RELATIVE IMPACT RESISTANCE OF ASPHALT SHINGLES

Summary of UL 2218 Impact Tests

AUGUST 2014

Overview

Part of IBHS' multi-faceted hail research program includes relative performance comparisons of impact resistance of roofing products using standardized impact tests. The focus of testing for 2013-2014 is on asphalt shingles where Underwriters Laboratory Test Standard 2218 (UL 2218) is recognized as the current test standard. Although these standardized tests do not exactly replicate natural hailstone impacts, they provide a way to compare relative product performances in controlled and repeatable laboratory tests. This paper describes results from UL 2218 impact tests on 22 different asphalt shingle products produced by five different manufacturers.

The UL 2218 impact test standard is a steel ball drop test to evaluate the impact resistance of prepared roof coverings. The Class 1 projectile is 1.25 in. in diameter, Class 2 is 1.50 in., Class 3 is 1.75 in., and Class 4 is 2.00 in. in diameter. These steel balls are dropped from the height necessary to achieve the same kinetic energy a hailstone of the same size would have in a thunderstorm (UL 2012). IBHS designed and built a custom testing device that meets the specifications of UL 2218 and makes testing efficient for use by a single operator. The device uses compressed air to lift the steel balls to the dropping height, where their position is held in place until triggered for the drop. The device is described further in the Appendix.

The results summarized in this paper provide an assessment of the relative performance of different roof shingle products when subjected to this standardized test and evaluated using the performance criteria adopted in the test standard. Performance criteria used in this assessment do not necessarily reflect the performance criteria used by insurance companies in determining whether to repair or replace an asphalt shingle roof cover following a hail event. Any evidence of opening—tearing, fracturing, cracking, or rupturing—on the back of the shingle is recorded as a test failure. The absence of an opening visible on the back of the shingle denotes a test pass. . Crushed or dislodged granules, dents, or openings visible only on the top of the shingle, are not considered failures in UL 2218 performance criteria.

It should be noted that the products tested by IBHS were obtained from local vendors and thus reflect the condition of products after they have been subjected to the supply chain which may involve multiple pallet stacking and exposure to a variety of storage conditions. All products tested were purchased in 2013. The shingle weights, thicknesses, bundle weights, and all identifying packaging information have been recorded in a shingle library database.

Test Methodology and Materials

Test panels (3 ft. x 3 ft.) were constructed with shingles installed according to the manufacturer's guidelines for the specific product. The panels were constructed, conditioned, stored, and tested according to UL 2218 requirements. Each product was impacted with two strikes of the appropriate size steel ball at a number of locations representing different features of the product assembly. Resultant impact marks were observed under a microscope.

Basic 3-tab and architectural shingles from each manufacturer were tested, along with basic Class 4 rated impact resistant (IR) 3-tab (if available) and architectural shingles. Manufacturers typically use a mesh or scrim on the back surface of an IR shingle to increase the impact resistance, as shown in Figure 1, while others use polymer modifiers in the asphalt, which has no visible difference when compared to a traditional shingle. Both types were tested and compared. Premium architectural products from three manufacturers also were tested, to evaluate the performance of thicker, heavier products. Table 1 describes the shingle selections.

Figure 1: Example of mesh on the back of an IR 3-tab shingle.

	Shingle Types Tested				
Manufacturer	Basic 3-tab	3-tab IR	Basic architectural	Architectural IR	Premium architectural
A	1	0	1	1	0
B	1	1	1	1	3
C	1	0	1	1	1
D	1	0	1	1	1
E	1	1	1	1	0
Total Count	5	2	5	5	5

Table 1: : Shingles selected for UL 2218 testing.

Performance Observations

Common Impact Marks

Crushed granules—the severity of which ranged from barely discernable to pulverized—were observed on every panel tested, as seen circled in red in Figure 2. These generally were visible both to the naked eye and under magnification. Although this kind of mark was observed on every panel tested, this damage mode is not seen in the field. Hailstones often will dislodge granules but are not hard enough to crush them. Additional marks included varying severities of dents and flattening of the shingle material, also shown in Figure 1 (rounded shingle edge traced in yellow). Flattening was evident particularly at joints, corners, and edges. The most severe dents occurred for impacts along the 2 x 4 brace in the center of the panel, where the deck was stiffened and there was not much flexibility to respond to the impact. This area simulates where roof trusses or rafters would be located.

Common UL 2218 Performance Criteria Failures

Although not always visible to the naked eye like crushed granules, when inspected using a microscope, typical damage that met the failure criteria of UL 2218 included tears at shingle edges or corners, on the back of shingles as shown in Figure 3a, as well as cracks in the center of shingles and at joints, visible on the back, as shown in Figure 3b. 3-tab shingles were impacted at six locations including the edge, joint, corner, eave edge, and two center locations (one in an area between 2x4 framing members supporting the roof sheathing and one on top of a 2x4 framing member) with double impacts. Architectural shingles were impacted at similar locations on both the single- and doubly-ply portions of the shingle, for a total of 12 impact locations with double impacts. To be considered an impact failure, a crack or tear must have been visible on the back surface of the shingle. The number of passing double impact locations, along with the number of failing double impact locations and photographs of the top and bottom of each location were recorded for each tested shingle panel.

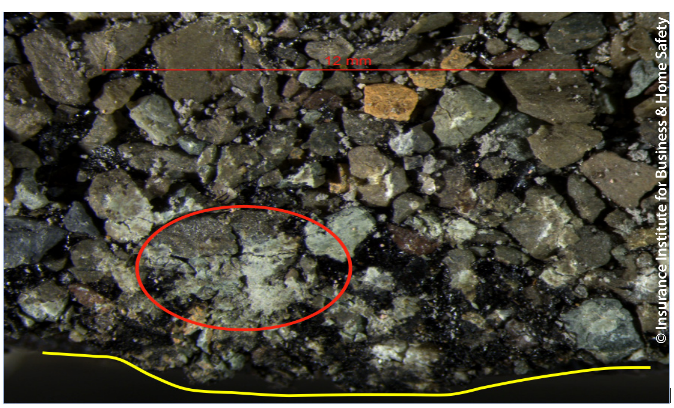

Figure 2: Common marks observed during UL 2218 tests included crushed granules (red circle) and flattening of the shingle edge (yellow trace). Image is magnified at 7.5x.

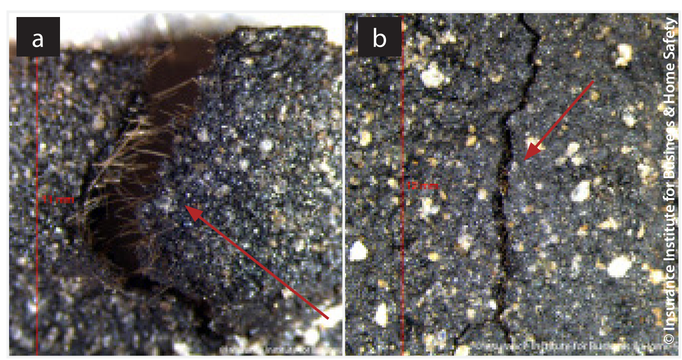

Figure 3a: Example of a tear visible at the edge of a shingle from the underside.

Figure 3b: Crack visible in the underside of a shingle. Both images magnified at 7.5x.

Performance Comparisons

To present relative performance comparisons, percentages of double impacts that resulted in test pass ratings were compiled for the various shingles tested. These results are shown in Figures 4 through 8. It should be noted that a failure at any one impact location on a specimen is defined as a test failure according to UL 2218, but the data presented here are the percentage of passing impact locations which allows for relative performance comparisons. The following summarizes the comparisons among the classes of asphalt shingle products. Products in the IR groups have Class 4 impact ratings, and thus should withstand testing without cracking or tearing on the shingle back for all four projectile sizes. However, none of the products tested—basic or impact rated—passed more than Class 2 impacts without at least one double impact location failing the UL 2218 performance criteria.

1. *Basic 3-Tab Shingles* versus *Basic Architectural Shingles:*

(FIGURE 4)

a. Class 1 UL 2218 impacts resulted in passing ratings for about 45 percent of the impact locations for 3-tab and about 55 percent of the impact locations for architectural shingles.

b. Class 2 UL 2218 impacts resulted in passing ratings for about 25 percent of impact locations for the 3-tab and about 40 percent of the impact locations for the architectural shingles.

c. Class 3 UL 2218 impacts resulted in passing ratings for about 25 percent of impact locations for the 3-tab and about 35 percent of the impact locations for the architectural shingles.

d. Class 4 UL 2218 impacts resulted in passing ratings for about 25 percent of impact locations for the 3-tab and about 30 percent of the impact locations for the architectural shingles.

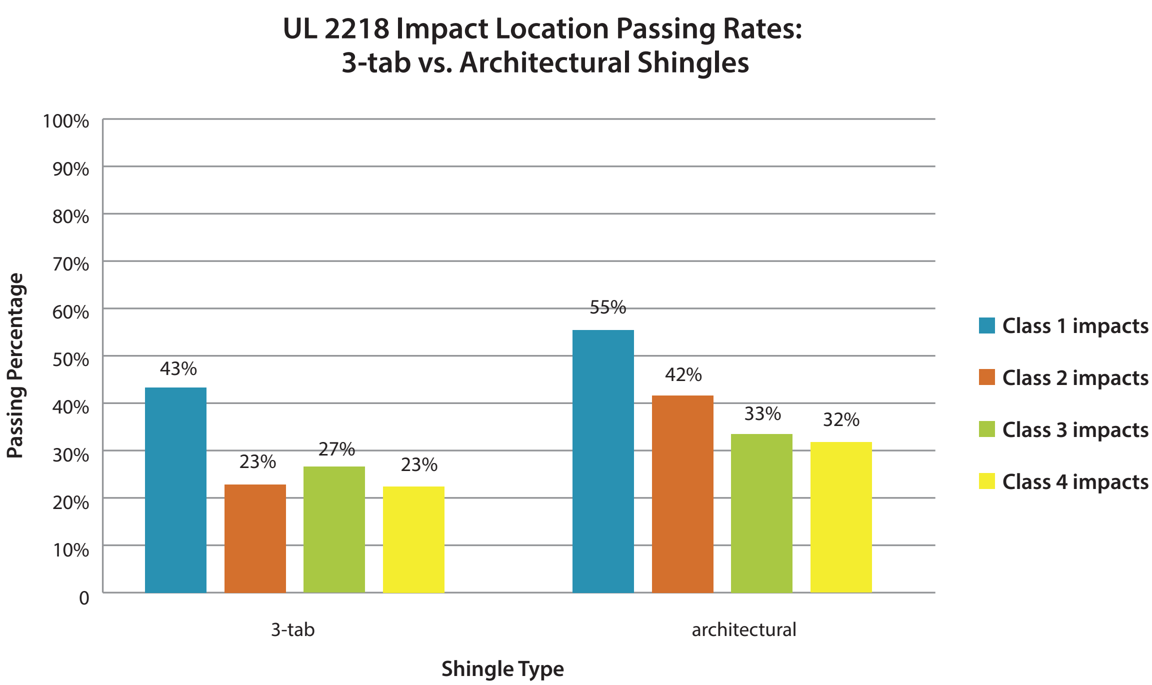

Figure 4. Comparison of basic 3-tab and basic architectural shingle performance to Class 1-4 impacts.

Performance Comparisons

2. Basic 3-Tab Shingles versus *IR 3-tab Shingles:*

(FIGURE 5)

a. Class 1 UL 2218 impacts resulted in passing ratings for about 65 percent of the impact locations on the IR 3-tab shingles versus about 45 percent for the basic 3-tab shingles.

b. Class 2 UL 2218 impacts resulted in passing ratings for about 75 percent of the impact locations on the IR 3-tab shingles versus about 25 percent for the basic 3-tab shingles.

c. Class 3 UL 2218 impacts resulted in passing ratings for about 60 percent of the impact locations on the IR 3-tab shingles versus about 25 percent for the basic 3-tab shingles.

d. Class 4 UL 2218 impacts resulted in passing ratings for about 60 percent of the impact locations on the IR 3-tab shingles versus about 25 percent for the basic 3-tab shingles.

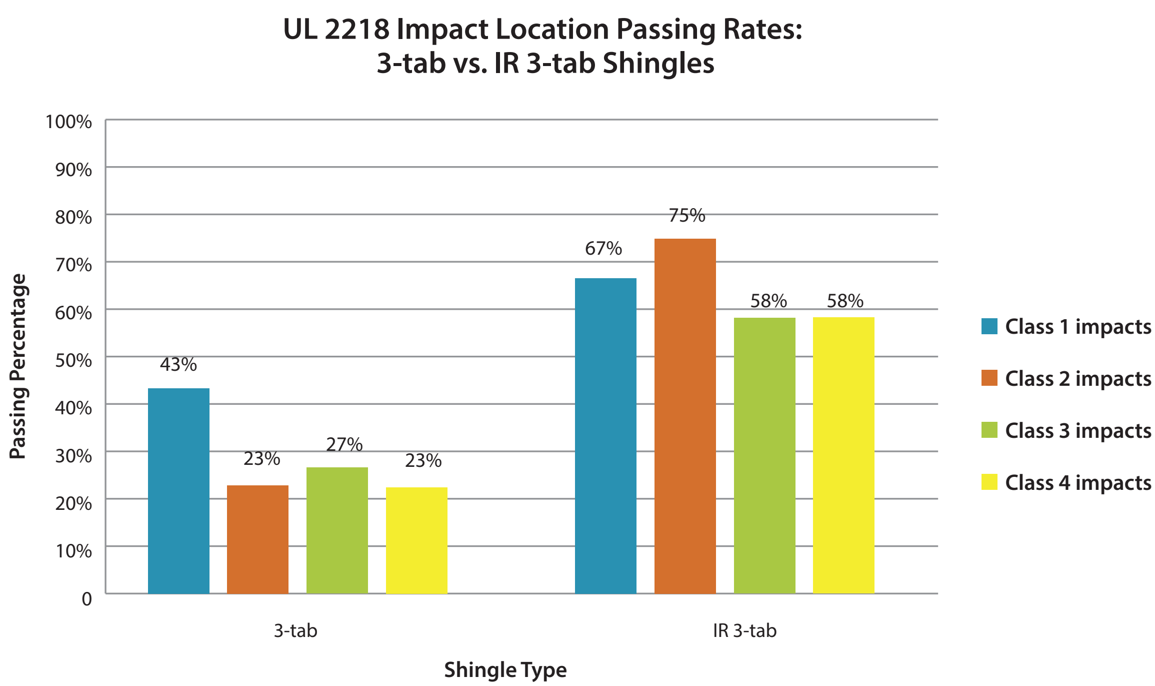

Figure 5. Comparison of basic and IR 3-tab shingle performance to Class 1-4 impacts. It should be noted that the IR products are rated to withstand Class 4 impacts.

Performance Comparisons

3. *Basic Architectural Shingles versus IR Architectural Shingles:*

(FIGURE 6)

a. Class 1 UL 2218 impacts resulted in passing ratings for about 75 percent of the impact locations on the IR architectural shingles versus about 55 percent for the basic architectural shingles.

b. Class 2 UL 2218 impacts resulted in passing ratings for about 70 percent of the impact locations on the IR architectural shingles versus about 40 percent for the basic architectural shingles.

c. Class 3 UL 2218 impacts resulted in passing ratings for about 60 percent of the impact locations on the IR architectural shingles versus about 35 percent for the basic architectural shingles.

d. Class 4 UL 2218 impacts resulted in passing ratings for about 40 percent of the impact locations on the IR architectural shingles versus about 30 percent for the basic architectural shingles.

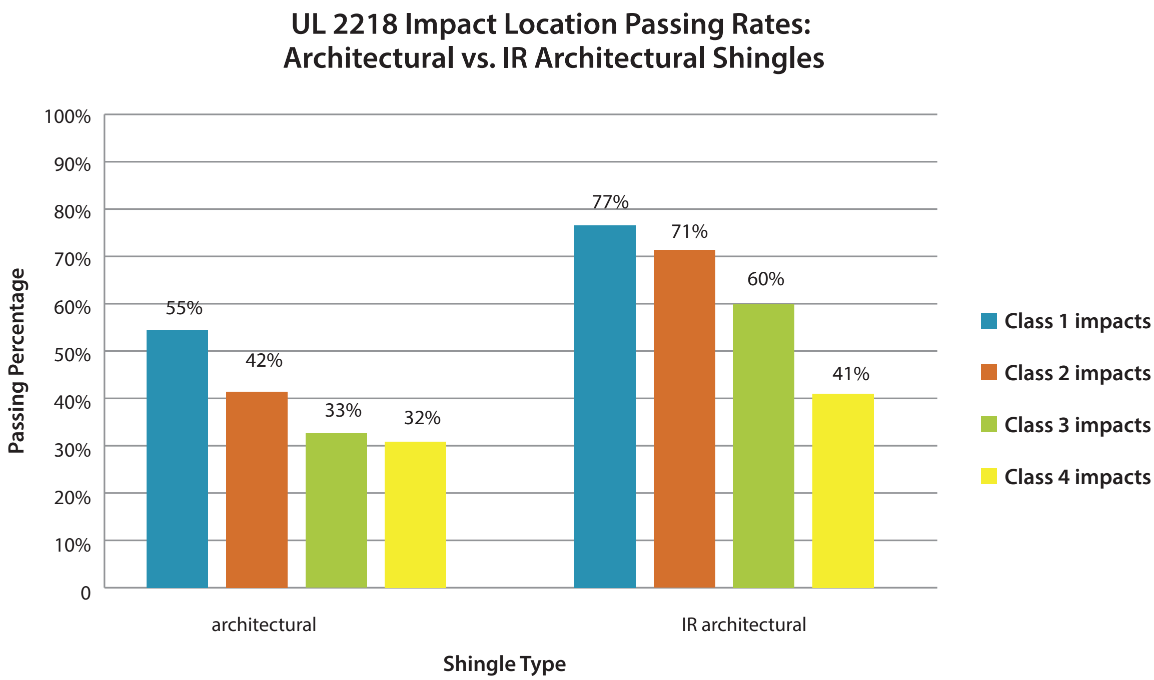

Figure 6. Comparison of basic and IR architectural shingle performance to Class 1-4 impacts. It should be noted that the IR products are rated to withstand Class 4 impacts.

Performance Comparisons

4. *Premium Architectural Shingles* versus *Basic and IR Architectural Shingles:*

(FIGURE 7)

a. Class 1 UL 2218 impacts resulted in passing rates for about 60 percent of the impact locations on the premium architectural shingle products.

b. Class 2 UL 2218 impacts resulted in passing ratings for about 45 percent of the impact locations on the premium architectural products.

c. Class 3 UL 2218 impacts resulted in passing ratings for about 40 percent of the impact locations on the premium architectural products.

d. Class 4 UL 2218 impacts resulted in passing ratings for about 35 percent of the impact locations on the premium architectural products.

e. In all four classes of testing, the passing rate of the premium architectural products was higher than the basic products, but lower than the passing rate of the IR products.

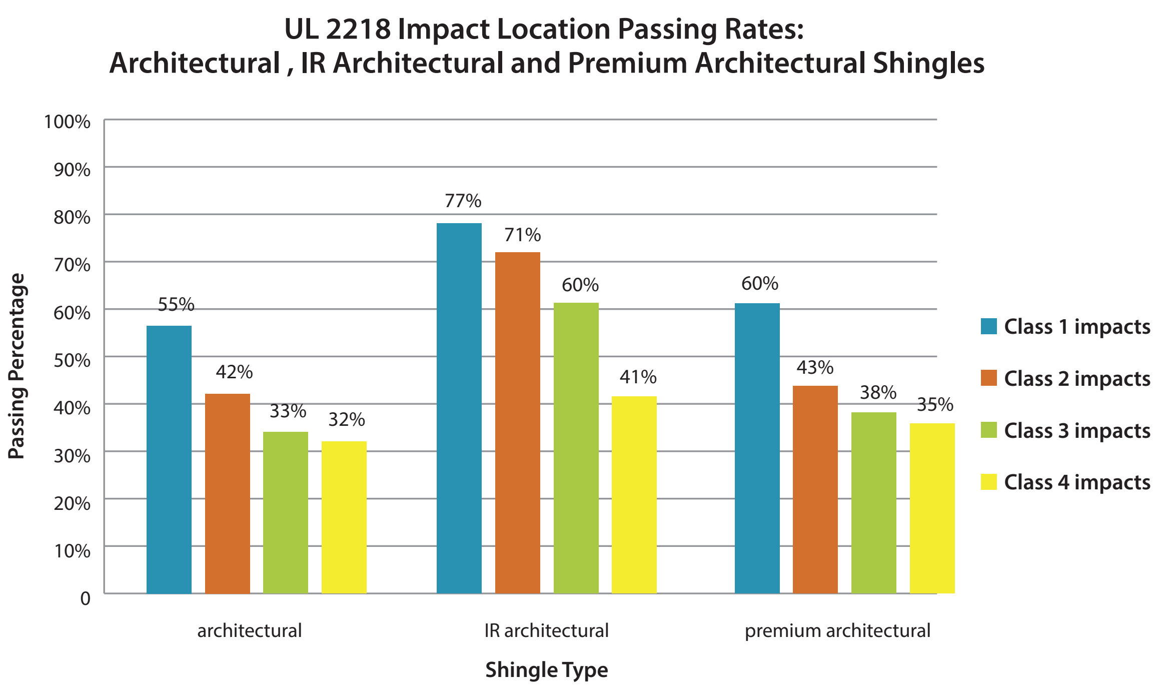

Figure 7. Comparison of basic and IR architectural shingle performance to Class 1-4 impacts. It should be noted that the IR products are rated to withstand Class 4 impacts.

Performance Comparisons

5. Polymer Modified IR Shingles versus Traditional IR Shingles:

(FIGURE 8)

a. Class 1 UL 2218 impacts resulted in passing ratings for about 85 percent of the impact locations on the polymer modified IR products compared to about 70 percent for the traditional IR shingles.

b. Class 2 UL 2218 impacts resulted in passing ratings for about 90 percent of the impact locations on the polymer modified IR products compared to about 60 percent for the traditional IR shingles.

c. Class 3 UL 2218 impacts resulted in passing ratings for about 75 percent of the impact locations on the polymer modified IR products compared to about 50 percent for the traditional IR shingles.

d. Class 4 UL 2218 impacts resulted in passing ratings for about 55 percent of the impact locations on the polymer modified IR products compared to about 35 percent for the traditional IR shingles.

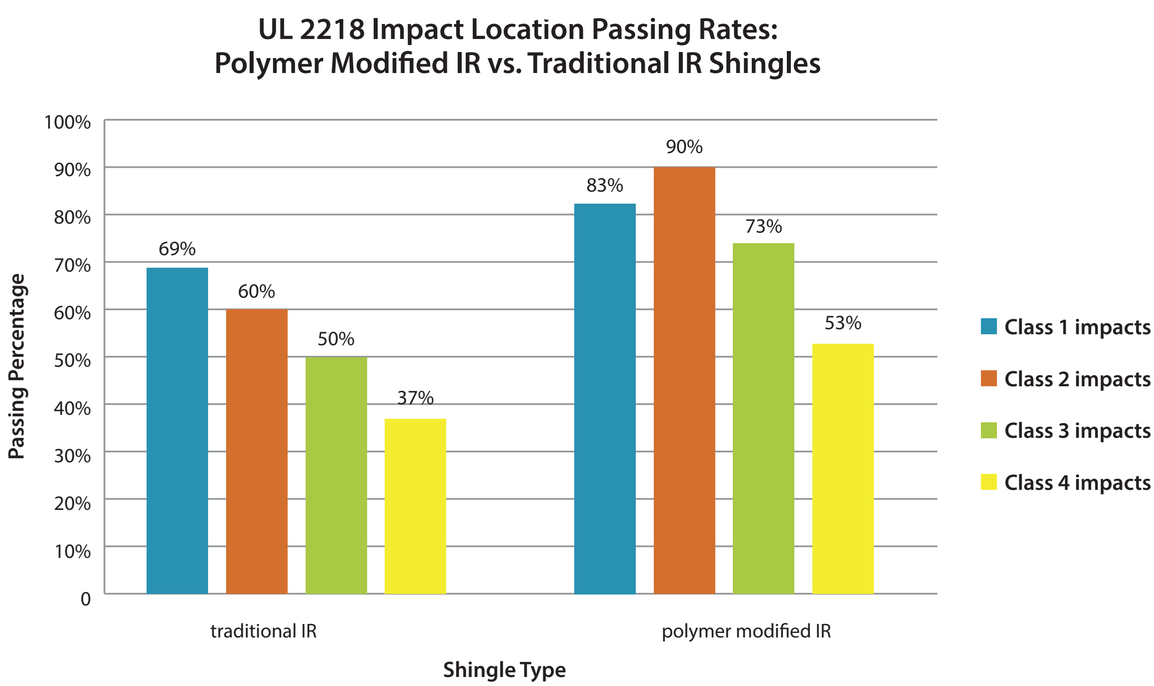

Figure 8. Comparison of traditional IR and polymer modified IR shingle performance to Class 1-4 impacts. It should be noted that these IR products are rated to withstand Class 4 impacts.

Performance Comparisons

More detailed analyses of the passing and failure modes were conducted, as it is currently unclear if some modes are more detrimental to product performance than others, and claims adjusters will rarely be able to view the back of shingles after a hail event without causing more damage. These passing and failure modes were defined as follows:

PASS

no tears or cracks visible on top or bottom of shingle surfaces.

PASS-TEAR TOP ONLY

tear visible on the top only at shingle edges or corners.

PASS-CRACK TOP ONLY

crack visible on the top only at shingle joints and centers.

FAIL-TEAR

tear visible on the bottom at shingle edges or corners.
A tear may or may not have been visible on the top of the shingle.

FAIL-CRACK

crack visible on the bottom at shingle joints and centers.
A crack may or may not have been visible on the top of the shingle.

An example of this more detailed analysis is provided in Figure 9, which shows that the polymer modified IR shingles perform better in each impact test class than the traditional IR shingles. From this dataset, the polymer modified products are less likely than the traditional products to have a crack visible on the top without also being visible on the bottom. They also are less likely to exhibit tears at edges and corners and the dominant damage mode is cracking at joints and shingle centers.

Performance Comparisons

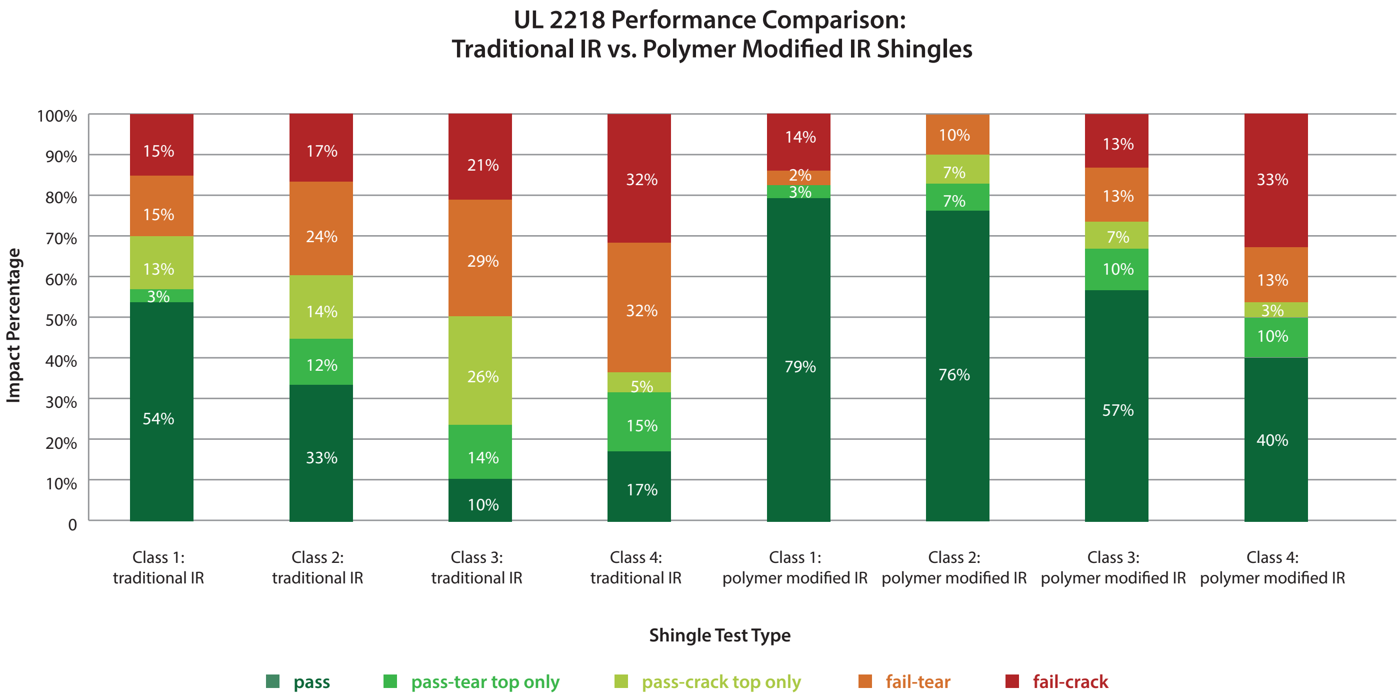

Figure 9: Detailed analysis of passing and failure modes for traditional IR and polymer modified IR shingles. It should be noted that the IR products are rated to withstand Class 4 impacts.

With the exception of two product groups, the data exhibit well-behaved declines in passing percentages with increasing steel ball sizes. The graphs suggest the basic 3-tab shingles performed better under Class 3 impacts than Class 2 impacts, and the IR 3-tab products performed better under Class 2 impacts than Class 1 impacts. However, this is likely a reflection of the variability in results given the relatively small samples sizes of six or 12 impact locations per product for each steel ball size, and two or five products in each product group. Additionally, in comparing impacts classified as "pass" as outlined above (no tears or cracks visible on top or bottom) in this testing series, with those classified in the same manner in a previous testing series, differences of about 3 to 30 percent were observed. It also is reasonable to expect some variation due to the subjective nature of rating the impacts. To examine these two factors, a test series is underway to evaluate the performance of multiple replicates of three shingle products (one basic architectural, one IR architectural, and one polymer modified IR architectural) when rated by multiple researchers. This test series should help to quantify expected variability in the results.

Summary and Results

Using the UL 2218 tests and performance criteria, the following results were found for the products tested:

- Basic architectural shingles perform slightly better than basic 3-tab shingles (about 5 to 20 percent difference).

- IR 3-tab products performed better than the basic 3-tab products (about 55 to 225 percent better) for all steel ball impact classes. The basic products had relatively consistent passing rates for the Class 2 and larger steel ball impacts, while the IR products showed consistent passing rates for Class 3 and larger steel ball impacts.

- IR architectural products performed better than the basic architectural products (about 25 to 80 percent improvement) for all steel ball impact classes. The basic products showed consistent passing rates for Class 3 and 4 steel ball impacts, while the IR products showed a steady decline in performance but much higher passing rates.

- IR architectural shingles performed about the same as IR 3-tab shingles, except for Class 4 steel ball impacts, where the performance of IR 3-tab shingles was about 40 percent better than the IR architectural shingles.

- Premium architectural shingles performed slightly better than the basic architectural shingles (up to 15 percent better), but not as well as IR architectural shingles (about 15 to 40 percent worse) when subjected to all four steel ball impact classes. All three products showed a decline in passing rates with increasing steel ball size, but the decline began tapering off for the basic and premium products.

- Polymer modified IR shingles performed better than traditional IR shingles (about 20 to 50 percent improvement) for all four steel ball impact classes. This was most noticeable at the larger steel ball sizes (1.50-2.00 in.) where the polymer modified shingles performed at least 40 percent better than the traditional IR shingles.

Next Steps

These results will be shared with shingle manufacturers and Underwriters Laboratory with the goal of improving shingle testing and performance. The test series to examine panel-to-panel and subjective rating variability for three sample products is ongoing. At the completion of those tests, selected asphalt shingles will be tested with pure ice spheres according to the FM 4473 test method and all 22 asphalt shingles will be tested using IBHS' own methods with more realistic laboratory hailstones. The effects of layering shingles, substrate type, aging, and the comparative performance of other roofing material types will be evaluated in the future. The effects of batch-to-batch variability in shingle performance and how the characteristics of the shingles (thickness, weight, etc.) affect impact performance are being explored.

References

Underwriters Laboratory. (2012). UL 2218: Standard for impact resistance of prepared roof covering materials. UL: Northbrook, IL.

Appendix A

An overall diagram of the IBHS test apparatus for conducting UL 2218 standardized tests is shown in Figure A1. The test panel is located directly below the drop tubes shown on the left side of the diagram, while the lift tubes to bring the steel balls up to the appropriate drop height are shown at the right side of the diagram. The tubes connecting the lift and drop tubes are slightly sloped to ensure the balls roll down into their drop positions. The drop system dimensions are shown in Figure A2.

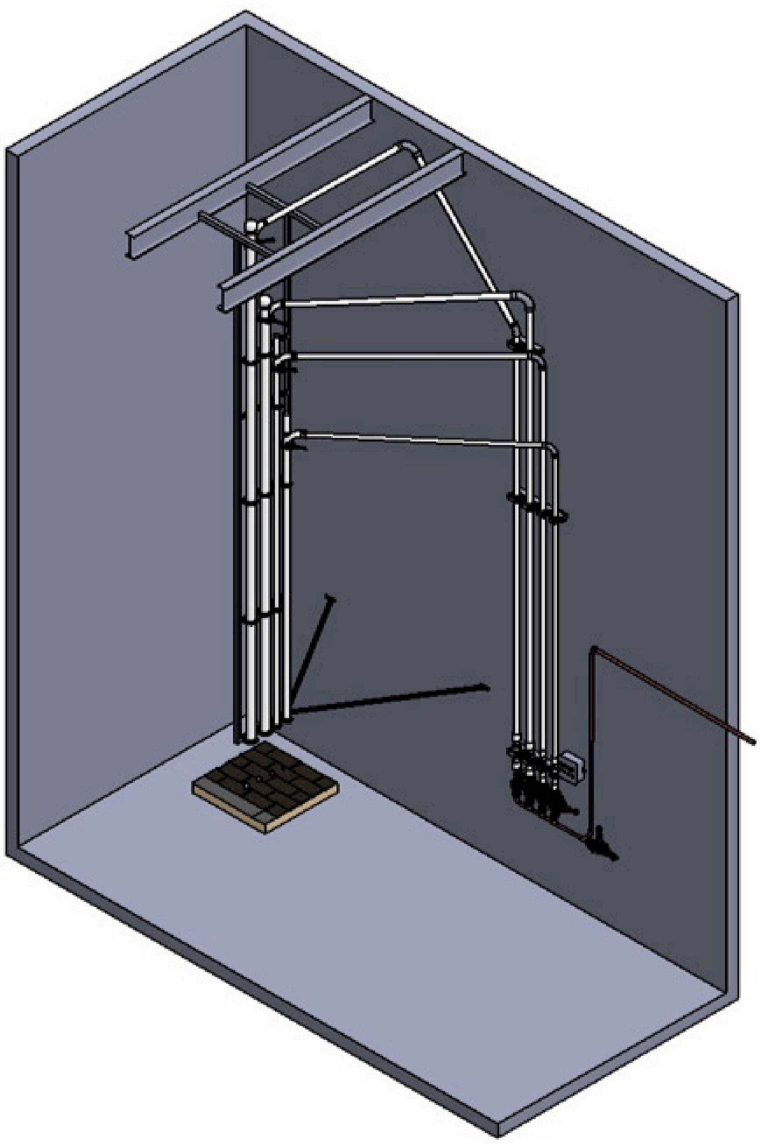

Figure A1: Overall diagram of the IBHS constructed UL 2218 test apparatus, shown mounted on the wall and ceiling.

Appendix A

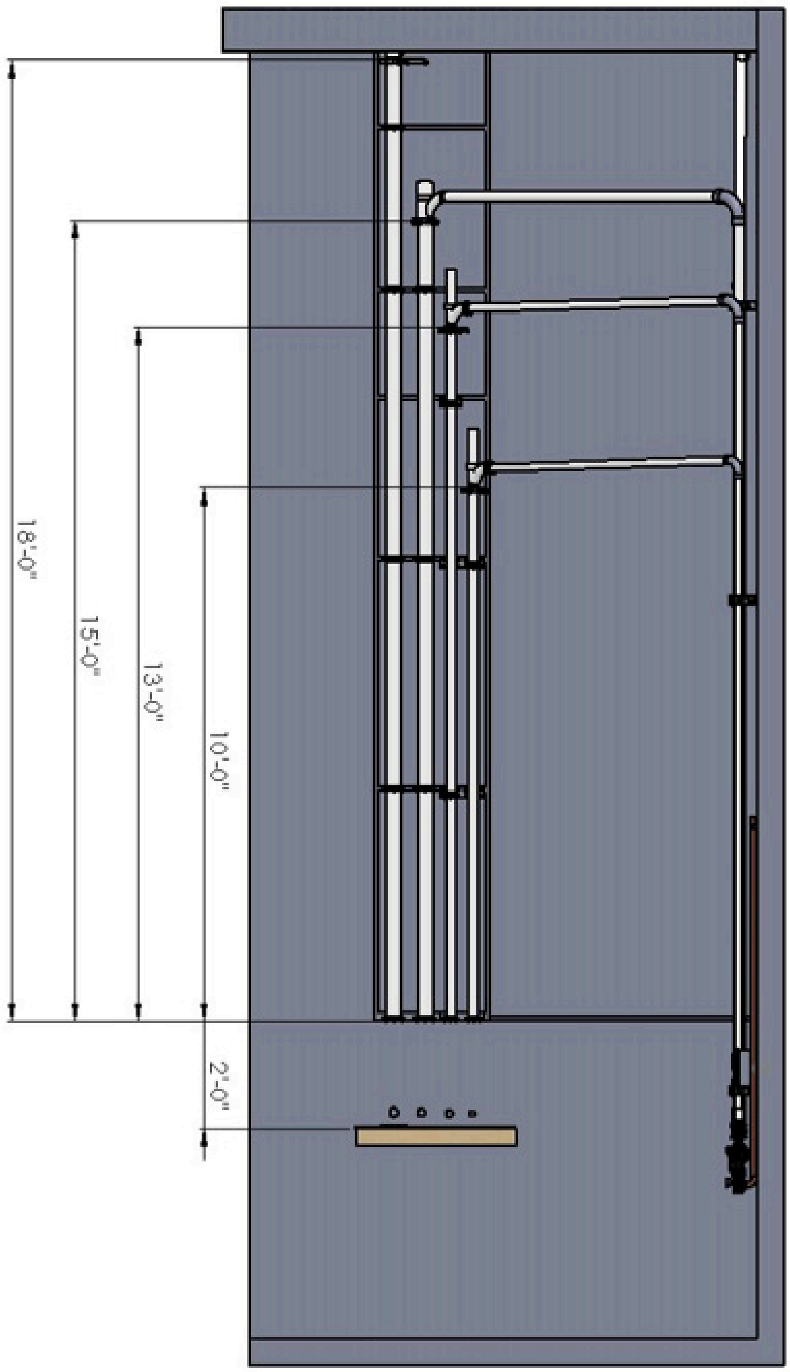

Figure A2: Drop tube dimensions.

Appendix A

The system uses compressed air to lift the steel balls to the appropriate drop height, where they are held in place until triggered. The operator can stand at ground level to load the steel balls in the lift tubes and actuate the lift and drop triggers. Figure A3 depicts the operator controls at ground level. The compressed air is regulated at the control system. Once the operator places a steel ball in the appropriate lift tube and closes the sleeve, the top button on the control panel is depressed to open a valve allowing the compressed air to lift the ball until it reaches the full height of the lift tube and rolls down the slope to the drop position. The bottom button on the control panel is pressed to trigger the drop. The trigger design is detailed in Figure A4 for the 1.75 in. and 2.00 in. drop tubes. A similar design is used for the 1.25 in. and 1.50 in. drop tubes. Magnetic laser levels are located at the bottom of the drop tubes to create a crosshatch indicating the precise position of each drop location, ensuring the operator can target specific shingle features such as corners, joints, and edges.

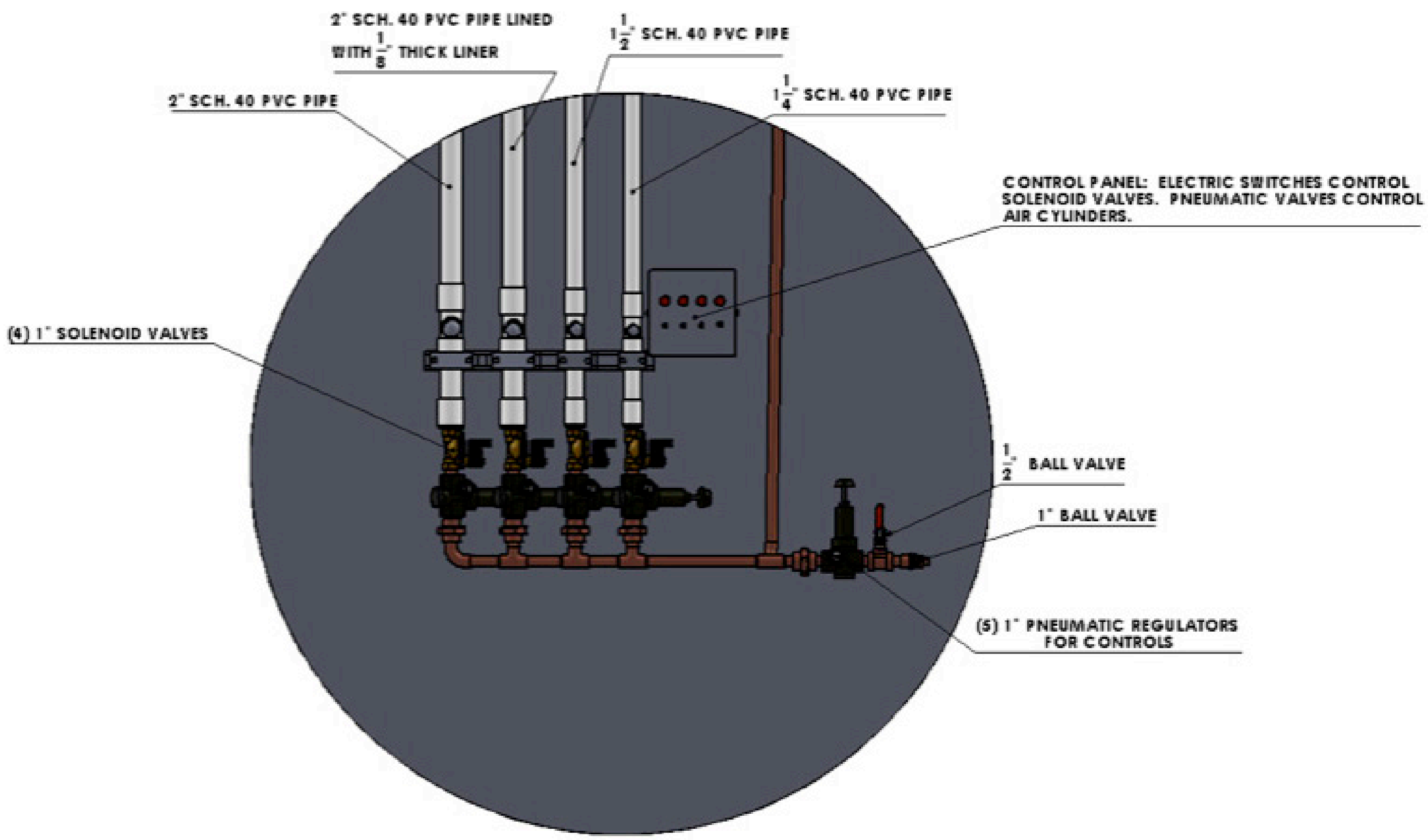

Figure A3: The control system is operated at ground level, where compressed air is regulated and valves opened to lift the appropriate size steel ball.

Appendix A

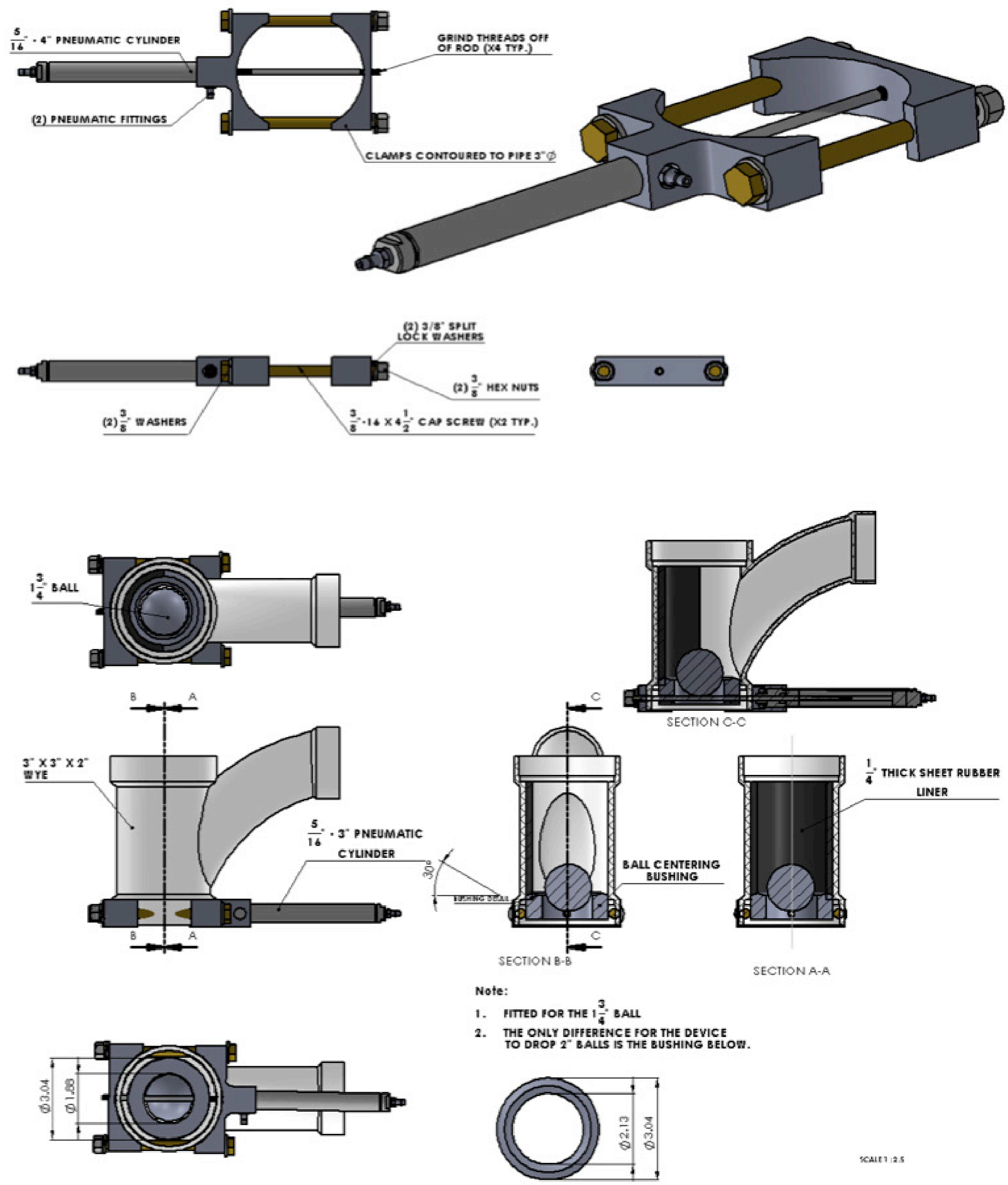

Figure A4: Drawings illustrate the entry of the steel ball into the drop tube, where it is secured in place until the operator presses the trigger button. The pneumatic cylinder then releases, and the ball is dropped.

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