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# Basics Concepts Used During Post- harvesting Grain Handling

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# Important Concepts



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- Grain Quality

Grain quality can only be maintained after harvest, it cannot be improved. Quality is affected by weather, combine adjustments during harvest, grain handling, drying and cooling process

- High quality grain
  - Few fines and foreign materials
  - Little physical damage and stress cracks
  - Absence of mold and insect damage

# Important Concepts



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- Equilibrium Moisture Content (EMC): grain moisture content that is in equilibrium with surrounding air
- Equilibrium Relative Humidity (ERH): air relative humidity that is in equilibrium with stored grain

Since grain is hygroscopic it will exchange moisture with the surrounding air until a state of equilibrium is reached.



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**Table 3-7. Maximum storage life for shelled corn.**

Values for corn held at a constant temperature, i.e. with respiration heat removed by aeration. These values are **not** the time allowed for wet grain holding—they **are** the total acceptable storage life from corn harvest to the time it is used. Do not use all the storage time on your farm—save some storage time for the next users so they have a quality product to work with. For example, 26% MC (moisture content) corn held at 60 F for 4 days used ½ of its life (4 days/8 days). If then dried to 15½% MC and held at 50 F, the corn has only 225 days remaining ( $\frac{1}{2} \times 450$ ).

The values are based on ½% dry matter loss by weight—a one grade decrease or ½% of the corn dry matter is lost to deterioration. Such grain is usually visibly moldy.

w.b. = wet basis.

Developed from Thompson, *Transactions of ASAE* 333-337, 1972.

| Grain<br>temperature<br>F | Moisture content, % w.b. |     |     |     |     |    |    |    |
|---------------------------|--------------------------|-----|-----|-----|-----|----|----|----|
|                           | 15½                      | 18  | 20  | 22  | 24  | 26 | 28 | 30 |
|                           | ----- days -----         |     |     |     |     |    |    |    |
| 30                        | 2,276                    | 648 | 321 | 190 | 127 | 94 | 74 | 61 |
| 35                        | 1,517                    | 432 | 214 | 126 | 85  | 62 | 49 | 40 |
| 40                        | 1,012                    | 288 | 142 | 84  | 56  | 41 | 32 | 27 |
| 45                        | 674                      | 192 | 95  | 56  | 37  | 27 | 21 | 18 |
| 50                        | 450                      | 128 | 63  | 37  | 25  | 18 | 14 | 12 |
| 55                        | 299                      | 85  | 42  | 25  | 16  | 12 | 9  | 8  |
| 60                        | 197                      | 56  | 28  | 17  | 11  | 8  | 7  | 5  |
| 65                        | 148                      | 42  | 21  | 13  | 8   | 6  | 5  | 4  |
| 70                        | 109                      | 31  | 16  | 9   | 6   | 5  | 4  | 3  |
| 75                        | 81                       | 23  | 12  | 7   | 5   | 4  | 3  | 2  |
| 80                        | 60                       | 17  | 9   | 5   | 4   | 3  | 2  | 2  |



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**Table 3-1. Maximum moisture contents for grain harvest and safe storage.**

Values for good quality, clean grain and aerated storage. Reduce 1% for poor quality grain.

| Grain type & storage time  | Maximum moisture content |                       |
|----------------------------|--------------------------|-----------------------|
|                            | For harvesting<br>%      | For safe storage<br>% |
| Shelled corn and sorghum   |                          |                       |
| Sold as #2 grain by spring | 30                       | 15½                   |
| Stored 6-12 mo             | 30                       | 14                    |
| Stored more than 1 yr      | 30                       | 13                    |
| Soybeans                   |                          |                       |
| Sold by spring             | 18                       | 14                    |
| Stored up to 1 yr          | 18                       | 12                    |
| Stored more than 1 yr      | 18                       | 11                    |
| Wheat, oats, barley        |                          |                       |
| Stored up to 6 mo          | 20                       | 14                    |
| Stored more than 6 mo      | 20                       | 13                    |
| Sunflower                  |                          |                       |
| Stored up to 6 mo          | 22                       | 10                    |
| Stored more than 6 mo      | 22                       | 8                     |
| Flaxseed                   |                          |                       |
| Stored up to 6 mo          | 15                       | 9                     |
| Stored more than 6 mo      | 15                       | 7                     |
| Edible beans               |                          |                       |
| Stored up to 6 mo          | 20                       | 16                    |
| Stored more than 6 mo      | 20                       | 14                    |

**Table 1. Equilibrium moisture content for shelled corn.**

Dashed lines indicate examples in text. (Developed from Chung-Pfost equation, ASAE paper 76-3520.)

| Temp.<br>deg. F | Relative humidity, percent                        |      |      |      |      |             |             |      |      |
|-----------------|---------------------------------------------------|------|------|------|------|-------------|-------------|------|------|
|                 | 10                                                | 20   | 30   | 40   | 50   | 60          | 70          | 80   | 90   |
|                 | ----- Equilibrium moisture content, percent ----- |      |      |      |      |             |             |      |      |
| 20              | 9.4                                               | 11.1 | 12.4 | 13.6 | 14.8 | 16.1        | 17.6        | 19.4 | 22.2 |
| 25              | 8.8                                               | 10.5 | 11.9 | 13.1 | 14.3 | 15.6        | 17.1        | 19.0 | 21.8 |
| 30              | 8.3                                               | 10.1 | 11.4 | 12.7 | 13.9 | 15.2        | 16.7        | 18.6 | 21.1 |
| 35              | 7.9                                               | 9.6  | 11.0 | 12.3 | 13.5 | 14.8        | 16.3        | 18.2 | 20.8 |
| 40              | 7.4                                               | 9.2  | 10.6 | 11.9 | 13.1 | 14.5        | 16.0        | 17.9 | 20.5 |
| 45              | 7.1                                               | 8.8  | 10.2 | 11.5 | 12.8 | 14.1        | 15.7        | 17.6 | 20.5 |
| 50              | 6.7                                               | 8.5  | 9.9  | 11.2 | 12.5 | 13.8        | <u>15.4</u> | 17.3 | 20.2 |
| 55              | 6.3                                               | 8.2  | 9.6  | 10.9 | 12.2 | <u>13.5</u> | 15.1        | 17.0 | 20.0 |
| 60              | 6.0                                               | 7.9  | 9.3  | 10.6 | 11.9 | 13.3        | 14.8        | 16.8 | 19.7 |
| 65              | 5.7                                               | 7.6  | 9.0  | 10.3 | 11.6 | 13.0        | 14.6        | 16.5 | 19.5 |
| 70              | 5.4                                               | 7.3  | 8.7  | 10.0 | 11.4 | 12.7        | 14.3        | 16.3 | 19.3 |
| 75              | 5.1                                               | 7.0  | 8.5  | 9.8  | 11.1 | 12.5        | 14.1        | 16.1 | 19.1 |
| 80              | 4.9                                               | 6.7  | 8.2  | 9.6  | 10.9 | 12.3        | 13.9        | 15.9 | 18.9 |
| 85              | 4.6                                               | 6.5  | 8.0  | 9.3  | 10.7 | 12.1        | 13.7        | 15.7 | 18.7 |
| 90              | 4.4                                               | 6.3  | 7.7  | 9.1  | 10.4 | 11.9        | 13.5        | 15.5 | 18.5 |
| 95              | 4.1                                               | 6.0  | 7.5  | 8.9  | 10.2 | 11.7        | 13.3        | 15.3 | 18.4 |
| 100             | 3.9                                               | 5.8  | 7.3  | 8.7  | 10.0 | 11.5        | 13.1        | 15.1 | 18.2 |

# Moisture Content in Grains



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- Usually expressed in % of total weight
- Grain is dry matter (DM) + water
- Moisture content (wet basis) is

$$M_{wb} = \frac{W_w \times 100}{W_{dm} + W_w}$$

- Moisture content (dry basis) is

$$M_{db} = \frac{W_w \times 100}{W_{dm}}$$



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- Dry basis and wet basis relationship

$$M_w = \frac{100 \times M}{100 + M}$$

$$M = \frac{100 \times M_w}{100 - M_w}$$

# Moisture test



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- Oven method is the standard (217° for 72 h)
- Moisture meters will not measure moisture directly
- Dielectric properties of the grain are used to estimate moisture content
- Tester are subjected to several factors that can influence results such as: grain temperature, grain type, etc

# Moisture test



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- Usually the higher the moisture content in the grain, the less reliable the meters are
- Producers are recommended to calibrate their testers with a local elevator or laboratory

# Grain Quantity



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- Bushel is a volume measurement. One bushel is equal to 1.25 ft<sup>3</sup>
- The weight of one bushel is dependent on the moisture content
- One bushel of corn weighs 56 lbs @ 15.5%
- Soybeans: 60 lbs @ 13%
- Wheat: 60 lbs @ 13.5%



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| Moisture<br>content, % | Shelled<br>corn | Wheat | Soybeans | Barley | Oats  | Rye   | Sunflower             | Grain<br>sorghum |
|------------------------|-----------------|-------|----------|--------|-------|-------|-----------------------|------------------|
|                        | -----lb/bu----- |       |          |        |       |       | -----lb/cwt base----- |                  |
| 5.0                    | 49.81           | 54.63 | 54.95    | 43.20  | 28.97 | 50.69 | 94.73                 | 90.53            |
| 5.5                    | 50.07           | 54.92 | 55.24    | 43.43  | 29.12 | 50.96 | 95.24                 | 91.01            |
| 6.0                    | 50.34           | 55.21 | 55.53    | 43.66  | 29.28 | 51.23 | 95.74                 | 91.49            |
| 6.5                    | 50.61           | 55.51 | 55.83    | 43.89  | 29.43 | 51.51 | 96.26                 | 91.98            |
| 7.0                    | 50.88           | 55.81 | 56.13    | 44.13  | 29.59 | 51.79 | 96.78                 | 92.47            |
| 7.5                    | 51.16           | 56.11 | 56.43    | 44.37  | 29.75 | 52.07 | 97.30                 | 92.97            |
| 8.0                    | 51.44           | 56.42 | 56.74    | 44.61  | 29.91 | 52.35 | 97.83                 | 93.48            |
| 8.5                    | 51.72           | 56.72 | 57.05    | 44.85  | 30.08 | 52.63 | 98.36                 | 93.99            |
| 9.0                    | 52.00           | 57.03 | 57.36    | 45.10  | 30.24 | 52.92 | 98.90                 | 94.51            |
| 9.5                    | 52.29           | 57.35 | 57.68    | 45.35  | 30.41 | 53.22 | 99.45                 | 95.03            |
| 10.0                   | 52.58           | 57.67 | 58.00    | 45.60  | 30.58 | 53.51 | 100.00                | 95.56            |
| 10.5                   | 52.87           | 57.99 | 58.32    | 45.85  | 30.75 | 53.81 | 100.56                | 96.09            |
| 11.0                   | 53.17           | 58.31 | 58.65    | 46.11  | 30.92 | 54.11 | 101.12                | 96.63            |
| 11.5                   | 53.47           | 58.64 | 58.98    | 46.37  | 31.10 | 54.42 | 101.69                | 97.18            |
| 12.0                   | 53.77           | 58.97 | 59.32    | 46.64  | 31.28 | 54.73 | 102.28                | 97.73            |
| 12.5                   | 54.08           | 59.31 | 59.65    | 46.90  | 31.45 | 55.04 | 102.86                | 98.29            |
| 13.0                   | 54.39           | 59.65 | 60.00    | 47.17  | 31.63 | 55.36 | 103.46                | 98.85            |
| 13.5                   | 54.71           | 60.00 | 60.35    | 47.45  | 31.81 | 55.68 | 104.05                | 99.42            |
| 14.0                   | 55.02           | 60.35 | 60.70    | 47.72  | 32.00 | 56.00 | 104.66                | 100.00           |
| 14.5                   | 55.35           | 60.70 | 61.06    | 48.00  | 32.19 | 56.33 | 105.26                | 100.58           |
| 15.0                   | 55.67           | 61.06 | 61.41    | 48.28  | 32.38 | 56.66 | 105.89                | 101.18           |
| 15.5                   | 56.00           | 61.43 | 61.78    | 48.57  | 32.57 | 57.00 | 106.52                | 101.78           |
| 16.0                   | 56.33           | 61.79 | 62.14    | 48.86  | 32.76 | 57.34 | 107.15                | 102.38           |
| 16.5                   | 56.67           | 62.16 | 62.52    | 49.15  | 32.96 | 57.68 | 107.79                | 102.99           |
| 17.0                   | 57.01           | 62.53 | 62.89    | 49.45  | 33.16 | 58.03 | 108.44                | 103.61           |
| 17.5                   | 57.36           | 62.91 | 63.28    | 49.75  | 33.36 | 58.38 | 109.10                | 104.24           |
| 18.0                   | 57.71           | 63.30 | 63.66    | 50.05  | 33.56 | 58.74 | 109.76                | 104.88           |
| 18.5                   | 58.06           | 63.69 | 64.05    | 50.36  | 33.77 | 59.10 | 110.44                | 105.52           |
| 19.0                   | 58.42           | 64.08 | 64.45    | 50.67  | 33.98 | 59.46 | 111.11                | 106.17           |
| 19.5                   | 58.78           | 64.47 | 64.85    | 50.98  | 34.18 | 59.83 | 111.81                | 106.83           |
| 20.0                   | 59.15           | 64.88 | 65.25    | 51.30  | 34.40 | 60.20 | 112.51                | 107.50           |
| 21.0                   | 59.90           | 65.70 | 66.08    | 51.95  | 34.83 | 60.96 | 113.93                | 108.86           |
| 22.0                   | 60.67           | 66.54 | 66.93    | 52.62  | 35.28 | 61.75 | 115.39                | 110.26           |
| 23.0                   | 61.45           | 67.41 | 67.80    | 53.30  | 35.75 | 62.55 | 116.89                | 111.69           |
| 24.0                   | 62.26           | 68.29 | 68.69    | 54.01  | 36.21 | 63.37 | 118.43                | 113.16           |
| 25.0                   | 63.09           | 69.20 | 69.61    | 54.73  | 36.70 | 64.22 | 120.00                | 114.67           |
| 26.0                   | 63.95           | 70.14 | 70.55    | 55.47  | 37.20 | 65.09 | 121.62                | 116.22           |
| 27.0                   | 64.82           | 71.10 | 71.51    | 56.22  | 37.70 | 65.98 | 123.29                | 117.81           |
| 28.0                   | 65.72           | 72.10 | 72.51    | 57.00  | 38.22 | 66.89 | 125.00                | 119.44           |
| 29.0                   | 66.65           | 73.10 | 73.53    | 57.80  | 38.77 | 67.84 | 126.77                | 121.13           |
| 30.0                   | 67.60           | 74.15 | 74.58    | 58.63  | 39.31 | 68.80 | 128.58                | 122.86           |

# Quick exercise



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- Farmer harvested an average of 10,000 lb of corn per acre @ 25% moisture. He wants to know the yield (bu/ac)

If 1 bu of corn weighs 56 lbs then yield is  
 $10,000 \text{ lb} \div 56 \text{ lb/bu} = 178.5 \text{ bu/ac}$ , right?

1 bu of corn @ 25% moisture weighs 63.09 lbs. The  
yield is  $10,000 \text{ lb} \div 63.09 \text{ lb/bu} = 158.5 \text{ bu/ac}$

# Quick Exercise Contd.



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- How much shrinkage will be when drying 10,000 lbs @ 25% to 15.5%?

$$FQ = \frac{(100 - IM\%) \times IQ}{(100 - FM\%)}$$

FQ = Final Quantity; IM = initial moisture; IQ = initial quantity; FM = final moisture

$$FQ = \frac{(100 - 25) \times 10,000}{(100 - 15.5\%)} = 8,876$$

# Drying Systems



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- Objective of drying: to remove moisture from the grain
- Low Temperature Drying
  - natural air + up to 10 degrees
  - Limited use in sub-tropical weather
- High Temperature Drying
  - Bin dryer
  - Self-contained dryer
  - Dryeration (more energy efficient)
  - Quality problems



| Type of drying system                          | Drying capacity | Airflow rate, cfm/bu | Air temperature °F                     | Grain quality | Investment or equipment cost | Typical seasonal drying volume bu | Disadvantages                                                                                                                                        |
|------------------------------------------------|-----------------|----------------------|----------------------------------------|---------------|------------------------------|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Low temperature drying                         | Low             | 1 - 2                | 0 - 10 above outside air               | Excellent     | Low to Medium                | up to 50,000                      | Limited capability at high moisture contents                                                                                                         |
| Bin-batch                                      | Medium          | 10 - 25              | 90 - 180                               | Good          | Low to Medium                | 10,000-30,000                     | May require manual leveling. Batch transfer requires labor and downtime. Limited expansion capability.                                               |
| Continuous flow bin                            | Medium          | 5 - 10               | 120 - 180                              | Good          | Medium                       | 20,000 - 100,000                  | Metering equipment may require frequent servicing. Many mechanical components, tends to be spread out.                                               |
| Heated air manual batch (PTO Batch Dryer)      | Medium          | 20 - 70              | 140 - 220                              | Good          | Low to Medium                | 10,000 - 30,000                   | High labor requirements to load and unload dryer.                                                                                                    |
| Heated air automatic batch                     | High            | 70 - 125             | 140 - 240                              | Good          | Medium to High               | 15,000 and up                     | Requires support handling systems. Requires wet holding. High drying and cooling rates cause brittle, easily damaged kernels. Low energy efficiency. |
| Heated air continuous flow                     | High            | 70 - 125             | 140 - 240                              | Good          | High                         | 30,000 and up                     | Requires support handling systems. Requires wet holding. Requires sophisticated controls.                                                            |
| Combination low temperature/high temperature   | High            | 10 - 125 and 1 - 2   | 120 - 240 and 0 - 10 above outside air | Excellent     | High                         | 15,000 and up                     | Maximum movement of grain.                                                                                                                           |
| High temperature dryer with dryeration         | High            | 10-125 and ½ - 1     | 120 - 240                              | Excellent     | Medium to high               | 25,000 and up                     | Requires extra grain handling. Managing moisture condensation moisture content.                                                                      |
| High temperature dryer with in-storage cooling | High            | 10 -125 and ½ - 1    | 120 - 240                              | Good          | Medium to high               | 25,000 and up                     | Managing moisture condensation. Harder to get the desired moisture content. More management for cooling.                                             |



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### NATURAL AIR DRYING EQUIPMENT

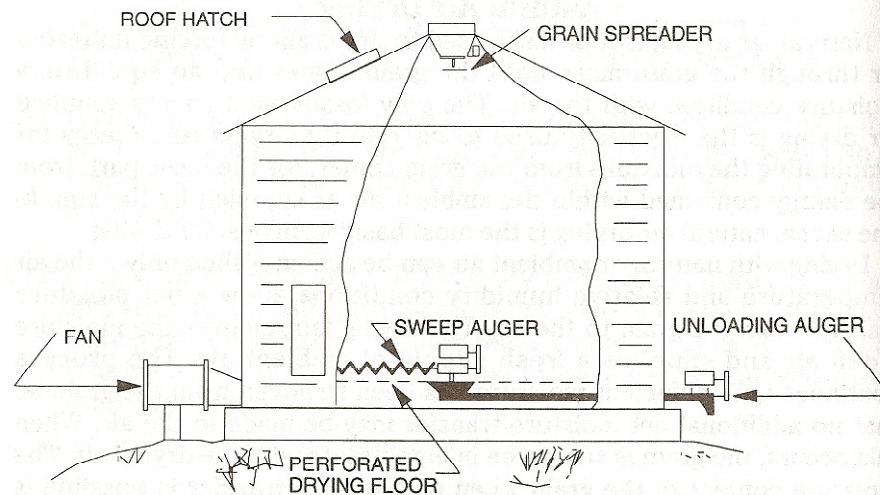


Figure 3.1—Natural air drying equipment.

### LOW TEMPERATURE DRYING EQUIPMENT

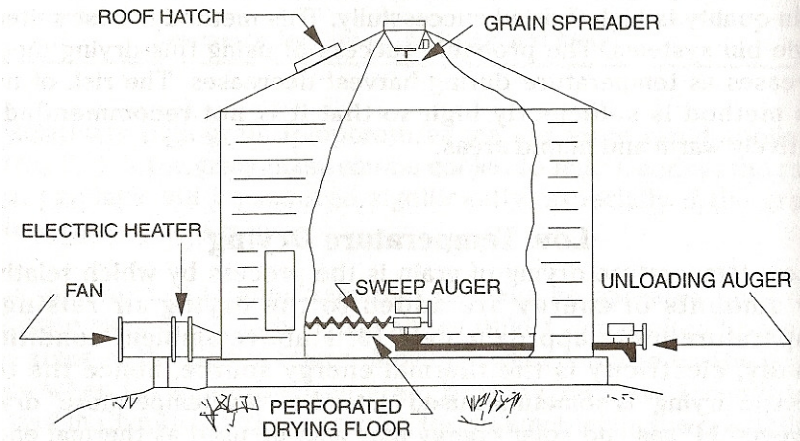
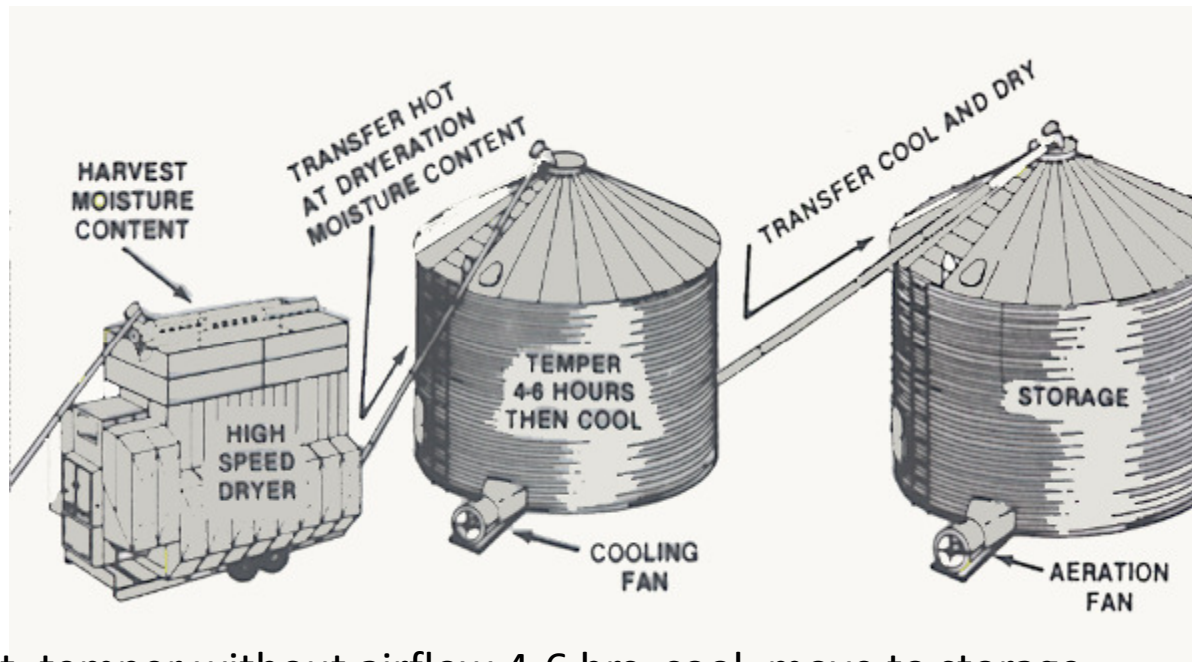


Figure 3.6—Low temperature drying equipment.

# Dryeration



Dump hot, temper without airflow 4-6 hrs, cool, move to storage

Increases dryer capacity 50%-75%,

Reduces energy by about 25%

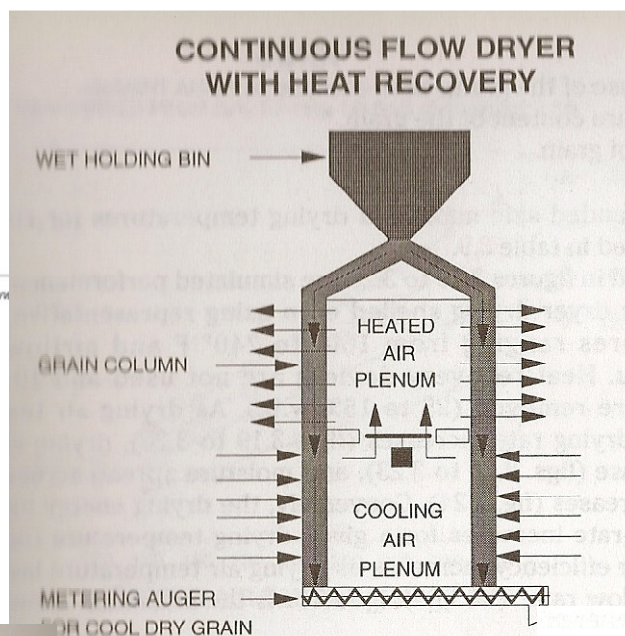


Figure 3.18—Continuous flow dryer with heat recovery

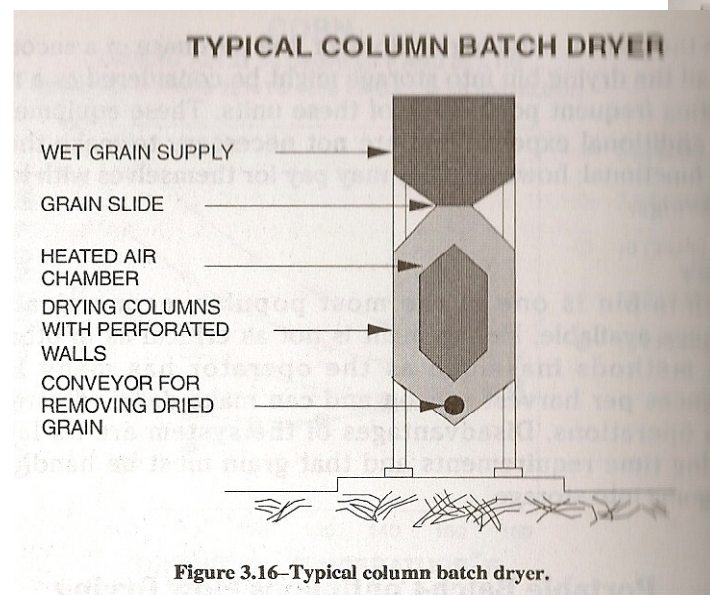


Figure 3.16—Typical column batch dryer.

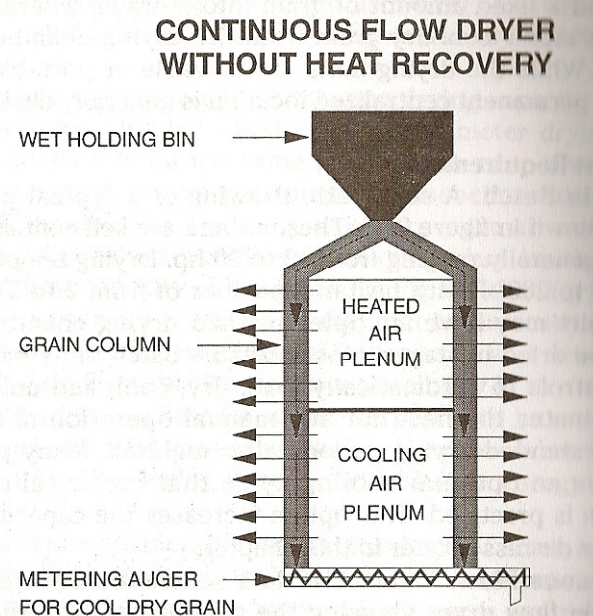


Figure 3.17—Continuous flow dryer without heat recovery.

# Grain Aeration



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- The objective of aeration is to cool the grain to safe temperature levels that inhibits insect activities
- Minimum air flow of 0.25 cfm/bu
- Cooling cycle should be 30-60 hrs (5 to 7 hrs. at a time)
- Preference to suction (down-flow) systems
  - Insects get to the grain from the top
  - Cooling the top part of the grain shuts-off insect activity

# Causes of grain storage problems



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- Grain is too warm
- Grain is too wet
  - Moisture migration; leaks
- Too much foreign materials and fines
  - Less resistant to mold and insects than whole grain
  - Fines concentrate in the spout line and are more difficult to dry or cool

# Causes of grain storage problems



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- Uneven temperatures in grain bin
  - Moisture migration
- Bin not cleaned before harvest
  - Lead to insect damage
- Grain not monitored frequently enough during storage
  - Check for hot spots
  - Water leaks
  - Check grain at least once a week

# Aeration Airflow Rate Selection



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## Cooling Time

$$T = \frac{15}{q}$$

T = time, in hours

q = airflow, cfm/bu



# Tips for checking grain condition



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- Smell the exhaust air to detect musty odor
- Check grain surface for wet areas, crust
- Check grain temperature and moisture
- Inspect inside and outside of the bin



**Table 6-16. Grain production conversions.**

A standard bushel is 1.245 ft<sup>3</sup> by volume. Because different grains have different standard bushel definitions by weight, a special conversion factor is used for each crop. Values based on lb/bu from Table 6-4 and 2,200 lb/metric ton.

| Grain    | Bushels to<br>metric tons | Metric tons<br>to bushels |
|----------|---------------------------|---------------------------|
|          | Multiply by               |                           |
| Corn     | 0.0255                    | 39.286                    |
| Soybeans | 0.0273                    | 36.667                    |
| Wheat    | 0.0273                    | 36.667                    |
| Oats     | 0.0145                    | 68.750                    |
| Rapeseed | 0.0227                    | 44.000                    |
| Barley   | 0.0218                    | 45.833                    |
| Rye      | 0.0255                    | 39.286                    |
| Flaxseed | 0.0255                    | 39.286                    |

**Table 6-17. Yield conversions.**

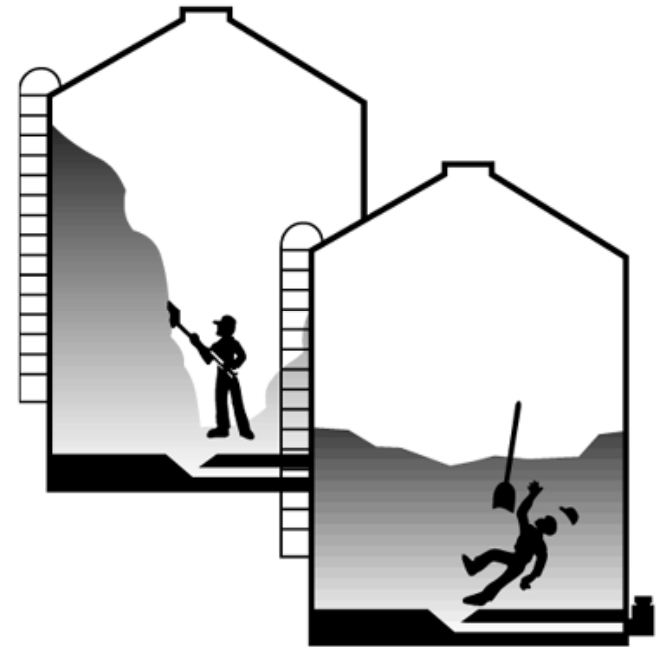
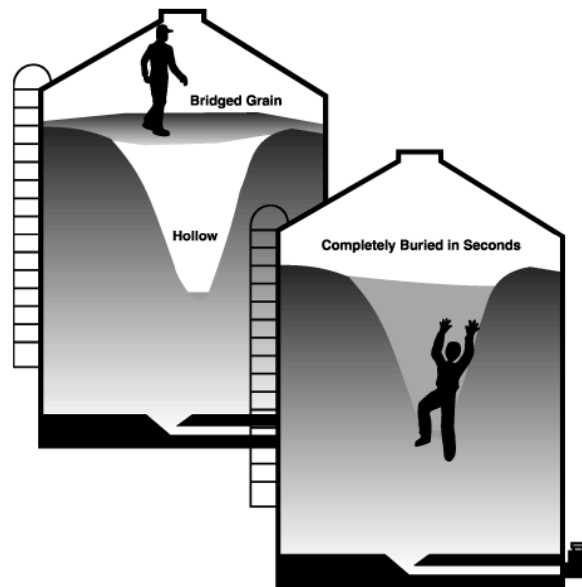
| Grain    | bu/ac to<br>kg/ha | kg/ha to<br>bu/ac |
|----------|-------------------|-------------------|
|          | Multiply by       |                   |
| Barley   | 53.81             | 0.0186            |
| Corn     | 62.78             | 0.0159            |
| Flaxseed | 62.78             | 0.0159            |
| Oats     | 35.87             | 0.0279            |
| Rapeseed | 56.05             | 0.0178            |
| Rye      | 62.78             | 0.0159            |
| Soybeans | 67.26             | 0.0149            |
| Wheat    | 67.26             | 0.0149            |

# Corn Flowability



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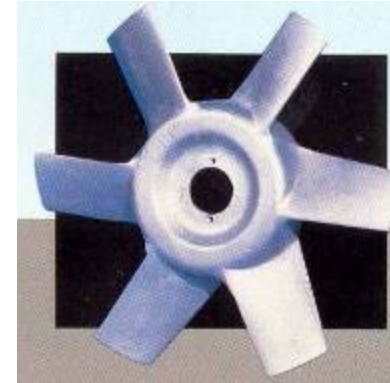
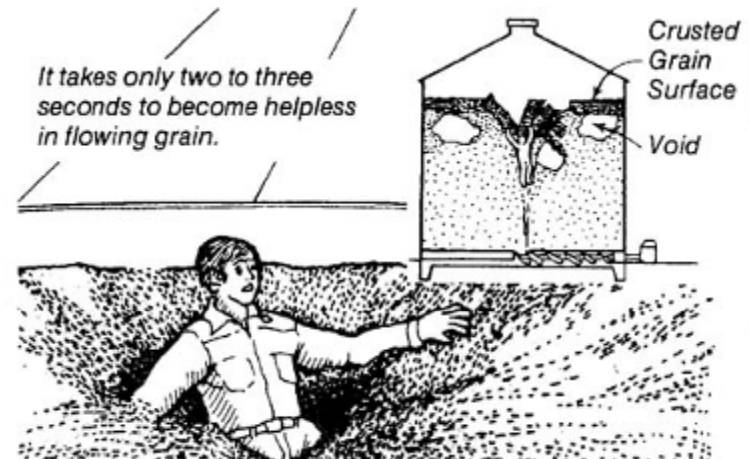
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# Grain Hazards



Bridging transfers load to the bin wall



**CAUGHT IN THE GRAIN!**  
**AE-1102**

# Moldy Grain Health Hazard



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At least a N-95 rating