An Automatic Sliding Door Litigation Primer

ESSENTIALS FOR THE PLAINTIFF'S ATTORNEY

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This primer is intended to give plaintiffs' attorneys a quick fix on the principal technical issues that bear on cases involving automatic sliding pedestrian doors. It is not intended to be exhaustive. Indeed, there are many, many variations and special considerations that arise in particular cases that are not discussed here. Rather, only the dominant issues that are at the core of the majority of such cases are presented. In fact, the presentation is restricted to consideration of automatic sliding doors only. The reason is two fold. First, the majority of installed automatic pedestrian doors are of this type. Second, many, but not all, of the issues that pertain to sliding doors pertain as well to swinging and revolving doors, which are not considered.

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Background Information

What is an automatic door?

For the purposes of this discussion, an automatic door is a commercially available power operated or power assisted door used to facilitate public pedestrian traffic. Doors intended for other purposes, such as overhead garage doors, are not considered. Nor are automatic doors considered that are used for access to restricted areas, such as the operating area of a hospital or to private warehouse facilities.

There are, generally, three types of automatic pedestrian doors - sliding, swinging and revolving. Only the sliding type will be considered here. Other types exist but are very rarely seen.

An automatic sliding door unit may employ either one or two sliding panels, invariably glazed. In the latter design, referred to as a *biparting* or *center-parting* door, the sliding panels retract in opposite directions. Fixed glazed panels may be included adjacent to the sliding panel, or panels. The sliding panel(s) then open by withdrawing behind or in front of the fixed panels, depending upon the design.

In case of power failure, or other emergency, the sliding panels of some designs "break out" under moderate pressure. That is, the panels can be forced to fall or swing outward to permit escape from the area serviced by the door. Yet other designs incorporate fixed panels that break out as well. Though the break out feature is not mandated by the relevant national standards, doors so equipped must be clearly marked with signs reading "IN EMERGENCY PUSH TO OPEN."

How does an automatic door work?

All automatic doors are equipped with a sensor that triggers opening of the door as a pedestrian approaches. Prior to about 1972, this sensor was invariably a control mat that actuated the door by closing an electrical switch, or switches, embedded within the mat under the weight of the approaching individual. Since control mats respond to weight, they serve also to hold the door open as well as to initiate its opening. In fact, they will hold the door open for as long as the individual remains standing anywhere on the active area of the mat. This characteristic makes control mats much safer for elderly pedestrians, who are likely to move relatively slowly, than the "high tech" alternatives with which they have largely been replaced.

Since about 1972, it has become fashionable to replace control mats with combinations of beam sensors that ostensibly duplicate the functionality of the mats. Unfortunately, the "high tech" beam sensor designs that currently predominate have been naively conceived and, as a consequence, incorporate a number of serious design flaws that make elderly pedestrians particularly susceptible to accident.

In virtually all beam designs, the approach of an individual is detected by a microwave *motion* sensor. This consists of a microwave beam (operating at about 10.5 GHz) launched by a horn antenna concealed within a small cosmetic enclosure mounted on the door header and aimed generally outward and downward from the door opening. The principal shortcoming of the microwave motion sensor is that it responds only to motion: an object within the beam that is simply present but not moving, or that is moving too slowly, cannot be "seen" by the sensor. In this respect, the motion sensor clearly does not duplicate the characteristics of the mat, which can maintain detection indefinitely regardless of the state of motion.

After the door is triggered to open by the microwave motion sensor, the *presence* of the individual within the door opening itself is detected using any one of several technologies, of which the most common is an infrared beam. Photobeams (electric eyes), sonar (ultrasonic sound beam) and control mats are also employed and may be used in various combinations, including with an infrared beam. The purpose of the presence detector is to prevent a fully opened door from closing when a person is in the door closing path.

In some designs, a second microwave motion sensor is placed on the egress side of the door so that the door is actively commanded open even after the individual has passed though the door opening. The intention is to produce a very conservative interval during which the door remains open. Unfortunately, the egress side motion sensor may occasionally serve also to hold the door open just long enough for a subsequent individual to enter the door opening undetected, leading to an accident.

A hold time, mandated by applicable standards to be a *minimum* of 1.5 seconds, is appended to each of the detection signals generated by the sensors in the system. That is, each detection signal, whether from the motion or presence sensors, is artificially extended by a minimum of 1.5 seconds after it would otherwise cease. The purpose, again, is to produce a conservative interval sufficient to allow the individual to pass through the doorway before the door closing sequence is initiated.

How does the motion sensor work?

Microwave motion sensors use the Doppler principle to detect motion. Microwaves reflected from objects within the microwave beam are received by the same antenna from which they are launched. If the reflecting object is moving directly *toward* the antenna, or if it has a component of motion toward the antenna, the wavelength of the reflected microwaves will be *shorter* than in the transmitted beam. Conversely, if the reflecting object is moving directly *away from* the antenna, or if it has a component of motion away from the antenna, the wavelength of the reflected microwaves will be *longer* than in the transmitted beam. And, if the object is *not moving*, the reflected wavelength will be *identical* to that in the transmitted beam. The variation of the reflected wavelength with the state of motion relative to the beam source is referred to as the Doppler effect.

The electronic circuitry within the motion sensor compares the wavelengths of the transmitted and reflected beams (*homodyne* process). If they differ sufficiently, the circuitry generates a detection signal. Relatively sophisticated designs can discriminate between motion toward the sensor (shorter reflected wavelengths) and motion away from the sensor (longer reflected wavelengths). Ingress-side motion sensors with this capability usually are designed to ignore longer reflected wavelengths under the assumption that they represent departing motion not requiring the door to be triggered to open.

Note that motion sensors that utilize the Doppler effect do not generate a detection signal if the reflected wavelength equals, or differs too little from, the wavelength of the transmitted beam. As a result, they cannot differentiate between an object that is present, but not moving or is moving too slowly, from the complete absence of an object within the microwave beam. Consequently, if a person within the microwave beam stops, or moves too slowly, he or she may cease to be detected. On expiration of the hold time appended to the detection signal, the door may begin its closing sequence even though the person is still within the motion sensor beam and may be moving slowly toward the door opening.

In principle, the waves reflected from stationary objects, or very slowly moving objects, could be analyzed as well to permit the sensor to function both as a *motion* sensor and as a *presence* sensor. However, a level of sophistication considerably higher than that evidenced by currently available designs would be demanded. This prospect is discussed further under *How automatic sliding doors could be made safer* below.

How do presence sensors work?

A variety of methods are available for detecting the presence of a person within the open doorway.

Photobeams **-** A photobeam presence detector contains one or more light beam sources and a corresponding set of receivers. The light wavelength may fall within the visible spectrum, or outside it, typically in the infrared. The light sources are usually mounted on one of the door jambs and / or the guard rails, if present, that extend in either direction beyond the door opening. The light beams are directed across the door opening toward the receivers mounted on the opposite jamb and / or guard rail. A presence detection signal is generated whenever an object breaks any one, or several, of the light paths between a source and receiver. In the past, this scheme was referred to as an "electric eye."

The photobeam method can be quite reliable. However, a judicious distribution of sources and receivers is required to minimize the possibility that a person could enter the door opening without interrupting at least one light path.

Consider the example of a system containing only a single light beam transmitted from jamb-to-jamb horizontally across the door opening. Such single photobeam systems are not uncommon. The height of the beam must be set low enough so that it does not pass over the heads of children and people of short stature who use the door. However, the head and shoulders of a person who is stooped, typically an elderly person, may enter the doorway above the position of the light beam. Because of the person's bent posture, the lower body may not then be positioned so as to break the path of the light beam. The person is bent over the light beam without intersecting it. Since the light path is not broken, the person's presence is not detected, though the upper body is in the door closing path, leading to the possibility of an accident.

Physical constraints imposed by the mechanical design of the door, which ultimately translate into manufacturing cost tradeoffs, may restrict the locations available for mounting photobeam source / receiver pairs. Designs in which the first presence sensing photobeam is placed several inches beyond the door opening on the *egress* side are not uncommon. In such a design, a person who is not stooped can literally stand erect in the door opening and not be detected.

Sonar **-** Sonar presence sensing systems contain an ultrasonic sound source (loud speaker or other transducer) and a receiver, or receivers (microphones). The plane of the door opening is bathed in ultrasonic sound. Echoes or "shadows" induced by the presence of a person within the bathed volume generate a presence detection signal.

Sonar presence detection systems suffer from a number of serious problems. The most troublesome is that the propagation of ultrasound is significantly influenced by the relative humidity and temperature of the air through which it travels. This leads to drifting of the detection threshold and erratic, unreliable operation. For this reason, sonar systems, though available, have largely fallen out of favor and are not seen frequently in the field.

Sonar systems suffer also from a problem shared with other techniques, such as infrared, that rely on echoes for generating the detection signal. Because ultrasound waves tend to spread out as they travel away from their source, it is virtually impossible to confine the region within which detection takes place to a volume that comes close enough to the door to detect a person within the doorway with acceptable reliability, but simultaneously to fail to respond to the door itself as it closes. If the system is adjusted so that the closing door will not trigger the presence signal, then the detection volume will fall too far from the door opening to be useful as a presence detector for individuals within the path of the closing door.

The solution, adopted for infrared systems as well, is simply to shut off the presence sensor just prior to closing the door. This constitutes a serious design flaw the implications of which are discussed under *How do accidents occur?* below.

Infrared - Infrared (IR) presence sensors contain light emitting diodes (LED's) that produce "light" in the infrared part of the electromagnetic spectrum. That is, at wavelengths beyond (longer than) the red end of the visible spectrum. Usually, the IR LED's are mounted on the door header so that they emit directly downward toward the floor. Photo-diodes, -transistors or other infrared receptor devices are mounted in close proximity to the LED's and are oriented so that they respond to the infrared light reflected back upward from objects within the doorway. Generally, the closer an object within the doorway is to the door header, the stronger will be the detected infrared reflection. The presence detection signal is generated when the strength of the infrared reflections exceeds a preset threshold value.

The threshold value is determined and set experimentally. Typically, a box about 21 inches high is placed on the floor in the door opening directly below the LED's in the door header. The bulk of the infrared light reflected back to the receptors in the header then comes from the top surface of the box, about 21 inches above the floor. The technician adjusts the detector sensitivity so that the reflections from the box are just capable of producing a detection signal. When the box is removed, the reflections from the floor, which is 21 inches farther from the devices in the header, are, presumably, well below the level necessary to generate a detection signal. This is a consequence of the familiar fact that the intensity in a light beam decreases continuously with distance from its source.

To a first approximation, the presence sensor is adjusted so that it responds only to objects within the doorway whose tops are more than 21 inches above the floor. This would certainly appear to be conservative enough to detect all but a very small child standing in the door closing path. However, account must also be taken of the inevitable variation of the ability to reflect infrared radiation exhibited by various materials. Materials that strongly absorb, rather than reflect, infrared radiation may not produce sufficient reflected energy for detection until they are brought quite close to the sensors in the door header. A person wearing such a material in the form of, say, a hat might not be detected by the presence sensor even though the nominal detection level extends downward to within 21 inches of the floor.

Indeed, the principal reason for setting the detection threshold at 21 inches above the floor is to assure that variations over time in the infrared reflection characteristics of the floor do not cause the presence detector to "see" the floor on occasion. Obviously, if the presence detector were to respond to the floor, the door would never be allowed to close. Factors that might introduce variability in the reflectance of the floor are a film of water coating the floor on a rainy day or snow and slush tracked in on a snowy day. Also, dirt, paper or other debris that may fall or blow into the doorway might trigger erratic operation unless the detection threshold is set well above the level of the floor.

Finally, infrared presence sensors of the design just described suffer also from the beam spreading problem already mentioned in connection with ultrasonic methods. For precisely the same reasons as for ultrasonic devices, infrared systems must be shut off just prior to the door closing. Otherwise, the infrared sensor will "see" the door itself as it closes and will command it to reopen, leading to a never ending cycle. Shutting down the presence sensor to permit the door to close constitutes a serious design flaw the implications of which are discussed in the following section.

How do accidents occur?

In the nutshell, an accident can occur when a pedestrian, usually a slowly moving elderly person, manages to reach the door opening immediately after the presence detector has been automatically switched off to permit the door to close. With the system thus "blinded" to the presence of the person in the doorway, the door closes, striking the person and knocking him or her down. In the elderly, the fall may result in a shattered pelvis, broken femur or other serious injury. This much has been appreciated by attorneys handling such cases for some time.

What has not been so obvious is that there exist two additional serious design flaws that conspire to enhance the likelihood of an accident of the sort just outlined. Together with the need to switch off the presence sensor, they constitute the "triple design flaw," discussed in a subsequent section, that is the centerpiece of the liability argument in such cases. They are the keys that explain how it is possible, in spite of often vigorous assertions to the contrary by manufacturers, for a person to reach the door opening just as the presence sensor is being turned off without being detected by the other sensors in the system.

The evidence suggests two distinct accident scenarios. In the first, the injured party manages to get into the door opening after the presence sensor has been turned off entirely through his or her own actions, abetted, of course, by the flaws in the design. In the second, the injured party is preceded by a more sprightly person, often a companion, who actually triggers the door opening cycle. Under the false impression that he/she has triggered the door opening, the second person enters the door opening at the inopportune moment, unaware that he/she has not in fact been "seen" by the door, and is struck.

A third scenario is also likely, though to date I am not aware of any test data or discovery sufficiently rigorous to elevate it to the status of a definite possibility. In this scenario, the microwave echoes that would otherwise be sufficient to generate a proper motion detection signal are swamped by unusually strong echoes from highly conducting metallic objects that happen also to fall within the microwave beam. Possible candidates are wire eyeglass rims with dimensions that happen to match closely the microwave beam wavelength, and the aluminum tubing of walkers often used by the elderly. In a manner not unlike the effect of chaff used to foil microwave military radars, it is conceivable that such metallic objects could seriously compromise motion detection.

Whether or not such possibilities are borne out, the current total absence of standards for sensor dynamic range and multiple target discrimination is discomforting.

Preparing the Case

The ATLA Automatic Door Litigation Group

Perhaps the most valuable single step in preparing for an automatic door litigation is to contact and become a member of the ATLA (Association of Trial Lawyers of America) Automatic Door Litigation Group. The address for the ATLA Automatic Door Litigation Group is:

Edson Howard Rafferty, Co-chairman
ATLA Automatic Door Litigation Group
545 Concord Avenue, Suite 10
Cambridge, MA 02138

617-864-1600 (Telephone)
617-864-1603 (FAX)

Membership includes a periodic newsletter, access to extensive materials from previous cases, referrals to expert witnesses, and access to prepared exhibits and videotapes. You can also be put into contact with other attorneys who are, or have recently, tried similar cases.

What existing documentation should I gather?

In making the case for liability on the technical aspects of the door operation, it is essential to gather written information from a wide range of sources. These pertain both to the design, operation and maintenance of the door itself and to the expert testimony of defense witnesses in other cases. Some of the kinds of documentation that should be sought are:

a) Initial proposals for the door installation. Evidence revealing the evolution of the *proposed* door configuration could be invaluable. Such documents may reside with the manufacturer, architects, contractors, builders, etc.

b) Invoices and correspondence sufficient to reveal *exactly* what equipment and features were delivered and included in the original installation. In response to interrogatories, manufacturers sometimes provide a welter of irrelevant technical information having nothing to do with the specific model or version involved in the case. The demonstration of liability can depend critically on precisely which of the many variations offered by the manufacturer was actually present.

c) Advertising and promotional material used in connection with the door. This may include materials targeted toward the end user, as well as material aimed at builders, architects, etc. Of particular relevance are claims made in such materials that the door conforms to the applicable ANSI and UL standards. See *What standards apply to automatic doors?* below.

d) Documentation prepared by the original installing technicians showing exactly how the door was configured and adjusted at installation. Try to determine the *actual numerical values* of settings such as the hold times appended to the motion and presence sensor signals, location of photobeam sensors, number of infrared presence sensor LED’s enabled, door speed (normal and check), exact frequency of operation of each microwave motion sensor beam in the system (if more than one), and the sensitivity setting of each motion and presence sensor in the system.

e) A complete maintenance history of the door from installation up to and *beyond* the time of the accident. This can be invaluable for many reasons. For example, it can uncover door subsystems that have a history of erratic behavior or personnel with a penchant for having maintenance technicians adjust the door to extreme settings. A technician’s casual remark on a work order can sometimes settle a critical point. Adjustments or changes to the door made just prior to or soon after an accident can also be telling.

f) A complete history of any modifications made to the door subsequent to the original installation. Correspondence that may reveal the motivation for such changes can be important.

g) Complete technical documentation relating to the door and equipment *actually installed and in operation* at the time of the accident. This kind of information is notoriously difficult to obtain in a useful form. Here, the sense of the word “complete” is illustrated by the following partial list of specific technical data required:

> Clear diagrams, both functional and circuit, for all door subsystems; a clear discussion of the theory of operation of each door sensor subsystem; a clear discussion of the operation of the door and its sensors as an integrated system; actual laboratory and field statistical data relating to reliability testing of sensor subsystems; comparative reliability data justifying sensor technology design choices; experiential statistical field data characterizing the various failure modes observed for the door, their frequency, and mean time to failure.

It should be determined if any door components, especially the sensor subsystems, have been provided to the door manufacturer by an OEM (Original Equipment Manufacturer). If so, it may be advisable to bring suit against both the door manufacturer and the OEM for at least two reasons. First, the manufacturer may attempt to avoid liability by claiming that the OEM subsystem or component was responsible for the accident. Second, you may discover that the door manufacturer used the OEM component in a manner that exceeded the specifications set by the OEM, thereby shifting liability back to the door manufacturer.

Finally, sworn deposition and trial testimony of the relevant defense expert witness(es) should be gathered. The ATLA Automatic Door Litigation Group can be invaluable in this effort (see above). Comparison of such testimony from various cases may yield unexpected bonuses. As an example, the principal expert witness for one of the major automatic door manufacturers is on record describing how he can “fake out” his own company’s door. The method he describes conforms precisely to the steps predicted on theoretical grounds. See *What’s wrong with current designs?* below. Elsewhere, he “tends to agree” that his company’s door fails to comply with applicable ANSI standards.

What material evidence should I gather?

Accident demonstration videotape **-** The most effective single piece of evidence that you can prepare is a videotape showing the actual door in question repeatedly closing on a person as he / she steps into the door opening. If possible, arrange for the door to be optimally adjusted by the manufacturer, or an approved agent, immediately prior to videotaping. Because of the design flaws incorporated into the door, no amount of adjustment will eliminate the tendency of the door to close on a pedestrian under the requisite circumstances.

The test subject should approach the door straight on. That is, at right angles to the plane of the door opening and along the center line of the path through the doorway. It is *not* necessary to approach from the side, where the motion sensor beam may be less effective. The point made by the videotape will be most dramatic if the demonstration is conducted in such a way that the door is clearly at the greatest possible advantage.

Assume that the hold time delay appended to the motion detector signal has been set to the minimum acceptable value of 1.5 seconds. The subject should stop at a point close to the plane of the door opening and wait motionless for 1.5 seconds. When the subject is in the correct position, the door will begin to close 1.5 seconds (the hold time) after becoming motionless. If too close, the door will not close because the subject is within range of the presence sensor. Some experimentation may be required to locate the position closest to the door just beyond the range of the presence detector.

The subject, having reached the correct position and become motionless, should mentally gauge the passing of the 1.5 second hold time. The object is to step forward into the path of the closing door a fraction of a second after the presence sensor has switched off. It may be possible simply to wait for the door to start to close and then immediately to step forward. Motion should be *smoothly* forward, with as little an up-and-down component as possible. If you suspect that the vertical motion of the subject's hands or feet are triggering the motion sensor to re-open the door, have the subject wear a wide brimmed hat so that his/her limbs are not "seen" by the microwave motion sensor. With a little practice, the subject will have no difficulty getting the door to strike him/her. A videotaped sequence of ten or so such events will make a very strong impression on the jury.

Documenting infrared sensors **-** If the door in question uses an infrared presence sensor, you may want to document the number and placement of the LED infrared sources. Though infrared light is invisible to the eye, it can be photographed by video cameras that use vidicon image tubes. Cameras that use CCD (charge coupled device) arrays for image detection may also work, but you will have to make an experimental determination.

Ordinary photographic film may also respond in the infrared. However, the infrared LED's may operate in a pulsed (intermittent) mode. If the camera's shutter happens to open when the LED's are off, they will not be seen in the resulting slide or print. One of the advantages of using the video camera is that you can see the LED's in the camera's view finder real time and do not have to wait for film development to know if you have been successful.

The presence sensor LED's are typically mounted behind a glass shield in the door header and are aimed toward the floor. Standing in the doorway, direct the video camera upward toward the header. If your camera is sensitive to infrared, you will immediately see the LED's in your view finder, though you will not be able to see them with your unaided eye. The volume covered by the presence detector is determined, in part, by the number of active LED's. The video camera will reveal immediately how many are operating, which count can be later verified against the intended number.

Sensor adjustments/tampering **-** As soon as possible after accepting the case, you should thoroughly photograph the door in question. Besides general views in and around the door, you should be sure to get the following photographic documentation:

a) Take close up (a few inches to a foot) photographs of both sides of each microwave antenna housing on the door headers. Be sure to include identification of some kind so that you can later correlate your photographs with the individual devices.

   These photographs will not only establish the current microwave antenna aiming angles, but may reveal attempts to tamper with their adjustment either prior to or after the photographs were taken. There are screws that lock the antenna in position that, if not properly released before adjustment, may produced easily photographed scratches on the antenna mounts. If present, such scratches may indicate tampering with the pointing adjustment. For this reason, it cannot be emphasized too strongly that these photographs should be taken as soon after initiation of the case as possible.

   Documenting the absence of scratches and the current pointing angle may also insure against a subsequent claim by the defense that the sensors had been tampered with prior to the accident. Such photographs could certainly provide convincing evidence of any attempt to create the impression of tampering after the fact.

b) Take close up (a few inches, if possible) photographs of the heads of all screws positioned so that they must be released in order to gain access to any door sensor or to the control unit, which is usually mounted within the door header. Be sure to include such photographs of the presence detector, as well as of the motion sensors as described above. Often, critical screws are covered by seals after installation or authorized servicing. The photographs will document any broken or absent seals, as well as any evidence of physical damage.

c) Compliance with relevant standards requires that certain warning decals be mounted on automatic pedestrian doors. Be sure to get photographs showing all decals mounted on either side of the door, and in the immediate vicinity of the door. The camera should be positioned so that the decal text will be easily seen in the slide or print. Get photographs that convey the relative visibility of the various decals throughout the door operation cycle. In particular, important warnings may become partially or totally obstructed when the door is fully open.

Be on the look out for labels affixed to or near the door by service personnel. Close up photographs of these, which may contain important addresses and telephone numbers, may prove invaluable in piecing together the service history of the door.

As with the technical photographs, it is essential that photographs of the door labeling be taken as soon as possible after the case is initiated.

What standards apply to automatic doors?

There are two key national standards that apply to automatic pedestrian doors - American National Standards Institute, Inc., ANSI A156.10 and Underwriters Laboratories, Inc., UL 325. These standards are available from:

American National Standards Institute, Inc.
11 West 42nd Street
New York, NY 10036
212-642-4900

Underwriters Laboratories, Inc.
333 Pfingsten Road
Northbrook, IL 60062-2096
708-272-8800

These standards pertain specifically to the design, installation and operation of automatic doors. Other standards apply to such items as wiring and cables, switches, transformers, fuseholders, etc. The latter are generally not of concern in automatic door cases because they do not apply to the operation of the door as an integrated system.

Of the two standards, ANSI A156.10 provides a far more comprehensive set of guidelines on the configuration and operation of automatic pedestrian doors than does UL 325. For this reason, ANSI A156.10 is generally more relevant to automatic door cases than UL 325.

UL 325 first appeared in 1973 and has been revised several times since. The currently most recent revision is dated October 27, 1992. ANSI A156.10 first appeared in 1979, with revisions appearing in 1985 and 1991. These are designated A156.10-1979, A156.10-1985 and A156.10-1991.

While most revisions represent minor changes, a very significant change occurred between ANSI A156.10-1985 and A156.10-1991. Prior to the 1991 version, the ANSI standard specified that motion detectors had to be capable of detecting a specific object moving within the detection field. The material, dimensions and state of motion of the object were precisely specified. See § 5.1.2, § 5.2.2 and Figure A-13 in ANSI A156.10-1985. All mention of the test object has been dropped in the 1991 version of the ANSI standard, ANSI A156.10-1991.

Though no explanation is given, it seems clear from consideration of the principles that govern operation of microwave motion sensors that the omission is a concession to the manufacturers of current systems. That is, current designs cannot successfully detect the motion of the test object or, at best, have great difficulty doing so. As explained under *What's wrong with current designs?*, the problem stems from characteristics intrinsic to current designs that cannot be overcome without significant design revision. Rather than, in effect, mandating design revision and possible upgrading of current installations, the ANSI standard was simply downgraded.

In this regard, it should be noted that the ANSI standard is sponsored, published and copyrighted by *Builders Hardware Manufacturers Association, Inc.* (BHMA). Though designation as an ANSI standard suggests independence and detachment, ANSI A156.10 appears on closer examination to be a standard written by the industry for the industry. Moreover, ANSI A156.10 contains the following disclaimer:

"The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to this standard."

Do automatic doors comply with the standards?

Manufacturers often make vigorous claims in their promotional materials that their doors conform to applicable standards, and in particular to the ANSI A156.10 standard. In fact, automatic doors that employ infrared or sonar presence detectors in the plane of the door opening *fail to comply* with a significant provision of both ANSI A156.10 and UL 325.

Section 5.2.2 of ANSI A156.10-1991, pertaining to sliding doors, states:

*"**A presence sensing safety device shall be used to prevent (a) fully open door(s) from closing when a person is in the door closing path."***

A presence sensor is defined by § 2.19 of ANSI A156.10-1991 as:

*"**A device located in the vicinity of the doorway to detect the presence of people or objects."***

Likewise, § 28.5 (B) of the UL 325 standard states:

[The sliding pedestrian door,] ***"if it develops kinetic energy of more than 2-1/2 foot-pounds (3.39 J), shall employ a reopening device or other means to prohibit motion of the door when an obstruction is in its path."***

As described under *How do presence sensors work?*, sonar and infrared presence sensors must be deliberately turned off in order to allow the door to close. Otherwise, the closing door would be "seen" by the sensor, causing the door to be commanded to re-open. On expiration of the hold time delay, the cycle would repeat, leading to endless cycling of the door operation. Since the presence sensor is automatically switched off just prior to the door closing, such designs clearly fail to meet the ANSI and UL standards cited above.

Presence sensors using photobeams may also fail to comply with the ANSI and UL standards if they permit part, or all, of a person's body to be within the door closing path without interrupting at least one photobeam. See the discussion of photobeams under *How do presence sensors work?* above.

Qualifications of the plaintiff's expert

Traditionally, the plaintiff's technical expert has been someone familiar with the general design, installation and operation of automatic pedestrian doors. These experts have drawn attention to the flaw in current designs that requires the presence sensor to be shut down just prior to the door closing. They have also highlighted that such designs do not comply with ANSI and UL standards and have the potential for serious accidents. See previous sections.

What has not been emphasized heretofore is that there exist two additional serious flaws in current designs that conspire with the shut down of the presence detector to create a much greater accident hazard for the elderly, a subset of the anticipated users of the door, than was previously recognized. See *What's wrong with current designs?* below. Recognition and elucidation of these additional flaws requires significant familiarity with the principles, both theoretical and practical, of electromagnetic radiation, especially of microwaves.

Therefore, a plaintiff's technical expert should be sought who has both a familiarity with the overall design, installation and operation of automatic pedestrian doors, as well as an expert grasp of electromagnetic, and, in particular, microwave, theory and practice.

The Plaintiff's Case

The centerpiece of the plaintiff's case is the triplet of design flaws incorporated in sliding doors that use microwave motion sensors in conjunction with a presence sensor that must be disabled in order to close the door.

What's wrong with current designs?

The most obvious flaw in current designs is the necessity to shut down the presence sensor in the plane of the door opening just prior to closing the door. As such, they fail to comply with relevant ANSI and UL standards. See previous sections.

Moreover, current designs fail to incorporate an effective backup or alternate detection scheme that can take over for the presence sensor when it is shut down. If such backup detection were reliably available, it could command the door to re-open, re-enabling the presence detector in the process, preventing a person from being struck by the door as it closes.

Manufacturers argue that current designs utilizing microwave motion sensors already provide the necessary "backup" detection capability. That is, they argue that the microwave motion sensor, which is never disabled, will, if properly adjusted, command the door to re-open and will re-enable the presence detector if a person steps into the path of the closing door.

The fact is that motion sensors have been incorporated into the design of the door in a naive way. As a consequence, they have little or no residual capability with which to compensate for the shut down of the presence detector. The etiology of the problem is not obvious to the human eye because microwaves, and their behavior, cannot be seen. However, straightforward consideration of the elementary properties of microwaves immediately reveals the deficiencies inherent in current designs. See the next section.

What is the "triple design flaw?"

The triplet of design flaws incorporated into current designs includes:

a) the shut down of the presence sensor just prior to closing the door,

b) the tendency for Doppler shift to go to zero immediately beneath the motion sensor on the door header, and

c) the fact that, of necessity, a person about to enter the plane of the door opening is at the edge, rather than the center, of the microwave motion sensor beam.

The shut down of the presence sensor has already been discussed. The Doppler shift and microwave beam shape problems, which complete the triplet, are described below.

Doppler shift **-** Microwave motion sensors utilize the Doppler principle to detect motion. See the previous section *How does the motion sensor work?*. As explained, the Doppler effect depends upon the motion of the reflecting object (person) relative to the location of the source of the microwaves. That is, relative to the microwave horn mounted on the door header.

When a person first approaches the door, far out in the microwave beam, the person's motion has a large component toward the microwave horn. While the person is not moving as a whole directly toward the horn, the person's motion is "largely" toward the horn and, as a consequence, tends to produce a substantial Doppler shift. Under these circumstances, the person's motion is easily detected.

On the other hand, when the person reaches a point directly beneath the microwave source, just prior to entering the plane of the door opening, the person's motion is essentially at right angles to the direction toward the source. To the extent that the person is moving horizontally, there is no component of motion toward or away from the microwave source. Under these circumstances, there is essentially no Doppler shift and the person's motion cannot be detected.

One sees that, purely as a consequence of the geometry of the placement of the microwave sensor, the ability to produce Doppler shift, and, hence, to detect motion, decreases toward zero as the region immediately beneath the microwave source is approached. This is a most unfortunate circumstance for it is precisely at this point, just prior to entering the plane of the door opening, that the ability to detect motion becomes most critical. If the motion sensor fails to detect horizontal motion immediately in front of the door opening and if the presence sensor has shut down, the person can step into the door closing path and be struck. Neither the presence sensor nor the motion sensor will be effective; the former because it has been shut off, the latter because it has been naively placed on the door header immediately above the horizontally moving pedestrian where the tendency to produce Doppler shift is minimal.

Microwave beam shape **-** Illustrations in the literature and manuals distributed by door manufacturers depict the microwave motion sensor beam as a "solid" conical volume with sharply defined edges. The impression is conveyed that the motion of an object (person) is equally capable of being detected anywhere within the beam. Moreover, it appears that the beam has a well-defined edge outside of which the detection capability drops suddenly to zero. This picture is a gross distortion of the actual physical characteristics of the microwave beam that has significant implications for the ability to detect motion.

We have already seen that motion detection capability is not uniform throughout the microwave beam due to variations in the ability to produce Doppler shift, upon which motion detection depends. The origin of this variation is geometric, having to do with the placement of the sensor relative to the pedestrian; it has nothing to do with the shape of the microwave beam itself. However, the shape of the microwave beam too compromises motion detection capability in a way that, unfortunately, compounds the degradation introduced by the Doppler shift variation. To see how this comes about, one must have a more accurate picture of the actual "shape" of the microwave beam and must understand the practical constraints on the aiming of the beam.

There are a number of ways in which the intensity of the microwave beam deviates from the simplistic representation of the manufacturer. The one that contributes most significantly to the circumstances that lead to accidents has to do with the beam cross section. Unlike the manufacturer's diagrams, the microwave beam is *not* uniformly intense over its cross section. Rather, the beam is most intense at the center and decreases smoothly as one moves away, in any direction, from the center. If one could "see" the beam as ordinary light projected onto the floor, there would be a bright spot in the center surrounded by regions of ever decreasing intensity. No clear edge would be discernable. Instead, the beam would simply fade away so gradually that it would be impossible to find the beam "edge."

This property of the beam cross section is an inescapable consequence of the laws of physics that determine the shape of the beam as it is launched from the microwave horn antenna. The sharpness of the beam edge is related to the *depth* (or length of the *throat*) of the microwave horn. All commercially available microwave motion sensors employ a horn that is far too shallow to yield a well defined beam edge. In order to do so, the depth of the horn would have to be increased to at least 10 or 12 inches. Such a long horn would probably protrude too far to be considered acceptable.

The oft used analogy with a flashlight beam is of no help. The edge of a flashlight beam is far more sharply defined than that of the microwave motion sensor beam. Indeed, it is difficult to think of an example from everyday experience that conveys the softness of the microwave beam perimeter.

So, what does the sharply defined beam edge depicted in the manufacturer's diagrams represent if there is nothing about the beam itself that can be ascribed to a well defined "edge?" The answer is that the manufacturer's diagrams depict an *operationally defined* beam edge. To see what this means, consider how the installing technician sets the aiming angle of the microwave horn antenna.

The technician begins by rotating the microwave sensor horn antenna downward until its beam intersects the door. That this point has been reached is signalled by the fact that the mechanical door operator begins to cycle endlessly. What has happened is that the beam has been tilted so far downward that the motion sensor "sees" the door itself. Since it cannot distinguish a moving door from a moving person, it commands the door to open. On expiration of the hold time delay, the door starts to close, whereupon the motion detector again senses the motion of the door. This leads to endless cycling of the door operation. Next, the technician tilts the beam slowly upward until the cycling of the door just ceases. At this point, the microwave beam is aimed as close to the door as it can be without it “seeing” the door itself.

There are two points to be observed. First, this adjustment provides an operational definition of the beam edge. That is, the beam edge so defined is simply the imaginary line in space on one side of which the sensor is able to “see” the door and on the other side of which it cannot. The location of that line depends to a great extent on the ability of the door to be “seen.” That is, on the ability of the door to reflect microwaves back to the motion sensor. Since different materials and textures can be expected to reflect microwaves differently, the operational “edge” of the beam for a pedestrian, rather than the door, may be in quite another place. In other words, the point at which a pedestrian falls below the threshold of motion detection may deviate considerably from the manufacturer’s operationally defined beam edge.

The second observation is that, though the idea of an operationally defined beam edge creates the impression of a sharply defined beam perimeter (notwithstanding uncertainty due to variations in microwave reflectance), the actual characteristics of the beam at that point are that its intensity is decreasing rapidly toward zero. That is, the operationally defined beam edge falls at a point well down the “side” of the true beam shape.

The practical significance of these observations is that, at the point that one is just about to enter the plane of the door opening, one is moving away from, rather than toward, the motion sensor beam center. Rather than being near the beam center where the intensity is well above threshold so that motion in any direction has little effect on detection, the design places one at the “side” of the beam where the intensity is so far diminished that one actually passes below the detection threshold. Indeed, this is the operational definition of the beam edge. Moreover, one is moving in the least favorable direction. That is, away from, rather than toward, the part of the beam where the detection capability is strongest.

Again, this is a most unfortunate circumstance for it is precisely at this point, just prior to entering the plane of the door opening, that the ability to detect motion becomes most critical. Note that this corresponds exactly to the point at which Doppler shift variation minimizes the ability to detect horizontal motion. Hence, the Doppler shift problem and the beam shape problem are not unrelated, but conspire to enhanced the overall likelihood that a person may not be detected by the motion sensor just prior to stepping into the path of the closing door with the presence sensor disabled.

One sees that the nature of the design itself forces operation at the edge of the motion sensor beam. It cannot be otherwise because of the need to avoid endless cycling of the door. Likewise, one recognizes the unfavorable placement of the motion sensor on the door header, leading to minimum Doppler shift at the same critical point. These, and the need to shut down the presence sensor in order to close the door, are the hallmarks of a naively conceived design. The designers have failed to take into account the implications of their choices at the systems level. It is a situation in which each of the components of the system may work perfectly, but the door itself fails as an overall system. In fact, this is borne out in practice. A perfectly adjusted door can be readily demonstrated to strike a pedestrian, in spite of assertions by the manufacturer to the contrary.

Why “high tech” automatic doors?

The available evidence suggests that the industry-wide transition to doors employing “high tech” beam presence and motion sensors has been driven primarily by marketing considerations and very little, if at all, by any serious examination of their relative safety. Ironically, the beam sensor technology is also considerably more expensive than the mat technology that it replaces.

Complementing the criticism of the beam designs in the plaintiff's case should be attention to the merits of the older, "low tech" control mat solution. Besides being less expensive, the control mat exhibits one very significant virtue - it need not be disabled in order to close the door. Because it lies in, or on, the floor, the door is free to close over it without interference. This applies, of course, to sliding, swinging and revolving doors alike.

Attention should also be brought to the second great virtue of the control mat - it does not mandate special cooperative behavior on the part of the pedestrian in order to achieve successful door operation. That is, the pedestrian is *not* required to walk at or above a specific speed, in a preferred direction, in a suitable manner (that is, with sufficient "bounce" to trigger motion detection directly below the motion sensor), or to refrain from wearing clothing that may absorb infrared or microwaves too strongly or tend to shield (as a wide brimmed hat) the body. The control mat continually senses one, and only one, invariant parameter, the weight of the individual standing on it.

The Defense's Case

Prior to introduction of the additional criticisms relating to the motion sensor Doppler shift and beam shape, the defense usually took one of the two following positions:

The plaintiff was not struck by the door - The design of the door is foolproof. It is not possible for a person to be struck by a properly adjusted door. The plaintiff must have fallen for reasons unrelated to operation of the door.

The plaintiff was struck by the door, but - The door controls must have been maladjusted by someone other than the manufacturer, or an authorized service agent, after installation. An improperly adjusted door cannot be expected to perform correctly. Hence, the defendant is not responsible.

Of course, accidents do occur and it is no secret that a person can readily be struck by a properly adjusted door. The fact that an automatic door can be "faked out" has been admitted under oath by a prominent witness for one of the major door manufacturers. The elucidation of the Doppler shift and beam shape problems in recent cases has simply rounded out the physical explanation of a phenomenon that is known to occur. Yet, in addition to the two standard positions, the defense now argues vigorously against the Doppler shift and beam shape factors.

There are several tactics used by the defense in its attempt to discredit the Doppler shift and beam shape criticism:

a) The analysis of the Doppler shift and beam shape effects is purely theoretical and bears little relationship to actual events.

b) The plaintiff's expert's orientation is too theoretical. He/she hasn't had sufficient practical experience to appreciate the way things work in the real world.

c) The defense proffers any number of what appear to be counter examples intended to show the irrelevance of the claims of the plaintiff's expert.

What's wrong with the defense's arguments?

***Plaintiff was/was not struck* -** The defense's argument that the design of the door is foolproof is patently specious. It is known, and has been admitted by at least one defense expert, that it is possible to be struck by a properly installed and adjusted door. In fact, a video tape showing an expert being repeatedly struck by a sliding door, so recently adjusted that the technicians can be seen in the background, is available from the ATLA Automatic Door Litigation Group. Putting aside the issues of the Doppler shift and beam shape problems, any design that must shut down an important sensor to allow the door to close can hardly be expected to be "foolproof."

The claim of maladjustment is an interesting one. On the face of it, it would seem that any adjustment away from optimum would surely increase the likelihood of an accident. Yet, ironically, due to the nature of the design flaws, in particular the Doppler shift and beam shape problems, an improperly adjusted door may be *less likely*, rather than more likely, to produce an accident.

When properly adjusted, the motion sensor "delivers" the pedestrian as closely as possible to the presence sensor region in the plane of the door opening. Any maladjustment of the motion sensor that did not result in door cycling could only "deliver" the pedestrian farther from the "trap" set by the shut down of the presence sensor. That is, motion sensor maladjustment would cause the motion sensor detection signal to cease when the pedestrian is *farther* from the door opening than intended. Being further away when the door begins to close means that it is *less* likely that the pedestrian could get into the door closing path before becoming aware that the door was closing. Hence, the likelihood of an accident is decreased.

Maladjustment of the presence sensor is moot. The presence sensor is shut down at the critical moment so that it is immaterial how it has been adjusted.

***Criticism of Doppler shift and beam shape* -** The defense's criticisms of the Doppler shift and beam shape arguments all share the common attribute that they attempt erroneously to place very small effects on an equal footing with the dominant effects. This may be a deliberate obfuscation by the defense expert, or the expert may truly believe the effects are on the same footing. In either case, the effect may be to confuse the jury, at best, and, at worst, to discredit the testimony of the plaintiff's expert unless steps are taken beforehand to prepare the jury. This is a particularly difficult area because neither the Doppler shift nor the beam shape are tangible to the jury. Unless they come to the jury with a specialized background, jurors have little with which to judge who is right and who is wrong.

By way of preparing the jury, it should be emphasized that when a technical person describes complex phenomena, whether to a lay or technical audience, it is customary, and in fact essential, to confine the description to the interrelationship of the dominant factors. When describing a rainbow it is hardly appropriate to delve into a discussion of meteorology, atmospheric physics, stellar evolution, quantum mechanics, etc. Though elements of all of these, and many more, are present, we readily subsume them under the statement that a rainbow appears as a multicolored arc in the sky opposite to the sun when water droplets are appropriately dispersed in the atmosphere. Likewise with the description of the principal factors that determine the operation of the microwave motion sensor.

In the language of the physicist, the relevant behavior is determined by "first order" (that is, dominant) effects. The additional effects that the defense brings forth are what are called "second order," "third order," or simply "higher order" effects.

That is, they are present but they contribute so little compared to the dominant first order effects that they can safely be dropped from the discussion. The jury must be assured that the plaintiff's expert is aware of the higher order effects, but has made an entirely appropriate judgement in selecting only the dominant effects for discussion.

Along these lines, the plaintiff's attorney must be quick to spot and, through the plaintiff's expert, point out to the jury the omissions or oversights that must inevitably be present to make a higher order effect "appear" to rank as first order. Most often, the giveaway is that the defense's counter example represents a highly idealized situation that, on reflection, has little to do with the facts of the case.

Example **-** The following example from a recent case illustrates the kind of arguments that may be presented by the defense's expert in an attempt to discredit the Doppler shift and beam shape criticisms (see *What is the "triple design flaw?"* above). Though it is rather technical, it conveys a sense of the landscape that may be helpful.

The defense argued that a person moving purely horizontally directly beneath the motion sensor may nevertheless produce Doppler shift, leading to detection, because of contours and surfaces on the person's body that are tilted with respect to the direction of motion. Therefore, the plaintiff's argument that Doppler shift tends to zero directly beneath the motion sensor on the door header was allegedly invalidated.

This is an example of a higher order effect (less significant) being ranked along side a first order effect (most significant). It is certainly true that, for geometric reasons, such tilted surfaces would produce a Doppler shifted echo at the motion sensor. What was omitted by the defense is that a tilted surface reflects most of the energy incident upon it *away* from, that is out of, the beam. Only non-tilted surfaces are oriented so that they reflect energy directly back into the microwave sensor antenna. Consequently, the reflections from non-tilted surfaces dominate and they happen to be the ones that produce zero Doppler shift. Hence, the validity of ignoring the higher order effects due to tilted surfaces in favor of stating simply that Doppler shift tends to zero for persons moving horizontally directly beneath the motion sensor.

The defense expert went on to "illustrate" the validity of his claim for tilted surfaces by describing how he could produce a detection signal by placing a rotating fan directly in front of the sensor horn. Here the fan blades rotate so that they are always travelling at right angles to the microwave source. Yet, because they are tilted, they produced sufficient Doppler shift to be detected.

There are many reasons why this "illustration" is irrelevant. The principal one is that it is too idealized. The reflections from the fan come from surfaces that are essentially all tilted. As there is little, or no, competition from non-tilted surfaces, it is not surprising that one can detect the higher order Doppler shift. Moreover, the fan was placed directly in the center of the beam where it is strongest, not at the beam edge as in the door; the distance of the fan from the horn was unspecified; the fan blades were likely made of metal making them especially reflective; the rotation speed was unspecified and could easily have resulted in blade tip speeds greatly exceeding that of an elderly person walking; fan blades are tilted in pairs so that they form a crude "dish" antenna that may have an unrepresentative ability to reflect directly back into the microwave source; etc.

Finally, the defense's argument carries the implicit assumption of cooperative behavior on the part of the pedestrian to assure that the door operates properly. The pedestrian might just be wearing a flat, wide brimmed hat that, from the perspective of the microwave source on the door header, completely shields body contours, especially those closest to the source where they would reflect most strongly. In such a case, consideration of Doppler shift from tilted body contours is irrelevant, even theoretically. All that is "seen" by the motion sensor is an approximately horizontal flat surface gliding along essentially horizontally, producing little or no Doppler shift.

Toward Safer Doors

A pivotal question in all product liability cases is whether the manufacturer could have produced a substantially safer design using technology available and feasible at the time. The answer in the case of automatic sliding doors is a resounding yes.

How automatic sliding doors could be made safer

Use of older technology - The most obvious approach would have been to stay with the already existing well established control mat technology. A ground rule in the sensible exploration of new technologies should always be that the new solution must not impose a performance degradation with respect to the older solution it replaces. This widely accepted tenant was violated *ab initio* by the requirement, in the new design, to shut off the presence sensor in order to close the door. This consideration alone should have been sufficient to set off an alarm bell in the minds of those responsible for approving new designs, putting aside the additional considerations of the motion sensor Doppler shift and beam shape problems.

One of the responses often heard to this suggestion is that control mats wear out, as if the control mat were the only electromechanical component of the door subject to wear. There are at least two counters to this response. The first is preventative maintenance. First, the mean life expectancy of a mat is determined. Then, a program of preventative maintenance is instituted in which mats are automatically replaced on an appropriate periodic schedule. The cost of periodic mat replacement becomes simply an overhead cost of operating the door, as does maintenance of all the other components of the door. Preventative maintenance is a concept that is widely practiced and, because mats are much less expensive than the beam technologies, would be cost effective.

The second counter is to insist that manufacturers invest some of their design resources into perfection of longer-lived mats. Materials science has produced modified and novel materials with astonishing wear properties for applications ranging from automobile tires to artificial joints to materials subject to the rigors of deep space. It is unreasonable to assume that control mat technology could not benefit as well from these advances.

Better use of current technologies - An appreciation of the shortcomings inherent in the sonar, infrared and microwave beam technologies suggests a number of strategies to improve door safety without abandoning these technologies.

The first stems from recognition that there will always be regions within the field of a microwave motion sensor beam in which Doppler shift will tend to a minimum. When the sensor is mounted on the door header, that region falls directly below, immediately in front of the door opening. Clearly, two or more motion sensors could be placed at different locations chosen so that the Doppler shift from at least one would not be at a minimum. That is, sensors could be arranged so that a pedestrian at any location would always produce an unambiguous Doppler shift from at least one motion sensor. The overall motion detection signal would then be a composite of the signals generated by the individual sensors. A signal from any one, or any combination, of the sensors would trigger the door to open.

The idea of combining motion detection signals from individual sensors extends to sensors using other technologies. In particular, control mats could be combined with microwave motion sensors. In fact, the simple combination of control mats with the current use of a single motion sensor on the door header would yield a substantial improvement in safety. If either one of the technologies failed, the door would still be as safe and reliable as a door with only the other technology installed.

***Advanced technologies* -** There is, of course, no inherent upper limit on the proposals one could make if advanced technologies are considered. However, an approach that could be described as giving the motion sensor a "brain" could be implemented with currently existing technology.

In this approach, a sophisticated microprocessor (computer) would be added to the motion sensor to extract a great deal more information from the echoes it receives and thereby give it "intelligence."

For example, a position transducer could be attached to the door and its output made available to the microprocessor. With the instantaneous position of the door known to the microprocessor, the Doppler echo characteristic of the motion of the door could be "subtracted out" of the raw signal developed by the motion sensor. The microwave motion sensor could then be aimed so that the door was included within its beam without inducing endless cycling of the door. In this way, the presence sensor could be shut off but motion, other than of the door itself, within the door opening would nevertheless trigger the door to re-open at any time, thereby eliminating the current hazard.

With yet more sophisticated programming of the microprocessor, including advanced signal analysis and target tracking techniques, the computer might actually determine and track the number, position and state of motion of all targets within the microwave beam. It could, for example, differentiate targets that are moving away from the door from those that are moving toward it. It could also keep track of targets that momentarily come to rest (stop) within the beam, remembering their positions and resuming their tracks when they begin again to move. While the required program would have to be rather sophisticated, the task is not beyond current capabilities and is, in fact, an approach often used in high performance military applications. The result could be a door sensor system with an "intelligence" approaching that of a human doorman / woman.