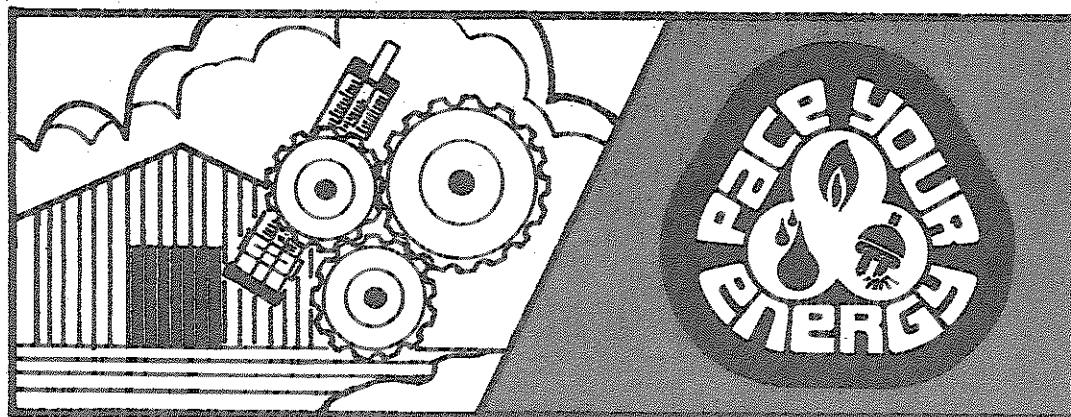# ENERGY IN THE HOME

GRAIN DRYING PERFORMANCE EVALUATION

Otto J. Loewer, T. C. Bridges, G. M. White,
and Robert L. Fehr

GRAIN DRYING PERFORMANCE EVALUATION

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When grain is harvested in Kentucky at moisture contents exceeding 13 to 14 percent, it must be dried to insure long-term safe storage. The drier the stored grain, the longer it will retain its quality.

The time required to dry corn or milo depends on several factors, including: air flow rate, drying air temperature and the quantity of moisture to be removed. Tentative investigations have indicated that if corn is above 18 percent moisture and 55°F for 24 to 48 hours, aflatoxin may develop, so this should also be considered when evaluating the performance of a grain dryer.

You may estimate how your grain drying system is performing by completing the following form and returning it to:

Dr. Otto J. Loewer
Agricultural Engineering Department
University of Kentucky
Lexington, KY 40506

1. **NAME**

2. **ADDRESS**

3. **PHONE NUMBER**

4. **TYPE OF GRAIN TO BE DRIED**
(corn or milo only)

5. **TEMPERATURE OF AIR ENTERING GRAIN, °F**
Typical values are:
a) Low temperature drying: 5 to 7°F above outside air temperature
b) Layer drying: 10 to 20°F above outside air temperature
c) Batch-in-bin drying: 125 to 145°F
d) Portable batch or continuous flow drying: 180 to 220°F

6. **CUBIC FEET PER MINUTE OF AIR SUPPLIED TO EACH BUSHEL OF GRAIN IN THE DRYING SYSTEM**
Typical values are:
a) Layer drying or low temperature drying: 1 to 3 CFM/BU
b) Batch-in-bin drying: 8 to 12 CFM/BU
c) Continuous flow or portable batch drying: 75 to 125 CFM/BU

Check your manufacturer's literature for fan or drying performance data. You may also wish to use one of the University of Kentucky fan selection programs to assist you.

7. ☐☐☐☐☐☐   PERCENT MOISTURE CONTENT OF GRAIN AT HARVEST OR BEFORE DRYING BEGINS.

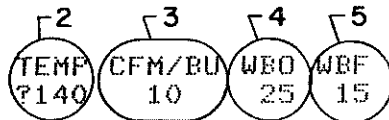8. ☐☐☐☐☐☐   DESIRED FINAL PERCENTAGE MOISTURE CONTENT OF GRAIN AFTER DRYING.

A sample computer analysis is shown below followed by a listing of terms.

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CORN,MILO,OR STOP
(?CORN)-1

       r2      r3     r4     r5
    (TEMP)(CFM/BU)(WBO)(WBF)
     ?140    10    25    15

              2-CROSS FLOW       r3            r6              r7
    DRYING AIR (140. DF) (10.0 CFM/BU) (0.0050 HO) (0.0192 HMAX)
1-(CORN)   4-(25.00 %WB) (50.0 F)-8
                   MOISTURE                  TEMPERATURE
  (TIME)-9    (MIN)-10  (AVE)-11  (MAX)-12  (MAX)-13  (AVE)-14  (MIN)-15  (EFF)-16
    2.320      17.27     23.87     25.45    108.0      75.5     66.8      63.32
    4.640      13.78     22.26     25.62    128.0      87.0     72.8      75.14
    6.960      11.53     20.47     25.66    133.3      94.8     74.1      80.92
    9.280       9.95     18.58     25.66    135.3     101.6     74.3      84.08
   11.600       8.77     16.59     24.40    136.4     107.9     74.5      85.98
   13.920       7.86     14.79     21.57    137.1     113.9     81.8      85.16
        (1807. BTU/LB WATER)-17  (0.073 BU/HR-FT2)-18
```

1. CORN—Type of grain to be dried (Question 4).
2. TEMP—Temperature of the drying air, °F, (Question 5).
3. CFM/BU—The cubic feet of heated air delivered to each bushel of grain in the dryer (Question 6).
4. WBO—Percentage moisture content of the grain before drying begins (Question 7).
5. WBF—Desired average percent moisture content of grain after drying (Question 8).
6. HO—Absolute humidity of air, lb of water per lb of dry air.
7. HMAX—Absolute humidity of the drying air as it exits the grain.
8. 50°F—Assumed outside air temperature before the air is heated.
9. TIME—The 1st column is time in hours from when drying begins.
10. MIN—The percent moisture content of the grain next to where the drying air enters the grain mass for specified times.
11. AVE—The average percent moisture content in the grain for specified times.
12. MAX—The percent moisture content of the grain where the drying air exits the grain mass for specified times.
13. MAX—The temperature of the grain next to where the drying air enters the grain mass for given times.
14. AVE—The average temperature of the grain for given times.
15. MIN—The temperature of the grain where the drying air exits the grain mass for given times.
16. EFF—The efficiency of the drying air in removing the moisture in the grain over given drying times.
17. BTU/LB WATER—The heat in BTU's required to heat the drying air divided by the amount of water in pounds that was removed from the grain.
18. BU/HR-FT^2—This is the bushels dried per hour for each square ft of dryer's surface area for each 1.25 ft of grain depth.

ESTIMATING ENERGY USAGE:

a. **L.P. gas or natural gas**

The quantity of water removed from each bushel of grain may be calculated using the following equation:

$$\left(\begin{array}{c}\text{lb of water}\\\text{removed}\end{array}\right) = \left(\begin{array}{c}\text{bulk density of}\\\text{grain, lb/bu}\end{array}\right) \times \left(\frac{IM - FM}{100 - FM}\right)$$

where IM = the initial moisture content of the grain before it was dried, %.

FM = the final moisture content of the grain after it was dried, %.

The bulk density of corn and milo is 56 pounds per bushel.

The amount of energy used per bushel for heating the air is:

$$(\text{BTU's per bu}) = \left(\begin{array}{c}\text{BTU/lb of water}\\\text{[Item No. 17]}\end{array}\right) \times (\text{lb of water removed})$$

The total energy used for heating the air is found by

$$(\text{Total BTU's}) = (\text{BTU's per bu}) \times (\text{total bu dried})$$

It may be converted to gallons of LP gas or 1000 cubic feet of natural gas from the following relationships:

$$1 \text{ gal of L.P. gas} = 92,000 \text{ BTU}$$
$$1000 \text{ cubic ft of Natural Gas} = 1,000,000 \text{ BTU}$$

The combustion efficiency of each fuel is approximately 80%.

To illustrate how the energy usage and cost might be estimated, suppose a farmer has 30,000 bu. of corn he wishes to dry from 25 percent to 14.79 percent moisture content in a 24 ft bin with 4 ft of grain. He uses L.P. gas at a cost of $0.50 per gallon. His operating conditions are the same as those presented with the sample output; that is, the drying air temperature is 140°F and 10 CFM per bushel is supplied by a 10 hp fan. This would be very typical of a batch-in-bin drying system.

To determine energy usage, the amount of water to be removed would be calculated:

$$\left(\begin{array}{c}\text{lb of water}\\\text{removed}\\\text{per bushel}\end{array}\right) = (56\frac{lb}{bu}) \times (\frac{25 - 14.79}{100 - 14.79}) = 6.71 \text{ lb/bu}$$

The energy to heat the drying air would be computed:

$$(\text{BTU's per bu}) = \left(\begin{array}{c}1807 \text{ BTU/lb}\\\text{[Item 17]}\end{array}\right) \times (6.71 \text{ lb/bu}) = 12,125 \text{ BTU/bu}$$

The total energy for heating the air to dry the grain is

$$(\text{BTU's, total}) = (30,000 \text{ bu}) \times (12,125 \text{ BTU/BU}) = 363,750,000 \text{ BTU}$$

This is converted to gallons of L.P. gas assuming a burning efficiency of 80 percent:

$$(\text{L.P. gas, gallons}) = \frac{363,750,000 \text{ BTU}}{(92,000 \text{ BTU/gal}) \times (0.8)} = 4942 \text{ gal}$$

The cost would be $2471 or 8.24¢ per bushel.

b. **Fan Energy**

The fan energy may be estimated using one of the other programs available. However, if it is assumed that for the example problem 10 hp is required to deliver the air through the grain at 10 CFM per bushel, the energy requirements would be

$$\left(\frac{\text{Fan Energy}}{\text{KW-hr}}\right) \cong \left(\begin{array}{c}\text{hours of}\\\text{operation}\end{array}\right) \times (\text{fan horsepower})$$

where 1000 watts ≅ 1 hp-hr when the efficiency of the motor is taken into account.

The area of the drying floor is:

$$(\text{Square ft of dryer floor}) = 3.1416 \times (\text{BIN DIAMETER})^2/4 = 3.1416 \times (24)^2/4 = 452 \text{ ft}^2$$

From the analysis, the drying rate is 0.073 bu per hour per 1.25 ft of grain depth for each square ft. of dryer surface area (Item 18). Therefore, the total time required to dry the grain is:

$$(\text{total drying time}) = \frac{(\text{Bu to be dried}) \times 1.25 \text{ ft}}{(\frac{\text{BU}}{\text{hr-ft}^2}) \times (\frac{\text{grain depth}}{\text{in bin}}) \times (\frac{\text{drying surface}}{\text{area}})}$$

$$= \frac{30,000 \text{ bu} \times 1.25 \text{ ft}}{(\frac{0.073 \text{ bu}}{\text{hr-ft}^2}) \times (4 \text{ ft}) \times (452 \text{ ft}^2)} = 284 \text{ hr}$$

The drying time could also be estimated by determining how many batches would be dried and multiplying this factor by the time required for each batch. For example:

$$\begin{array}{l} \text{No. of batches} \\ \text{(in batch-in-bin)} \\ \text{system} \end{array} = \frac{\text{total bu to be dried}}{(\frac{\text{floor area}}{\text{of bin, ft}^2}) \times (0.8 \frac{\text{bu}}{\text{ft}^3}) \times (\frac{\text{Depth of}}{\text{grain, ft}})}$$

$$= \frac{30,000 \text{ bu}}{(452 \text{ ft}^2) \times (0.8 \text{ bu/ft}^3) \times 4 \text{ ft}}$$

$$= 20.74 \text{ batches}$$

$$\begin{array}{l} (\frac{\text{Total hours to}}{\text{dry the grain}}) = (\frac{\text{hours per}}{\text{batch (Item 9)}}) \times (\text{No of batches}) \end{array}$$

$$= (13.92 \text{ hr}) \times (20.74 \text{ batches})$$

$$= 289 \text{ hr}$$

The difference in the answers using the two approaches is because of round-off error. The drying rate is bu / (hr-ft^2-1.25 ft), the inverse of drying time; that is, $(1/13.92) = 0.0718$ rather than 0.073, the value given in Item 18.

If we use the drying time figure of 289 hours, the electrical energy consumption estimate would be:

$$(\frac{\text{Fan Energy}}{\text{KW-hr}}) \quad (289 \text{ hr}) \times (10 \text{ hp}) = 2890 \text{ KW-hr}$$

If electricity may be purchased for 3.5¢/KW-hr, the electrical cost for drying would be approximately $101 or 0.34¢ per bushel. To this figure, we would have to add the cost of fan operation time for cooling the grain, typically 2 hr per batch or for this example, an additional 42 hr.

AVAILABLE PROGRAMS:

1. BNDZN: Computer analysis of economics, energy consumption and engineering design for a grain storage system.
2. CHASE: Computer model that evaluates and compares costs of selected methods of harvesting, handling, drying and storage of corn for an individual farmstead. Energy consumption is also estimated.
3. CACHE: Computer model for economic analysis of farm drying and processing systems.
4. SQUASH: Computer simulation of the harvesting-delivery-drying system used to determine bottlenecks in the system.
*5. ESTIMATING FAN SIZES FOR GRAIN DRYING SYSTEMS
*6. GRAIN DRYING PERFORMANCE EVALUATION
*7. DRYERATION PERFORMANCE EVALUATION
*8. NATURAL AIR-LOW TEMPERATURE DRYING PERFORMANCE EVALUATION
*9. FAN PERFORMANCE ON GRAIN DRYING BINS