ASTM IN THE REAL WORLD

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**Abstract**

Although well-thought-out, the written ASTM test standards are daunting and complicated. Applying them in the real world is actually quite simple, however. Through his ten years of experience in fielding questions and providing consultation to test engineers around the world, Todd Mikkelson has identified the most common misunderstandings within the standards, often costing one firm or another thousands of dollars. He will present clarification to all who wish for better adherence to water and air infiltration test standards. The better these standards are universally met, the healthier our testing and architectural industries will be.

**Speaker**

**Todd Mikkelson — The RM Group, LLC**

TODD MIKELSON is owner/president of The RM Group, specializing in test equipment. Over the last ten years, Mikkelson has had the unique experience of speaking with test engineers as they try to interpret ASTM standards for application in the real world. He developed his knowledge of the standards in order to make sure the industry-standard equipment he’s developed performs within the standards’ strict guidelines. His consultation is valued by professionals all over the world.
As the owner of a company focused solely on manufacturing and selling equipment to perform water and air infiltration field tests, I’ve had the unique experience over the last ten years to speak with people from all over the world who are performing ASTM standardized water and air infiltration tests. Clients rely on me to help them use our equipment properly. To do so, I focused on learning as much as possible about the standards and test methods surrounding field air and water infiltration testing.

When it comes to ASTM standards, it is often apparent that many people are taught how to perform the standardized tests in accordance with ASTM International, but do not understand the procedures. Common elements of testing that are not understood include the following:

- Why is this standard the standard?
- Why do you run the spray rack at that pressure?
- Why is the calibration test done that way using that other strange piece of equipment?

These individuals are challenged in the field by someone who knows far less about the standards than they do, yet they still find themselves stumped on how to answer an uninformed challenge. Some of the most common challenges made in the field are as follows.

- “You’re spraying too much water at that window!”
- “You’re not spraying enough water at that window!”
- “What do you mean that window passes? There’s water sitting on the inside ledge!”
- “What do you mean the window’s not at fault for the water damage? It leaked when you ran this test!”
- “Your equipment is not calibrated! It doesn’t work correctly!”

The objective of this paper is to inform the reader of common misinterpretations of ASTM standardized water penetration tests performed out in the field and how to deal with some of the most common challenges made to these test procedures.

**CALIBRATION**

One common challenge is the question of whether or not the equipment being used has been calibrated.

First of all, the standards do not state that the equipment has to be calibrated every six months. It says that the calibration test must be performed every six months. This is to ensure that the equipment is performing in a way that adheres to the test standard.

In the ASTM E1105 test standard, it specifically describes how the calibration test for the water spray rack must be performed. It is described very basically and with illustrations in two of the three paragraphs in section 9, “Calibration” (Figure 1).

A calibration challenge is a very reasonable one to make. In fact, it’s important that this challenge be made in case the test engineers have not run the calibration test on their spray rack. So as a witness or consultant present to make sure the test is run properly by the engineers, one should present this challenge. Keep in mind that it is not confrontational to do so; it is procedural. Present this challenge with a procedural tone rather than a confrontational or skeptical tone. If the engineer cannot provide evidence that he or she has performed the calibration test, that is enough to nullify any test results and should be noted.

As a test engineer, one should expect this challenge and be prepared to provide evidence that he or she has, in fact, performed the calibration test within the past six months in order to properly adhere to the ASTM E1105 standard. A simple calibration sheet with the final gallons-
per-square-foot-per-hour (gal/sq. ft./h) result, the pressure at which the rack was run during the calibration test, and the date on which the calibration test was performed will usually suffice. Our company provides an even more detailed calibration sheet with its spray racks that describes the distance the nozzles were from the test specimen and from each other in order to create an even spray across the test surface. This information proves the spray rack is providing the water volume evenly across the test specimen as stipulated in the calibration section of the standard.

Have a tape measure handy to show that the nozzles were placed in a manner that matches the way they were placed when the calibration test was run (Figure 2). Then run the rack at the same pressure that was used during the calibration test. This ensures the proper spray was provided to adhere to the standard. Here we see the spray bar of the spray rack is 20 inches from the calibration test box. When in the field, the test specimen would be in place of the test box. Measure 20 inches when running the spray test to match the spray rack’s setup during the calibration test and to demonstrate to any witnesses that this is so.

Sometimes someone will challenge the equipment by saying that the spray rack is spraying either too much or too little water. Again, the calibration sheet will provide proof that the proper amount of water is being sprayed evenly over the test surface.

Another objection testers hear is that spraying more than 5 gal/sq. ft./h is too much spray. I’m not sure where this misinterpretation originated, but I’ve heard it many times. Therefore, also be familiar with Section 9 of E1105, “Calibration,” and be prepared to refer to it when questioned.

Section 9 has a diagram of the calibration test water catch box to be used (Figure 3). You can see that there are four square-foot catch basins in the box. This is how the gal/sq. ft./h are measured.

Section 9, paragraph 9.1, reads:

A spray that provides at least 20-gal/h total for the four (square foot) areas...and not more than 10 gal/h in any one square (foot) shall be acceptable.

Of course, 20 divided by four is five. So no less than five gal/sq. ft./h, and no more than 10 gal/sq. ft./h are, in fact, what is implied in the E1105.

Having a copy of the test standard to prove what you have said is true again puts the blame for this person’s unhappiness about your performance onto the test standard itself. You’re merely sticking to the rules.

One problem I’ve experienced myself only once (and one of our clients called me with the same issue once) has to do with the design of the calibration box. It has the potential of delivering a false fail.

Many people have the opinion that the calibration box is sort of a joke. I didn’t understand it when I first saw the drawings, nor did I when I saw one in person. After building my own and running the calibration test a few times, I came to appreciate its...
design and purpose. It led me to appreciate many more elements of ASTM standards that are often criticized out in the field.

Although I appreciate the calibration box’s design, after running hundreds of calibration tests and encountering the problem we’ll cover next, I have a suggestion that I think may improve its accuracy and consistency. However, this problem occurs so seldom that it is not an immediately pressing issue.

Since our spray racks are all exactly the same, the result of the calibration test is very similar for each. But one time the result was not only very different, but this rack didn’t even pass the test. One of the square-foot catch basins produced a very high volume of water, and the catch basin just below had a very low water volume.

I decided to lower the spray rack about an inch. I ran the test again, and the result was the more usual close numbers between each catch basin with a passing final number result.

My analysis showed that the angle of the catch basins (30% grade) closely matches the angle of the spray from each nozzle on the spray rack. So if one of the nozzles’ spray enters right at the bottom line of one of the top basins without hitting the basin below at all, that top basin gathers an inordinate amount of water, and the one beneath it is starved of water spray (Figure 4). This does not properly depict the amount of water that would be hitting the surface of a test specimen. Moving the rack down even just one inch creates a result where these two basins collect nearly similar amounts of water.

This is the only potential false result with the calibration test box that I have discovered. Perhaps a remedy would be to lessen the degree of the catch basins’ angle and/or make the test box less deep. Otherwise, I stand behind its design.

SELECTING THE TEST PROCEDURE

We’ve been talking about the ASTM E1105 standard here because it is the most commonly used water infiltration standard on windows, doors, and sometimes curtain walls. There are two other water infiltration tests that may also be used. The E547 and E331 are performed very similarly to the E1105, but the choice you make among the three can simplify your final report on the test.

When writing your reports, you want to proclaim that you are running a modified E1105, or whatever test standard you are using. For instance, it is impossible to stick 100% to the E1105 because within the standard, one must choose either Method A or Method B. Method A is to be performed with uniform static air pressure, and B with cyclic static air pressure. So if using Method A, one keeps the negative air pressure difference on the inside of the test specimen (window) running the entire test. When using the B method, one runs the negative air pressure difference for five minutes, then shuts off the negative air pull for no less than one minute, then repeats this cycle a
number of times throughout the duration of the test. Writing a report on the E1105 would entail, at the very least, stating which of those two methods is used. Choosing either the E547 or the E331 in some situations can save the tester from having to point that out. The E547 is conducted only in the cyclic static air method, and the E331 only in the uniform static air method.

I would choose the E331 when testing a curtain wall, because there will likely be a very large air chamber in which it would be difficult to turn the air pressure off and then immediately back on to run at the precise level needed, simply because it takes a long time to exhaust enough air out of a large chamber before that specific pressure level is achieved.

Also, the diagrams in the E547 and E331 include a skylight system (Figure 5), whereas the E1105 does not. So for this reason, I would not use the E1105 when testing a skylight system. Either the E547 or the E331 would be better, depending on whether one wants to run the uniform or cyclic air pressure difference, and the size of the skylight may play into that choice.

Another major factor in choosing cyclic or uniform air pressure difference is whether or not the window being tested has moving parts. Most residential windows have moving parts that open and close. These windows are most accurately tested using the cyclic version.

Pulling an air pressure difference on the inside of such a window actually causes its seals to tighten up and helps to keep the water out. In a real-world wind-driven storm, the wind will blow against the window, and then stop blowing, and then blow again. When the wind lets off, the window relaxes and is potentially more prone to allow water infiltration. The cyclic static air pressure difference better simulates such a situation.

The E1105, Method B is usually used for residential windows (Figure 6), because by not including the skylight system, it is more concise than the E547 cyclic test.

**SELECTION AND EXAMINATION OF THE TEST SPECIMEN**

The E1105 is also referred to in ASTM E2112 and E2128, which also include installation procedures and many more forensic details that go beyond just the windows and doors. These installation procedures are important aspects in pointing out potential problems with water infiltration that go beyond what the E1105 covers.

Later, in Case Study #1, we'll observe that the test engineer uses portions of the E2112 before he even decides whether or not to begin the E1105 procedure on a window. In that case, he could find no window within the tolerance of square described in the E2112. If there were a window within the toler-
ance but still out of square, this would be an important observation to make because the gap between the operable sash and any part of the frame—jamb, head, or sill—of a residential-type window can be the cause for water penetration. This gap is compromised because the sash remains square while the frame is out of square. The result is that the gap is too thin at one end and too wide at the other. The widened portion often allows water infiltration, even when testing the window itself. This is true for casement, double-hung, or fanlight windows. But this potential failure is not the fault of the window because the window was compromised by improper installation.

In the window in Figure 7, there is a compromised gap on a double-hung window that was installed incorrectly. It is both out of square and slightly bowed. The bowing is likely caused by improper shimming. There’s a high potential for water infiltration on the left side because the gap is too wide. This is ultimately not the fault of the window itself, but of the improper installation.

The shims in Figure 8 allow the window frame to shift separately from the frame in the wall. In a proper installation, there is space between the window frame and the frame in the wall so that natural settling of the building does not put strain on the window frame, causing it to fall out of square (Figure 9).

This problem can also be discovered when one follows Section 8 of the E1105, “Examination of Test Specimens.” Although not as detailed as the E2112, paragraph 8.2 reads as follows:

Conduct a detailed visual examination of the test specimen and the construction adjacent to the test specimen. Record all pertinent observations.

Figure 7 – Here is a compromised gap on a double-hung window that was installed incorrectly. It is both out of square and slightly bowed. The bowing is likely caused by improper shimming. There’s a high potential for water infiltration on the left side because the gap is too wide. This is ultimately not the fault of the window itself, but of the improper installation.

Figure 8 – The shims allow the window frame to shift separately from the frame in the wall.

Figure 9 – In a proper installation, there is space between the window frame and the frame in the wall so that natural settling of the building does not put strain on the window frame, causing it to fall out of square.
Figure 10 – Here we see water on the sash and the bottom sash handle. No water dripped onto the wall frame, so this window is still a pass.

Paragraph 8.3 reads:

If the intent is to test an operable window, skylight, or door, the unit should be checked for proper installation by opening, closing, and locking the unit five times prior to testing, with no further attention other than the initial adjustment.

This examination will also reveal an out-of-square window frame because the sash may show resistance in moving up and down in a double-hung window, or opening and closing in a casement window.

If you’re the test engineer, you must conduct this part of the test; and if you’re an observer, you must note whether or not the test engineer performed these tasks. If he or she did not, the test can be judged as invalid, especially if the window fails. If a thorough examination of the test specimen is not performed, then it cannot be determined whether the failure is due to improper installation of the window or to the window itself.

Since an out-of-square condition can be caused by not properly shimming the window upon installation, Section 8 of the E1105 must be followed, although is often overlooked. ASTM E2112 describes proper shimming, as do the installation instructions for most windows. That is why referring to the section of E2112 that we will see in case study #1 is also a good idea when sampling and selecting the window on which to run the E1105.

The test specimen sampling is different for the other two spray test standards – E331 and E547. For instance, neither describes an operable window. They both describe curtain wall stipulations and full assemblies of multiple units put together as designed for installation. So using either E331 or E547 is not recommended when testing operable residential-type windows. Each of these standards is more appropriate for testing curtain walls and large assemblies that are usually designed for commercial applications. ASTM E1105 should be utilized for operable window assemblies, as it directly addresses operable assemblies.

AIR INFILTRATION TESTING

An air infiltration test has fewer variables and is, therefore, easier to adhere to than a water spray test. For this reason, there are fewer challenges in the field. Having a calibration test result sheet for the vacuum test kit on hand is still essential. But the standard is simpler and pretty cut and dried.

There is also only one ASTM air infiltration standard designed for use in the field. It is ASTM E783. You may also hear of ASTM E283, which is to be used specifically in the laboratory. It is more stringent than E783 and should not be used in the field.

UNDERSTANDING WATER PENETRATION

It is certainly important to understand the terminology and full criteria for pass/fail, yet one of the most misunderstood parts of the ASTM E1105 test standard is the description of the allowance of water inside the window before it is considered to fail the test. It is important to keep in mind the title of the E1105, Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference. There will be no fail unless there is penetration at the very least.

The description of penetration is in Section 3 of the standard, entitled “Terminology.” It reads:

3.2.3 water penetration, n—penetration of water beyond a plane parallel to the glazing (the vertical plane) intersecting the innermost projection of the test specimen, not including interior trim and hardware, under the specified conditions of air pressure difference across the specimen.

And further, paragraph 10.2 reads:

Water contained within drained flashing, gutters, and sills is not considered failure.

This means that the window can leak water and still pass (Figure 10). Understandably, this does not make sense to a lot of people. The entire top of the bottom window sash can be pooled in water, and yet the window will still pass the test. Of course, this result can bring about some contentious objections out in the field.

Here is how I explain this result in the real world:

If the water that has leaked to the inside of the window does not breach the innermost plane of the window itself, the water cannot damage the building because the window is still protecting it from any of the water infiltration.
Then I point out where this description is by saying, “ASTM E1105, section 3, paragraph 2, point 3 explains this.” Of course, I’ll have a copy of the standard handy to prove that I’m correct. Then perhaps I’ll clarify further that if the water does not break that innermost vertical plane, it is not considered to be water penetration, and therefore the window still passes the test. We’ll see in Case Study #2 how costly it can be to not thoroughly know this terminology.

The test process begins before the test is actually performed. Whether the test specimen is a window, skylight, or curtain wall will help determine which water penetration test standard would be the best to use, as covered previously. But another potentially serious issue can come up before the test begins, and if it’s not covered before the date of the test, it can be costly to numerous parties, especially if the test is part of a litigation case. The case study below illustrates this point.

**CASE STUDY #1**

In this real-life case, there was a residential structure with water damage around most of its windows. ASTM E1105 was to be performed, and the representative for the homeowner was considered the “specifying authority” and hired the test engineer. It would be a forensic test to determine if the water penetration was due to the windows themselves or an element of the installation of the windows, a common use of this test.

Section 10 of ASTM E1105 states that it’s the job of the specifying authority to sample and select the test specimens. The test engineer reminded the representative that he would need to choose two windows that were not exceedingly out of plumb and square. The engineer was using ASTM E2112, section 5, paragraph 5.15.4 for this stipulation. It reads as follows:

5.15.4 ...Products shall not be racked more than \( \frac{3}{8} \) in. (3.175 mm) out of square for dimensions up to 4 ft. (1.3 m) or more than \( \frac{3}{8} \) in. (4.763 mm) for dimensions greater than 4 ft. (1.3 m).

Note 5 within section 10 of ASTM E1105 reads as follows:

Although the specifying authority is responsible for establishing test specimen sampling, selection, and identification procedures, such procedures or modifications to said unit should be mutually agreed upon by all parties involved prior to testing.

The test engineer had made it clear that he would only test windows that were within the parameters of the E2112 section mentioned earlier here. The specifying authority agreed.

When the test engineer arrived at the test site where many witnesses were gathered in anticipation of a day of water-spray testing, he got out his level. Checking the two windows that the specifying authority had chosen, he found they were both more than 1/8 inch out of square. In fact, he could not find a window on the entire house within tolerable parameters.

As a result, there would be no testing done that day. Since the specifying authority was also the council representing the homeowner, he was ultimately responsible for that very expensive yet inconclusive day.

So why did this test engineer insist on not testing a window that was not within the E2112 tolerance for being square? Because any window that’s not square was installed incorrectly. This can be proven both with further parameters within the E2112 and within most window manufacturers’ installation instructions.

The window itself cannot be held at fault for any water penetration if it has not been properly installed. The E1105 standard will likely show water penetration, but it is already known that the problem is not the window itself. So what’s the use in spraying the water? It would only produce further destruction of the home.

Of course, this result did not make the homeowner very happy. We’ll speak further later about dealing with people who are made unhappy by results of spray tests. But here it’s important to pay attention to the overall purpose of the test.

This was to be a forensic test on window openings that were already known to have water penetration problems. If the problem is made apparent before the test is actually performed, the forensics are basically already complete. In this case, the reason for running the test was accomplished by the test engineer. But the same finding could have been revealed by the homeowner’s representative, who should have measured the square of each window before the test engineer and witnesses were scheduled to be there. A lot of wasted time and money could have been avoided.

It was the homeowner representative’s job to explain the debacle to the homeowner. But it was the test engineer’s job to explain the bad news to the homeowner’s representative. Although this engineer was very well-versed on many test standards, it would have taken quite a while for him to find the pertinent passage of E2112 had he not been prepared for this common occurrence.

That’s why it’s important to identify and memorize key passages in the standards that address common challenges. Being able to quickly and accurately refer to a specific paragraph of the standard is seen as proof of one’s thorough knowledge of the standard and assures others that one can be trusted to perform the test correctly and accurately. This also holds true if one is there to observe the engineer who is performing the test. One’s knowledge of the standards will allow others to trust that one can properly judge whether or not the engineer is performing the test correctly.

**CASE STUDY #2**

One example of the costly repercussions of misunderstanding the water penetration terminology of the standards is illustrated by the following case study.

One of our nation’s most beautiful and ornate state capitol buildings was undergoing a long-overdue renovation a few years ago. The building was over 100 years old, so installing new windows was a difficult task. There were 12 new custom-built window units that were about 12 feet tall by 6 feet wide installed around the top of the rotunda.

Testing these windows was a very difficult task, and the engineering firm that was tackling it was doing a great job. They had to create their own water supply up on the roof of the building and run two spray racks—one on top of another simultaneously—requiring a huge volume of water. They also had to pull negative air pressure on the inside of the giant window by building a very tight and efficient air chamber so that the vacuum test kit could pull the correct pressure differential by itself while sitting on a rotating scaffold system that could spin around the entire rotunda in order to test more than one of the windows. It was an impressive and expensive set up (Figure 11).

In order to adhere to the standard, they
had to get at least two of the 12 windows to pass the water infiltration test. By the time they called me, they had tested ten, none of which had passed...or so they thought.

They asked me to come and take a look at the situation to see if I could offer any help. They’d been testing for weeks and only had two more windows left, both of which had to pass the test. I noticed that each window had a very large interior sill pan. The pans were about five inches wide and two inches tall, running along the entire bottom of each window. When I noticed that, I asked if those sill pans were filling up enough to overflow (Figure 12). The answer was no. Water had collected into the pan of each window so far, which made them believe each window failed the test, but the pans never completely filled and ran over. I then asked if water was intruding anywhere else along the perimeter of the windows. Again, the answer was no.

I then ex-plained that every one of the ten windows they’d tested had, in fact, passed the test, because the innermost vertical plane of the window was never breached by water; therefore, there was no water penetration into the building itself, according to section 3, paragraph 3.2.3. The water intrusion would do no damage to the capitol building. The windows were doing their designed job of protecting the building from water penetration.

They didn’t know whether to feel overjoyed or depressed. They could have saved a lot of time and money had they understood that part of the E1105 standard. But at least they could report that the windows were built and installed quite well and passed the water infiltration test, saving many thousands of dollars down the road in remediation costs.

Now these were all very experienced and knowledgeable engineers, yet they’d not come across a situation where a fair amount of water leaked into a window, and they’d previously overlooked this part of the E1105 standard. Many skip over it because it’s in the introduction portion of the standard, and most assume they know the “terminology” being used. But here is where you’ll find a very specific definition of water penetration that seems counterintuitive yet is vital information.

The fact that these very experienced engineers were unaware of the language in the standard leads me to another point. When I discovered that the windows were in fact passing and that they were mistaken in thinking otherwise, how could I convince them of that without embarrassing or possibly even offending them?

What if you were the test engineer or the window manufacturer in this story, and the custodians of the state capitol building see all that water coming in during the test and collecting in the sill pan? To them, it looks like the windows are failing. Or what if you are testing windows in someone’s home and the homeowner sees water collecting on the top of the bottom window sash? They’re going to think they need new windows. How do you explain to them that the window still passes because the water never ran over and started dripping on the carpet?

These can be very sensitive situations. Handling situations like these begins during the first conversation that you have with your client.

In my story from the capitol building, when my clients called me asking if I might know of anything that could help them, I told them on the phone that I could not advise them until I saw the whole setup for myself in person. I didn’t speculate about any of the potential issues I thought might be occurring. Making speculations prematurely may result in false hope for the client, so I don’t reveal what I think the problem is until I’m quite sure it is, in fact, the problem.

If I were an engineer being hired to conduct a water spray test on a commercial building or someone’s house, I would make it very clear during the first conversation that I stick to the ASTM standards no matter what. I make no adjustments or judgments in favor of anyone’s best interest. Therefore, my client may not be happy with the results of the test. I make sure they know that my knowledge and experience in conducting the forensic standardized test is what should be of the highest value to them, no matter the outcome of the test.

In effect, I’m setting up a scenario where the ASTM standard itself is to blame if they
don’t like the results of the test. I always have the standard there with me. If they question my methods or procedures, I can show them that I’m adhering to the standard. As long as I adhere to the standard, it’s not my fault if they don’t like the results. “I don’t write the rules, ma’am, I just follow them.”

Now there may still be some people who won’t accept your results. That’s why it’s best to make sure all parties involved understand from the very beginning that you will not be influenced by anything other than what’s in the ASTM standard.

WHY THE STANDARD IS THE STANDARD

Knowing a very rudimentary history of the ASTM standards comes in handy when explaining why you are following an ASTM standard when testing a window or door. I have a way of explaining it very concisely that only takes about a minute, and it helps them understand why it’s necessary to have congruent test standards for this and many other types of tests, whether they be for quality assurance or forensic investigations.

I’ve found success using a quick ASTM history lesson as follows: It began with railroads. There were numerous suppliers of rails and spikes to build railroads across our country, but the rails and spikes all had to be uniform in size and quality of the steel. In order to effectively build a large infrastructure like the railway system, specific standards had to be established for all the materials. This methodology quickly spread to other industrial sectors, with ASTM standards now helping to ensure quality and safety in almost everything we use in daily life.

The ASTM standards for water and air infiltration are tried-and-tested methods for finding the exact source of water or air penetration problems. To not follow them would be to remain ignorant of the actual source of the problem, leading to potentially costly or even dangerous problems in the future.

CONCLUSION

We have covered the most common difficulties in adhering to the standards, ways to prove one is properly adhering to the standards, and tips for communicating with a client, customer, or other interested parties.

As a test engineer, being able to quickly refer to the exact paragraph that addresses these issues within each standard is the best way to be prepared for questions or challenges made to the procedures. There will be no need to feel defensive because if one sticks to the rules, one can blame the ASTM standard for any element of the test that might make someone unhappy.

If you are an observer who has a question or a challenge, knowing these pertinent paragraphs is helpful, as well. Because you’re only asking or challenging within the parameters of the test standard, you’re not being confrontational or unreasonable. Assuming you’re not behaving unreasonably, you can simply counter any negative reaction you may get by blaming the ASTM standard.

And remember that the purpose of the ASTM standards is to protect any party from injury—physical, financial, or otherwise. In the cases covered here, the standards are the best way to prevent water damage to a building if tests are performed during installation, such as at the state capitol building, or to forensically reveal the source of water damage so responsible parties can be determined. Without a standardized way of analyzing these and other issues, those protections are absent.