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Flow of Grain and Seeds Through Orifices

American Society of Agricultural and Biological Engineers

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ASABE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA, phone 269-429-0300, fax 269-429-3852, hq@asabe.org

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Keywords: Bins, Flow, Grain, Seeds.

1 Purpose and scope

1.1 This Standard gives equations and graphs that can be used to estimate the flow rate of specific grains and oilseeds through horizontal and vertical orifices for mass flow situations (Ref: Chang et al., 1984, 1988, 1990a). They can be applied to flow from bins and hoppers during emptying and are appropriate for specific ranges of moisture content.

2 Terms and definitions

2.1 hydraulic diameter: The hydraulic diameter of an orifice is 4 times the orifice area divided by the orifice perimeter.

2.2 aspect ratio: The aspect ratio of a rectangular orifice is the ratio of the length of the longer sides to the length of the shorter sides. For an orifice of a given area, the aspect ratio affects the hydraulic diameter of the orifice.

2.3 horizontal and vertical orifices: A horizontal orifice is parallel to the ground. An example is the orifice in the flat surface of a bin floor. A vertical orifice is perpendicular to the ground. An example is an orifice in the vertical wall of a bin.

2.4 large and small orifices: A small orifice is one that has a hydraulic diameter less than 15 times the minor diameter of the grain or seed. Orifices with hydraulic diameters ≥ 15 times the minor diameter of the grain or seed are large orifices.

3 Equations and graphs

3.1 Equation for prediction of flow rate. For mass flow situations, the rate of flow of grain and oilseeds through a horizontal or vertical orifice can be predicted by the following equation:

$$Q = C_0 A D^n$$

where

Q = volume flow rate, m^3/h

A = area of the orifice, cm^2

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D = hydraulic diameter of the orifice, cm

C_0 = coefficient from Table 1 (n varying, horizontal orifices), Table 2 (n varying, vertical orifices), or Table 3 (n = 0.7, horizontal and vertical orifices), $m^3/cm^{(n+2)}h$

n = exponent with a value between 0.5 and 1.0 (see Tables 1, 2, and 3)

3.1.1 Range of application and accuracy. This equation has been validated for square and circular orifices in both horizontal and vertical orientations. Ranges of orifices tested are shown in the tables. Use outside this range is not recommended. In the case of rectangular orifices, the equation has been validated only for horizontal orifices with aspect ratios form 1.33 to 2.67. However, results of a recent study (Ref: Chang et al., 1990b) suggest that the equations can be used for vertical rectangular orifices. Chang and coworkers also examined the effect of orientation of the rectangular orifice (long dimension vertical or horizontal). The best accuracy can be obtained using the values of n and C_0 shown in Table 1 for horizontal orifices and in Table 2 for vertical orifices. A simplified form of the equation is obtained by setting n = 0.7 for all grains. For this simplification, the equation is usually accurate with ± 6% for large orifices and ± 12% for small orifices. For a given orifice size, the flow rate is directly proportional to the value of C_0. Therefore, greater flows will be achieved for grains with larger values of C_0. The best choices for values of C_0 when n = 0.7, based on experimental results, are given in Table 3.

NOTE: The simplication, n = 0.7, gives the greatest error for cases where n varies substantially from 0.7 (see Tables 1 and 2). Extreme caution should be used for these cases.

3.1.2 Effects of grain depth. Flow was independent of grain depth in the experimental studies used to develop the equations and graphs in this Standard. These depths were typically 1 to 2 m (3.3 to 6.6 ft). Although no studies on the effect of grain depth have been published, there is a general consensus that grain depth has very little effect on flow rate for depths greater than the 1 to 2 m (3.3 to 6.6 ft) used in the experimental studies cited by this Standard. For depths less than 1 m (3.3 ft), flow can be affected by depth.

3.1.3 Effects of moisture content. Increased moisture content reduces the mass flow rate for corn and wheat but increases the mass flow rate for sorghum. However, when flow rate is stated on a volume basis (as given by the equation), much of the difference is accounted for by the change in bulk density with moisture.

3.1.4 Effect of orifice location. An orifice in the floor of a bin adjacent to a smooth vertical wall will discharge approximately 15% more grain than an orifice in the center of the bin floor.

3.2 Graphical data. For convenience in making rapid estimates in flow rates, the equation of paragraph 3.1 is plotted in Fig. 1 (horizontal orifices) and Fig. 2 (vertical orifices) for various grains at typical storage moisture contents. In Fig. 2, the curves for soybeans and sorghum were nearly identical and are shown as one curve. These graphs were generated using coefficients from Tables 1 and 2. Each graph has axes for diameters and flow rates in both SI (cm and m^3/h) and English (in. and ft^3/h) units.

3.3 Additional data. Experimental data on flow through orifices are available for other grains and granular materials and for flow through smaller orifices. Data are given by Gregory and Fedler, 1987, and Moysey et al., 1988.

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