# U.S. Standard for Revolving Pedestrian Doors Seriously Flawed

Warren F. Davis, Ph.D.
Davis Associates, Inc.
43 Holden Road
Newton, MA 02465-1909

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## Introduction

The current version of the *American National Standard for Power and Manual Operated Revolving Pedestrian Doors*, ANSI/BHMA A156.27-2003, published and copyrighted by the Builders Hardware Manufacturers Association, Inc., (BHMA) and approved by the American National Standards Institute, Inc., (ANSI) on June 5, 2003, sets ***minimum*** standards applicable within the U.S. for the operation of manual and automatic revolving pedestrian doors. Section 18.1 of that standard mandates that any automatic revolving door that operates within the "acceptable RPM range" that generates more than 2.5 lb-ft (pound-feet) of rotational kinetic energy must be equipped with so-called wing sensors to, at a minimum, reduce the kinetic energy to less than 2.5 lb-ft before the door makes contact with a user.[1, 2, 3]

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[1] The "acceptable RPM range" is simply any door rotation rate at or below the value that causes the periphery of the door wings to move at a linear speed of 180 feet/min. This criterion is entirely independent of the kinetic energy that may be developed by the door. In particular, being within the "acceptable RPM range" does not at all assure that the kinetic energy of the door will be below 2.5 lb-ft.

[2] Throughout ANSI A156.27-2003, the authors have specified kinetic energy in units of ft-lb (foot-pounds). However, these are the (English) units conventionally used for torque. While dimensionally identical, the correct unit in which to express kinetic energy is lb-ft (pound-feet). Consequently, lb-ft are used in this article.

[3] Representatives of major automatic revolving pedestrian door manufacturers in the U.S. have testified on the record and under oath that, in fact, such a door should never strike a user. This is, of course, a stronger and more satisfactory criterion from the standpoint of user safety than that of allowing contact as per §18.1 of ANSI

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To assist designers and door service technicians in meeting the kinetic energy requirement of §18.1 of the standard, equations and a table are provided in the Appendix of ANSI A156.27-2003 purporting to enable determination of the kinetic energy of a revolving door at a give rotation rate in rpm, and also the rotation rate of a given door at which it exhibits the specific kinetic energy of 2.5 lb-ft or 7.0 lb-ft.[4] Only a subset of revolving doors is considered by the equations and table. Namely, those with wings (panels) that extend radially outward from the center of rotation of the door and to which nothing additional is attached to the ends of the wings, such as a showcase or a curved panel concentric with the cylinder within which the door as a whole rotates. Thus, while being representative of the majority of automatic revolving doors operating in the field, not all door configurations are covered by the equations and table.[5]

And, while not included in the equations, the table purports to enable determination of the rotation rate that produces exactly 2.5 lb-ft of kinetic energy also for doors that possess a "core", though, again, to which nothing additional is attached to the ends of the wings.[6]

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[3](...continued)
A156.27-2003 and attests to the fact that ANSI A156.27 is a ***minimum*** standard.

[4] 7.0 lb-ft of kinetic energy applies to so-called "Access Controlled Revolving Doors" covered by §8. of the ANSI A156.27-2003 standard. These are doors actuated by a "knowing act", and are mandated by §8.11 to carry no more than 7.0 lb-ft of kinetic energy. Whereas a knowing act door assumes "knowledge of what will happen" (see §2.14), doors that are not actuated by a knowing act are, paradoxically, permitted by ANSI A156.10-2003 to carry an indefinitely high kinetic energy, subject only to the requirements of §18.1. By contrast, the standards of other countries, for example the British BS 7036 standard, mandate that under ***no circumstance*** shall the kinetic energy of a revolving door exceed 10 J (Joules) = 7.4 lb-ft. In fact, large non knowing act revolving doors installed and operating within the U.S. typically exhibit kinetic energies ***far in excess of*** 7.4 lb-ft.

[5] Note that the entries in Table 1 on page 15 of ANSI A156.27-2003 that pertain to revolving doors with two wings apply only to doors configured as just described. In particular, they do ***not*** apply to the common type of 2-wing revolving door in which both a showcase and a concentric curved panel are attached to the end of each wing.

[6] Section 2.10 of ANSI A156.27-2003 defines a "core" as "The rotating central portion, greater than 12 in. (150 mm) in diameter, of a large diameter revolving door to which the wings are attached." Note that, since there are 25.4 mm in an inch, 12 inches is equivalently 304.8 mm, and ***not*** 150 mm. This error occurs also in §2.7 of the standard.

Unfortunately, the authors of the ANSI/BHMA A156.27-2003 national standard for revolving doors have made at least two serious errors relating to the kinetic energy equations and table contained within the Appendix.[7] Consequently, ANSI A156.27-2003 ***cannot be relied upon*** by manufacturers, door service technicians and others for estimating the kinetic energy of a given door and, in particular, whether it exhibits in excess of the 2.5 lb-ft limit above which wing sensors are required. In most cases, the estimated kinetic energy will be significantly below the actual kinetic energy, with the result that wing sensors mandated for user safety may not be deployed. This article explains the nature of the errors and provides the correct equations and table entries.

This article also presents the correct equation for the rotational kinetic energy of the common type of 2-wing revolving door configured with both a showcase and a concentric curved panel at the end of each wing.

**Kinetic Energy Equation and Table Errors**

***Equations*** **–** The equations provided within the rectangular boxes on page 16 of ANSI/BHMA 156.27-2003 are incorrect. Namely,

$$\Omega_{2.5} = \frac{483}{D}\sqrt{\frac{1}{W}} \qquad \textbf{INCORRECT} \qquad (1)$$

and

$$\Omega_{7.0} = \frac{808}{D}\sqrt{\frac{1}{W}} \qquad \textbf{INCORRECT} \qquad (2)$$

where $\Omega_{2.5}$ and $\Omega_{7.0}$ are the door rotation rates in rpm at which the kinetic energy of the door equals 2.5 lb-ft and 7.0 lb-ft, respectively, $D$ is the diameter of the door in feet, and $W$ the total weight in pounds of all door wings combined. That is, if $w$ is the weight in pounds of a single door wing, and $n$ the number of wings, $W = n\,w$.[8]

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[7] In particular, reference is made to the equations appearing on page 16 and the table appearing on page 15 of the standard.

[8] Note that the assumption made on page 16 of ANSI A156.27-2003 relative to the kinetic energy equations that the "door panels [wings] are evenly spaced" is irrelevant, immaterial and, beyond that, naive. As long as the door is constrained to rotate about the fixed central axis, the angular spacing between the wings has no effect whatsoever on the kinetic energy. The kinetic energy for a given rotation rate is the same whether

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Equations (1) and (2) for the revolving door configurations being considered by ANSI A156.27-2003 pertain to doors in which the individual wings remain inertially fixed as they rotate around the central axis of the door. For example, if a wing is aligned in the "north-south" direction at one point in the rotation of the door, it remains always aligned in the "north-south" direction even though it is rotating as a whole around the central axis of the door. Figure 1 below illustrates for a four-wing door the motion to which equations (1) and (2) apply. Of course, this is ***not*** the motion of an actual in service automatic revolving door.

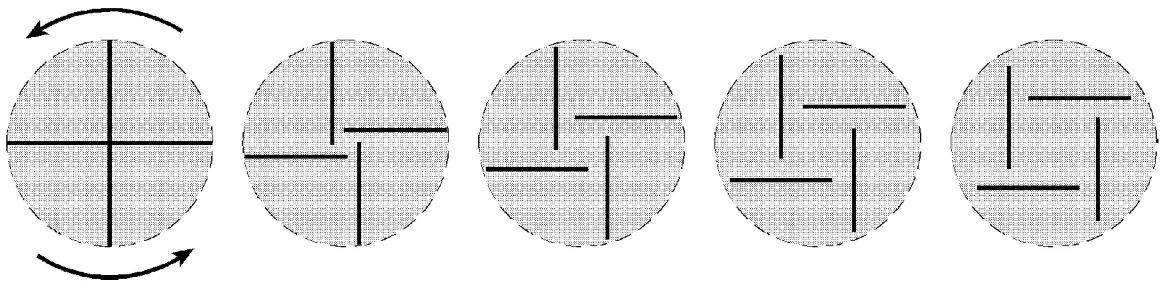

**Figure 1**. Door motion described by (incorrect) kinetic energy equations published on page 16 of ANSI A156.27-2003 national standard.

This is a common and immediately recognizable mistake frequently made by novitiates that arises from the mistaken notion that it is necessary only to assume for computational purposes that the mass of each door wing is concentrated at the center-of-mass of the wing and that it is the revolution of this concentrated center-of-mass alone (multiplied, of course, by the total number of participating wings) that determines the rotational kinetic energy of the door.

In fact this is quite incorrect. The novice fails to understand that, when rigid rotation is involved, as in the case of a revolving door, the individual wings also rotate (change their inertial orientations) about their centers-of-mass, and this additional rotation significantly increases the total rotational kinetic energy of the door.

As a consequence of this naive error, the equations on page 16 of ANSI A156.27-2003 significantly ***underestimate*** the kinetic energy of the door configurations being considered. The result is that anyone relying upon these equations will ***underestimate*** the kinetic energy of his or her door and may consequently conclude, erroneously, that the wing sensors mandated by §18.1 are not required.

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[8](...continued)
all the wings are bunched together, whether they are uniformly spaced around the central axis, or if they have any other distribution whatsoever around the central axis.

The correct equations, which describe actual doors in which the wings rotate in a rigidly ganged configuration, are

$$\Omega_{2.5} = \frac{419}{D}\sqrt{\frac{1}{W}} \qquad \textbf{CORRECT} \qquad (3)$$

and

$$\Omega_{7.0} = \frac{702}{D}\sqrt{\frac{1}{W}}\,. \qquad \textbf{CORRECT} \qquad (4)$$

Likewise, the equation for the kinetic energy of doors of the configurations being considered at any specified rotation rate Ω located at the bottom right corner of page 16 of ANSI A156.27-2003 is incorrect as a consequence of the same error. The equation contained within ANSI A156.27-2003 is

$$KE = \frac{W D^2 \Omega^2}{93091} \qquad \textbf{INCORRECT} \qquad (5)$$

whereas the correct equation is

$$KE = \frac{W D^2 \Omega^2}{70360}\,. \qquad \textbf{CORRECT} \qquad (6)$$

Because the denominator in (6), the correct equation, is smaller than that in (5), the incorrect equation provided in ANSI A156.27-2003 significantly ***underestimates*** the kinetic energy of the door at any given rotation rate Ω.

Note that a computational error has also been made in ANSI A156.27-2003 in using equation (5) to determine, as an example, the kinetic energy of an 8 foot diameter door revolving at 7 rpm with the total weight of its wings being 575 pounds. When these values of *D*, Ω and *W*, respectively, are used in (5), the result is 19.4 lb-ft of kinetic energy. The erroneous result published in ANSI A156.27-2003 is only 13.5 lb-ft. When equation (6) is used with the same parameter values, the correct result is found to be 25.6 lb-ft, some ten times the threshold value of 2.5 lb-ft above which §18.1 mandates the addition of wing sensors to the door.

***Table –*** Intended as a further aid, the authors of ANSI A156.27-2003 have used equation (1), one of the incorrect equations provided on page 16 of the standard, to compute and tabulate the rotation rate of various doors of the configurations being considered at which they exhibit exactly 2.5 lb-ft of rotational kinetic energy. These data are provided in Table 1 on page 15. As already mentioned, these data are incorrect because they are based on the incorrect equation (1) and, consequently, significantly ***overestimate*** the rotation rate that produces 2.5 lb-ft of kinetic energy.

In Table 1, the authors have also attempted to account for the additional contribution to the kinetic energy that results from the inclusion of a core. Unfortunately, this was done by introducing yet an additional significant error compounding the error already built into equation (1). The entries in Table 1 in which a core is (erroneously) considered are identified by a specific core weight in pounds being provided in the column labeled *Core Weight* rather than the entry "na".

The authors of ANSI A156.27-2003 have attempted to include the effects of a core by naively placing or distributing, for computational purposes, the mass (expressed as weight) of the core at the location of the centers-of-mass of the individual rotating wings. This ansatz is completely incorrect and reflects the naive notion that the correct result always follows from placing, for computational purposes, mass at the center-of-mass of something.[9] In this case, the centers-of-masses of the individual radial wings (non core) were chosen, though there is no basis in physical law for this choice.

As a consequence of this compound error, all entries in Table 1 of ANSI A156.27-2003 that pertain to doors with a core are incorrect because the computation of kinetic energy is based on ***both*** an incorrect equation ***and*** because the mass of the core has been improperly accounted for as well. Consequently, these entries would be erroneous even if the authors had used the correct equation, equation (3) above, for kinetic energy.

In fact, accounting correctly for the mass of the core cannot be done without specifying the size, orientation and location of each component of the core. Since these data are not specified – only the total weight of the core has been assumed in Table 1 of ANSI A156.27-2003 – it is impossible in ANSI A156.27-2003 correctly to account for the effect of the core on the total kinetic energy, so that all such entries in the final (right hand) column of Table 1 in ANSI A156.27-2003 are rendered meaningless.

Table 1 herein uses the ***correct*** equation, equation (3) above, for the rotational kinetic energy of doors of the configurations considered by ANSI A156.27-2003 to determine the ***correct*** rotation rates that yield 2.5 lb-ft of kinetic energy. Since the effect of a core cannot properly be accounted for without additional information, which information is

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[9] It was, in fact, this same naive error that resulted in the incorrect equations, shown here as (1) and (2), in ANSI A156.27-2003.

not available, the final column of Table 1 herein contains a question mark in association with all doors assumed to have a core.[10]

**Table 1.**

ROTATION RATES PRODUCING 2.5 LB-FT OF KINETIC ENERGY

| Diameter (inches) | No. Wings | Wing Width | Metal Wing Weight | Glass Wing Weight | Total per Wing | Extended Wing Weight | Core Weight | Total Weight | RPM at 2.5 lb-ft |
|---|---|---|---|---|---|---|---|---|---|
| 72 | 3 | 33 | 67 | 42 | 108 | 325 | na | 325 | 3.9 |
| 80 | 3 | 37 | 69 | 48 | 117 | 350 | na | 350 | 3.4 |
| 84 | 3 | 39 | 70 | 51 | 121 | 363 | na | 363 | 3.1 |
| 96 | 3 | 45 | 74 | 60 | 134 | 401 | na | 401 | 2.6 |
| 108 | 3 | 51 | 77 | 69 | 147 | 440 | na | 440 | 2.2 |
| 120 | 3 | 57 | 81 | 79 | 159 | 478 | na | 478 | 1.9 |
| 132 | 3 | 63 | 84 | 88 | 172 | 516 | na | 516 | 1.7 |
| 144 | 3 | 69 | 88 | 97 | 185 | 554 | na | 554 | 1.5 |
| 144 | 3 | 48 | 75 | 65 | 140 | 420 | 545 | 966 | ? |
| 168 | 3 | 56 | 80 | 77 | 157 | 471 | 596 | 1068 | ? |
| 192 | 3 | 64 | 85 | 89 | 174 | 522 | 647 | 1170 | ? |
| 216 | 3 | 72 | 89 | 102 | 191 | 573 | 698 | 1271 | ? |
| 240 | 3 | 80 | 94 | 114 | 208 | 624 | 749 | 1373 | ? |
| 72 | 4 | 33 | 67 | 42 | 108 | 433 | na | 433 | 3.4 |

[10] Note that the authors of ANSI A156.27-2003 have accounted for the additional weight of the metal framing associated with each wing by assuming implicitly that its mass (expressed as weight) is uniformly distributed over the entire two-dimensional extent of the wing. Given that the framing most likely entirely surrounds the wing and that it is uniform in nature, this is not an unreasonable assumption.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 4 | 37 | 69 | 48 | 117 | 467 | na | 467 | 2.9 |
| 84 | 4 | 39 | 70 | 51 | 121 | 484 | na | 484 | 2.7 |
| 96 | 4 | 45 | 74 | 60 | 134 | 535 | na | 535 | 2.3 |
| 108 | 4 | 51 | 77 | 69 | 147 | 586 | na | 586 | 1.9 |
| 120 | 4 | 57 | 81 | 79 | 159 | 637 | na | 637 | 1.7 |
| 132 | 4 | 63 | 84 | 88 | 172 | 688 | na | 688 | 1.5 |
| 144 | 4 | 69 | 88 | 97 | 185 | 739 | na | 739 | 1.3 |
| 144 | 4 | 46 | 74 | 62 | 136 | 544 | 694 | 1237 | ? |
| 168 | 4 | 54 | 79 | 74 | 153 | 612 | 762 | 1373 | ? |
| 192 | 4 | 62 | 84 | 86 | 170 | 679 | 829 | 1509 | ? |
| 216 | 4 | 70 | 88 | 99 | 187 | 747 | 897 | 1645 | ? |
| 240 | 4 | 78 | 93 | 111 | 204 | 815 | 965 | 1780 | ? |
| 120 | 2 | 40 | 71 | 52 | 122 | 245 | 1734 | 1979 | ? |
| 144 | 2 | 48 | 75 | 64 | 139 | 278 | 1835 | 2113 | ? |
| 168 | 2 | 55 | 80 | 76 | 156 | 312 | 1936 | 2247 | ? |
| 192 | 2 | 63 | 84 | 88 | 173 | 345 | 2036 | 2382 | ? |

**Kinetic Energy of 2-wing Door with Showcase and Concentric Curved Panel**

The configuration of the 2-wing revolving door considered is shown in the plan view in Figure 2. The following assumptions have been made in the derivation of the equation for the rotational kinetic energy of this door.

1. The rotating elements of the door correspond to those illustrated in the plan view shown in Figure 2 and are assumed to rotate together as a rigid unit.

2. The mass of each flat panel is distributed uniformly in the horizontal direction across the width of the panel. This assumption is not necessary for the curved panels because all points within each curved panel lie at the same distance *R* from the axis of rotation.

3. It is not necessary, and it is not assumed, that the panel masses are distributed uniformly in the direction parallel to the axis of rotation. That is, in the vertical direction.

4. The thickness of all panels is assumed to be a small fraction of the horizontal dimension of the panel.

5. Other components of the door that may be in motion, such as the ceiling, showcase floor and the drive mechanism, are not considered.

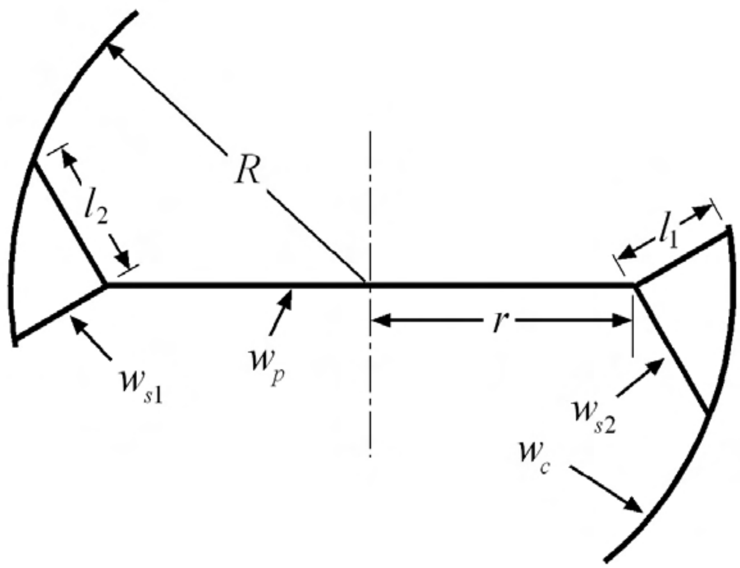


**Figure 2**. Plan view of the revolving elements of the 2-wing revolving door.

The rotational kinetic energy of a 2-wing revolving door as depicted in Figure 2 is

$$E = \frac{1}{2931.7}\left[ w_c R^2 + \frac{w_{s1} + w_{s2}}{2}\left(r^2 + R^2\right) - \frac{1}{6}\left(w_{s1} l_1^2 + w_{s2} l_2^2\right) + \frac{1}{3} w_p r^2 \right]\Omega^2 \qquad (7)$$

where the rotational kinetic energy $E$ is in units of pound-feet; the weights $w_c$, $w_{s1}$, $w_{s2}$ and $w_p$ of the door components are in pounds; the dimensions $r$, $R$, $l_1$ and $l_2$ are in feet; and the rotation rate of the door $\Omega$ is in revolutions per minute.[11]

An example of the use of equation (7) is provided by an actual case in which the requisite parameters have the following values:

| | | |
|---|---|---|
| $R = 6.6$ feet | $w_p = 89.1$ pounds | $\Omega = 3.7$ rpm |
| $r = 3.8$ feet | $w_{s1} = 63.3$ pounds | |
| $l_1 = 2.7$ feet | $w_{s2} = 93.8$ pounds | |
| $l_2 = 4.0$ feet | $w_c = 307.3$ pounds | |

The resulting rotational kinetic energy estimate from equation (7) is

$$E = 6.1547\ \Omega^2 = 84.3 \text{ lb-ft}$$

Note that this estimate is conservative as only the weight of the glass contained within the components of the door has been considered in arriving at the weights shown above. Unlike Table 1 in the ANSI A156.27-2003 standard, no attempt has been made to include the mass (weight) of the metal framing the glass components. Moreover, other moving components, such as the ceiling (if present and rotating with the door) and attached components such as the control electronics, the showcase floor and ceiling (if present), the drive mechanism, sensors and safety edges attached to the wings and panels, etc., have also not been included. All will increase the total rotational kinetic energy of the door at a given rotation rate $\Omega$.

Note also that the particular azimuthal location of the concentric curved panels in Figure 2 is immaterial. As shown, the curved panels have essentially no projection beyond the leading showcase panels in the direction of rotation of the door (counterclockwise in diagram) and a considerable projection in the opposite direction beyond the trailing showcase panels. They could as well be mounted so as to have an approximately equal projection in either direction, or any other combination of projections fore and aft. Equation (7) applies equally in all such cases.

[11] Note that the approximate value for the acceleration of gravity at sea level, $g = 32.15$ ft/sec$^2$, has been used in this derivation. The frequently used poorer approximation $g = 32$ ft/sec$^2$ will alter the result slightly. Namely, the constant in the denominator of the lead fraction in (7) becomes 2918.0. The result (7) is the more accurate and is to be preferred.