angle of repose is equal to the height of the pile divided by half the width of the pile.

For any right triangle,

$$\text{tangent of angle} = \text{opposite side of triangle} \div \text{adjacent side of triangle}$$

For a grain pile,

$$\text{tangent of angle of repose} = \text{pile height} \div (0.5 \times \text{pile width or diameter})$$

To get pile height if you know the width,

$$\text{pile height} = \text{tangent of angle of repose} \times (0.5 \times \text{pile width or diameter})$$

To get pile width or diameter if you know the height,

$$\text{pile width or diameter} = \text{pile height} \div (0.5 \times \text{tangent of angle of repose})$$

### Sloped sides and round base (cone)

To get the volume of a peaked pile that has a round base and no sidewalls,

$$\begin{aligned} \text{volume} &= 1/3 \times [(\pi \times \text{diameter squared}) \div 4] \times \text{height} \\ &= 0.262 \times \text{diameter} \times \text{diameter} \times \text{height} \end{aligned}$$

**Example calculations for a cone-shaped pile:** Corn is dropped from a permanently fixed 30-ft high spout on to a flat asphalt pad that has no retaining walls. Estimate the expected diameter and bushels contained in the pile.

We see from Table 1 that for corn, the expected angle of repose is about 23 deg (tan = 0.42).

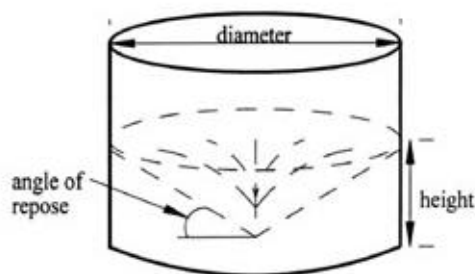
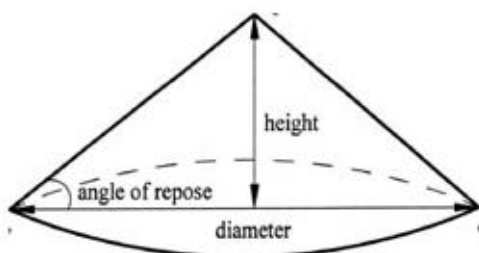
$$\begin{aligned} \text{pile diameter} &= \text{pile height} \div (0.5 \times \text{tangent of angle of repose}) \\ &= 30 \text{ ft} \div (0.5 \times 0.42) = \underline{143 \text{ ft}} \end{aligned}$$

The volume of a cone-shaped pile is

$$\begin{aligned} \text{volume} &= 0.262 \times \text{diameter} \times \text{diameter} \times \text{height} \\ &= 0.262 \times 143 \text{ ft} \times 143 \text{ ft} \times 30 \text{ ft} = \underline{160,729 \text{ cu ft}} \end{aligned}$$

The estimated number of bushels in the pile is

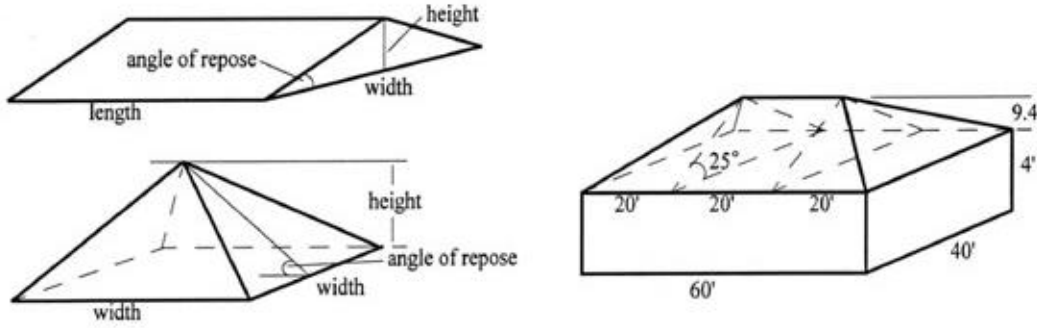
$$\text{vol bu} = 0.8 \times \text{volume} = 0.8 \text{ bu/cu ft} \times 160,729 \text{ cu ft} = 128,583, \text{ or } \underline{\text{about } 128,600 \text{ vol bu}}$$



### Partially empty cylindrical bin (cylinder with cone missing)

To estimate the volume of grain remaining in a round bin after grain stops flowing out of a center unloading sump,

$$\begin{aligned}\text{volume} &= \text{volume of a cylinder} - \text{volume of a cone} \\ &= (0.785 \text{ diameter} \times \text{diameter} \times \text{height}) - (0.262 \text{ diameter} \times \text{diameter} \times \text{height}) \\ &= 0.523 \times \text{diameter} \times \text{diameter} \times \text{height}\end{aligned}$$



### Sloped sides and ends, and square base (pyramid)

To get the volume of a peaked pile that has a square base and no sidewalls,

$$\begin{aligned}\text{volume} &= 1/3 \times \text{width squared} \times \text{height} \\ &= 0.333 \times \text{width} \times \text{width} \times \text{height}\end{aligned}$$

### Sloped sides, vertical ends, and rectangular base (triangular prism)

To get the volume of a long peaked pile that has vertical ends and no sidewalls,

$$\begin{aligned}\text{volume} &= 1/2 \times \text{width} \times \text{height} \times \text{length} \\ &= 0.5 \times \text{width} \times \text{height} \times \text{length}\end{aligned}$$

**Example calculations for flat storage building:** Estimate the number of bushels of wheat that can be stored in a peaked pile in a 40 ft x 60 ft building that has a 14 ft ceiling height and walls reinforced to handle the pressure of 4 ft of grain piled against them.

First, we need to see how high the peak of the pile will be if we use a 4-ft depth on the sidewalls. It's possible that ceiling height might limit the overall height and shape of the pile. From table 1, the expected angle of repose for wheat is about 25 degrees (tangent = 0.47).

$$\begin{aligned}\text{pile height above height on sidewalls} &= \text{tangent of angle of repose} \times (0.5 \times \text{pile width}) \\ &= 0.47 \times (0.5 \times 40 \text{ ft}) = \underline{9.4 \text{ ft}}\end{aligned}$$

$$\text{total pile height} = 4 \text{ ft on side walls} + 9.4 \text{ ft} = \underline{13.4 \text{ ft}}$$

Since the total calculated height is less than the 14-ft ceiling height, it will be possible to form a peaked pile down the center of the building that is 4 ft deep on the sidewalls and extends to just under the ceiling or lower chords of the truss rafters. Imagine that the pile consists of three geometric shapes:

1) a 60 ft x 40 ft x 4 ft rectangular base

$$\begin{aligned}\text{volume rectangular base} &= \text{length} \times \text{width} \times \text{height} \\ &= 60 \text{ ft} \times 40 \text{ ft} \times 4 \text{ ft} = \underline{9600 \text{ cu ft}}\end{aligned}$$

2) a 9.4 ft high x 40 ft wide by 20 ft long triangular prism

The length of the triangular prism at the top center of the pile is equal to the length of the rectangular base minus the length of both sloping ends. Each sloping end equals one half the width, so the length of the prism is just the base length minus the width.

$$\begin{aligned}\text{prism length} &= \text{base length} - [2 \times (0.5 \times \text{width})] \\ &= \text{base length} - \text{width} \\ &= 60 \text{ ft} - 40 \text{ ft} = \underline{20 \text{ ft}}\end{aligned}$$

$$\begin{aligned}\text{volume triangular prism} &= 0.5 \times \text{width} \times \text{prism height} \times \text{prism length} \\ &= 0.5 \times 40 \text{ ft} \times 9.4 \text{ ft} \times 20 \text{ ft} = \underline{3760 \text{ cu ft}}\end{aligned}$$

3) two 9.4-ft high pyramids with 40 ft x 20-ft bases, or if you put them together, one 9.4-ft high square pyramid with a 40 ft x 40-ft base (half of the pyramid is on each end of the triangular prism)

$$\begin{aligned}\text{volume square pyramid} &= 0.333 \times \text{width} \times \text{width} \times \text{height} \\ &= 0.333 \times 40 \text{ ft} \times 40 \text{ ft} \times 9.4 \text{ ft} = \underline{5008 \text{ cu ft}}\end{aligned}$$

The total volume of the pile is the sum of the three geometric shapes,

$$\begin{aligned}\text{total volume} &= \text{volume base} + \text{prism} + \text{pyramid} \\ &= 9600 \text{ cu ft} + 3760 \text{ cu ft} + 5008 \text{ cu ft} = \underline{18,368 \text{ cu ft}}\end{aligned}$$

Finally, convert total volume to volume bushels,

$$\text{vol bu} = 0.8 \times \text{volume} = 0.8 \text{ bu/cu ft} \times 18,368 \text{ cu ft} = \underline{14,694 \text{ bu}}$$

## **Bushels by Weight**

Most grains are bought and sold based on a standard bushel weight at a specified moisture content. Table 2 shows typical weights and moisture values for some common crops. Note that these are traditional values and not official or legal standards, and that buyers sometimes use a moisture value different from that shown in the table. For example, corn is sometimes bought on a 14% or 15% moisture basis instead of 15.5%, and oats are sometimes purchased using a 32-lb bushel.

Table 2. Typical bushel weights and moisture values for some common crops.

Crop	Bushel Weight (lbs)	Moisture Content (% wet basis)
Barley	48	14.5
Shelled corn	56	15.5
Oats	34	14.0
Soybeans	60	13.0
Sunflowers (oil)	30	10.0
Sunflowers (confectionery)	24	10.0
Wheat	60	13.5

To calculate bushels by weight, first divide the total weight of grain by the standard bushel weight. You can stop there if grain is less than or equal to the specified moisture.

If grain moisture exceeds the specified value, divide total weight by standard bushel weight to get wet bushels. Then, because wet bushels weigh more than standard bushels, you need to apply a shrink factor to get the number of bushels you would have if the grain were dried to the specified moisture. Moisture shrink factors are based on final grain moisture.

$$\text{wet bushels} = \text{total grain weight} \div \text{standard bushel weight}$$

$$\begin{aligned} \text{moisture shrink factor (\% weight per percentage point of moisture loss)} \\ = 100 \div (100 - \text{final moisture}) \end{aligned}$$

$$\text{moisture shrink (\% weight)} = \text{points of moisture difference} \times \text{moisture shrink factor}$$

$$\text{standard bushels} = \text{wet bushels} \times [(100 - \text{moisture shrink}) \div 100]$$

**Example grain shrink calculations:** Assume we have 1000 lb of 25.5% moisture corn, and we want to know how many bushels we would have at 15.5% final moisture:

$$\text{wet bushels} = 1000 \text{ lb} \div 56 \text{ lb/bu} = \underline{17.9 \text{ wet bu}}$$

$$\text{moisture shrink factor} = 100 \div (100 - 15.5) = 100 \div 84.5 = \underline{1.183 \% \text{ per point}}$$

$$\text{moisture shrink} = (25.5 - 15.5) \times 1.183\%/\text{point} = 10.0 \text{ points} \times 1.183 \%/\text{point} = \underline{11.83\%}$$

$$\text{standard bushels} = 17.9 \times [(100 - 11.83) \div 100] = 17.9 \times 0.8817 = \underline{15.8 \text{ std bu}}$$

In most cases, grain buyers use a shrink factor that is slightly larger than the moisture shrink factor to allow for their losses in drying, storing, and handling grain. Typical shrink factors used by grain buyers range from 1.25 to 2.0%/point.

If grain moisture is less than the standard value, bushels are simply calculated by dividing total weight by standard bushel weight. The number of bushels is not adjusted upward to the number that there would have been at standard moisture. This means that when grain is overdried (dried to less than standard moisture), not only is drying cost greater, but also the seller gets paid for fewer bushels.

## Converting Bushels by Volume to Bushels by Weight

You can estimate weight bushels from volume bushels (and vice versa) if you know the grain's test weight. Test weight is an expression of grain bulk density, which is weight per unit of volume. Test weight is affected by things like grain moisture, grain variety, growing conditions, presence of disease (scab, for example) and method used to fill the vehicle, pile, or storage, and so can vary greatly from one batch of grain to another, and even within a given batch of grain. This means that using test weight to convert volume bushels to weight bushels provides only a rough estimate of actual grain weight.

Grain test weight affects the amount of grain that occupies a given amount of space, but when you sell grain, test weight is not used to calculate the quantity of bushels. Test weight is used, however, as a quality indicator, and discounts are applied if test weight is low. Test weight usually increases as grain dries, but the exact relationship between moisture and test weight depends on drying conditions and grain characteristics and is difficult to predict.

Test weight is determined by weighing the amount of grain that it takes to fill a standard dry one-quart cup. A conversion factor is used to convert the weight of grain in the one-quart cup to pounds per volume bushel, or pounds per 1.25 cubic feet of grain.

To estimate weight bushels from volume bushels, multiply volume bushels by test weight and divide by the standard bushel weight for that grain. In the rare case that test weight equals the standard bushel weight, volume bushels equal weight bushels.

$$\text{weight bu} = (\text{volume bu} \times \text{test weight}) \div \text{standard bushel weight}$$

**Example of estimating grain weight from volume:** About how many bushels of corn (by weight) would you expect to sell from the cone-shaped pile used in an earlier example if the corn test weight is 52 lb/bu? (Assume that the grain is dry.)

$$\text{volume bu} = 128,583 \text{ vol bu}$$

$$\begin{aligned} \text{weight bu} &= (128,583 \text{ vol bu} \times 52 \text{ lb/vol bu}) \div 56 \text{ lb/weight bu} \\ &= 6,686,316 \text{ lb} \div 56 \text{ lb/weight bu} = 119,399 \text{ or } \underline{\text{about } 119,400 \text{ weight bu}} \end{aligned}$$

Remember, this is only an estimate and the actual number of bushels determined by weighing the grain and applying the buyer's shrink factor could differ substantially from this value.