Your turn: Grain bin 26' in diameter
Shelled corn dried from 24% to 14% w.b.
1800 bu/batch; outside air 55 F, RH = 70%
that has been heated 10°F
What CFM needed to dry corn in one week?

Step 1: How much H_2O needs to be removed?

Corn standard bushel weighs 56 lb and is 15% w.b. moisture content.
Corn dry matter →

$$.15 = \frac{m_w}{56\,lb} = \frac{m_w}{m_{total}} \rightarrow 8.4\,lb\ H_2O$$

$$56\,lb - 8.4\,lb = \boxed{47.6\,lb \text{ corn dry matter}}$$

Water in corn @ 24% wb

$$.24 = \frac{m_w}{m_w + 47.6\,lb} \Rightarrow .24m_w + 11.424 = m_w$$

$$11.424 = .76\,m_w$$

$$m_w = 15.03\,lb$$

water in corn @ 14% wb

$$.14 = \frac{m_w}{m_w + 47.6\,lb} \Rightarrow .14m_w + 6.66 = m_w$$

$$6.66 = .86\,m_w$$

$$m_w = 7.74\,lb$$

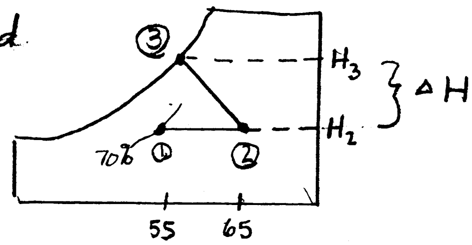
$$\text{Water to remove} = 15.03\,lb - 7.74\,lb = \boxed{7.28\,lb/bu}$$

$$\text{Total water to remove} = 7.28\,\frac{lb}{bu} \cdot 1800\,bu$$

$$= \boxed{13{,}115\,lb\ H_2O/batch}$$

Step 2: Determine how much H_2O each pound of dry air can remove.

Assume air is saturated when it exits the corn.



$H_3 = 0.009 \frac{lb_{H_2O}}{lb_{da}}$

$H_1 = H_2 = .0068 \frac{lb_{H_2O}}{lb_{da}}$

$\Delta H = 0.0022 \frac{lb_{H_2O}}{lb_{da}}$

Step 3: $CFM = \frac{ft^3}{min}$

Time = 1 week = 10,080 min.

$\bar{V}$ = pt ① to give CFM of outside air $= 13.1 \frac{ft^3}{lb_{da}}$

Need to remove $13,115 \frac{lb_{H_2O}}{batch}$; each ft^3 of air removes

$.0022 \frac{lb_{H_2O}}{lb_{da}} \cdot \frac{lb_{da}}{13.1 ft^3}$

$= 1.7 \times 10^{-4} \frac{lb_{H_2O}}{ft^3}$

$$CFM = \frac{13,115\ lb_{H_2O}/batch}{1.7 \times 10^{-4} \frac{lb_{H_2O}}{ft^3} \cdot 10080\ min}$$

= 7650 CFM

2. What is the approximate total pressure drop (in inches of H_2O) required to obtain the needed air flow?

We need to calculate the Δp in equation 2.36. We can do this either by using the equation (constants in table 2-5) or Shedd's curves (the book has metric, english on web site).

Equation $\Delta p = \dfrac{a C_f L V^2}{\ln(1+bV)}$

L = depth of corn in dryer

$= 1800\,bu \times \dfrac{1.244\,ft^3}{1\,bu} = 2239\,ft^3$

↑ p4 book

$a = 2.07 \times 10^4 \dfrac{Pa\,s^2}{m^3}$

$A_{bin} = \dfrac{\pi D^2}{4} = \dfrac{\pi (26')^2}{4} = 531\,ft^2 = 48.76\,m^2$

$b = 30.4$

$L = \dfrac{Vol}{Area} = \dfrac{2239\,ft^3}{531\,ft^2} = 4.22' = 1.28\,m$

V = maximum velocity through the minimum cross-section (ft/s)

$= \dfrac{7650\,\frac{ft^3}{min}}{531\,ft^2} = 14.4\,\dfrac{ft}{min} \cdot \dfrac{1\,min}{60\,s} = 0.24\,\dfrac{ft}{s} \cdot \dfrac{m}{3.3\,ft} = 0.073\,\dfrac{m}{s}$

$C_f = 1.5$ (text - line above equ. 2.36)

γ = specific weight of water to get " H_2O $= 1000\,\dfrac{kg}{m^3}\left(9.81\,\dfrac{m}{s^2}\right) = 9810\,\dfrac{N}{m^3}$

$$\frac{\Delta p}{\gamma} = \frac{2.07\times10^4 \frac{Pa\,s^2}{m^3}(1.5)(1.28\,m)(0.073\,m)^2}{\ln(1+30.4(.073)) \cdot 9810\frac{N}{m^3}} = \frac{211.8}{11469} = 0.018\,m \cdot \frac{3.3'}{1\,m} \times \frac{12\,in}{1\,ft}$$

$= 0.73''\,H_2O$

b) Using Shedd's curves

Y axis → $\frac{7650 \frac{ft^3}{min}}{531\ ft^2} = 14.41 \frac{CFM}{SQ\ Ft}$ outside range of charts

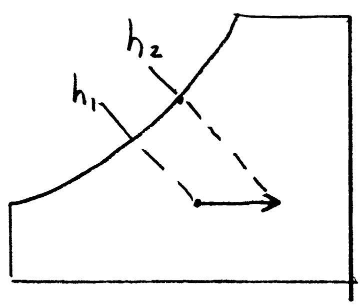
3) Estimated fan HP

$$= \frac{P \gamma Q}{\varepsilon}$$

$$= \frac{.73 \text{"} H_2O \left(\frac{1 ft}{12\text{"}}\right)\left(62.4 \frac{lb}{ft^3}\right)\left(7650 cfm\right)}{.65} = \frac{44476 \frac{ft\text{-}lb}{min}}{\frac{33{,}000 \frac{ft\text{-}lb}{min}}{1\ HP}}$$

$= 1.35\ Hp$

4) Drying costs @ \$0.065/KWH



$$\Delta h = h_2 - h_1 = 3 \frac{Btu}{lb_{da}}$$

$$545\,689\ lb_{da} \cdot \frac{3\ BTU}{lb_{da}} \cdot \frac{2.93 \times 10^{-4}\ kWh}{1\ BTU} \cdot \frac{\$0.065}{KWH}$$

$= \$\ 31.18$