

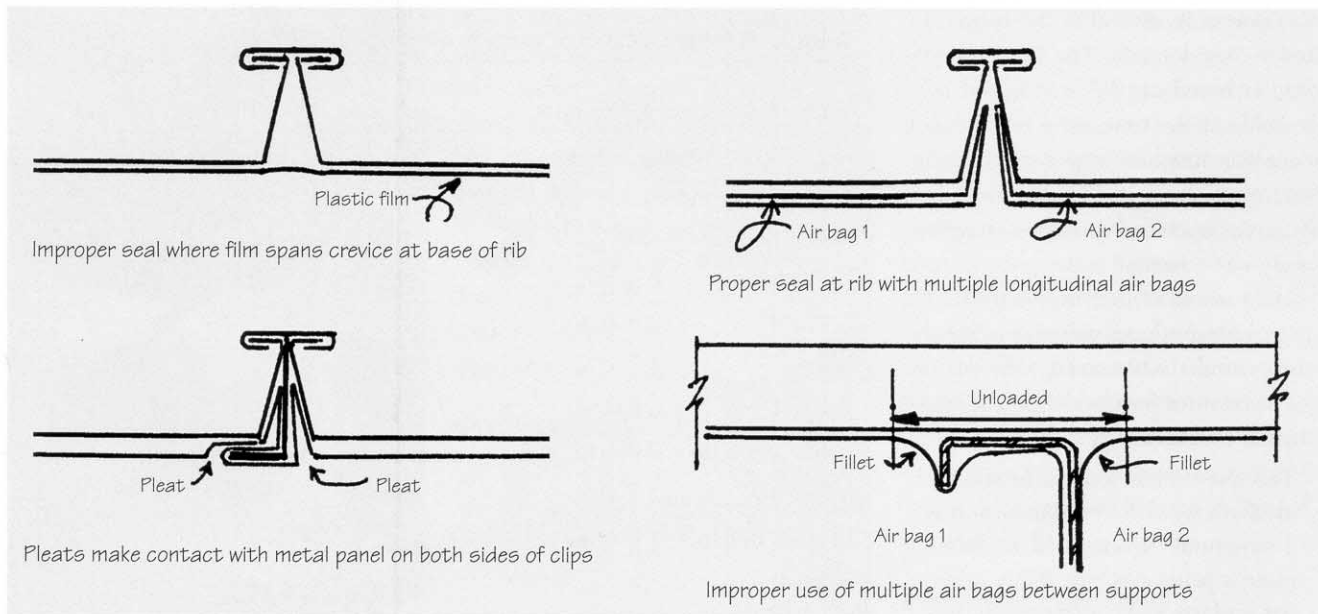
# Metal Roof Specifications

Specifying ASTM E1592 will ensure comparable structural capacity from all systems that are bid.

**A**STM E1592, the long-awaited static air pressure test for evaluating uplift properties of metal roofing, measures the structural performance of clip and panel components in a way that accurately reproduces the changes in shape that occur under air pressure. The procedure allows for an engineering approach to structural performance for all types of metal roofing. Publication of the standard in June 1994 culminated nine years of effort to bring industry members together under the auspices of ASTM to agree on items such as minimum specimen size, use of air bags and plastic film, loading procedure, and data to be recorded. ■ The procedure follows the principles of ASTM E330; however, it allows for the greater flexibility of sheet metal profiles compared to the typical curtain wall construction of extrusions, glass, and panels. The loading sequence is designed to detect unlatching and slowly developing failures that would not appear in a short single test but that could show up after repeated service loads. ■ As a test method, ASTM E1592 will replace the U.S. Army Corps of Engineers test, various "ASTM E330 Modified" procedures, and others

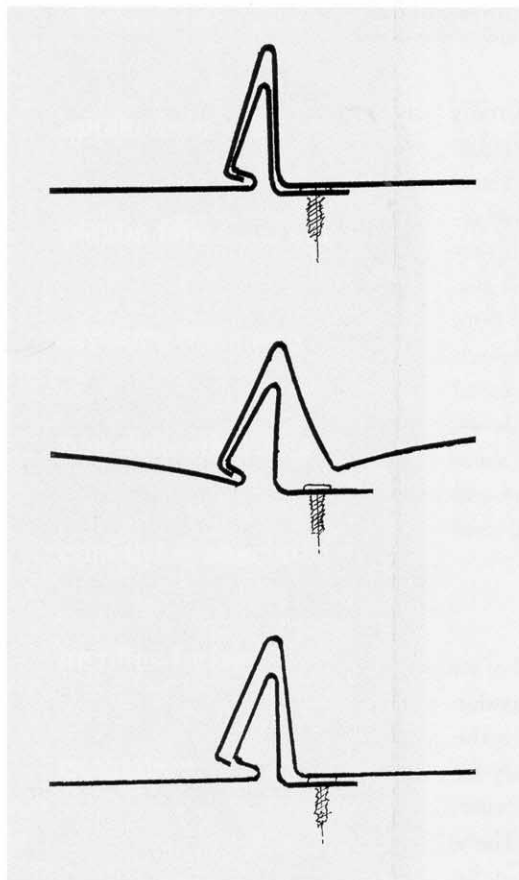
**by Richard C. Schroter**





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**Figure A. Proper use of film and air bags per ASTM E1592**



**Figure B. Typical unlatching failure**

Courtesy the author

not submitted to the consensus process. It should not be confused with insurance industry procedures for classifying or indexing products. Properly used in a specification, this standard will ensure comparable structural capacity from all systems bid. While most of the industry has been conducting air pressure tests of their systems during the last few years, not all are in complete conformance with the new procedure. Until all suppliers have a chance to get up to date, reviewers will be pressed to evaluate specific deviations.

#### **Use in Specifications**

ASTM E1592 is a standard test method, not a performance standard. Mere reference to it does not ensure good perfor-

mance. Therefore, as a minimum, add the following articles and criteria to specifications.

**System description.** Resist the design pressures indicated. Determine panel bending and clip-to-panel strength by testing in accordance with ASTM E1592. Capacity for gauge, span, or loading other than those tested may be determined by interpolating test results. Compute uplift loads on anchor screws with full recognition of prying forces from eccentric clip loading. Calculate holding strength of fasteners in accordance with the thickness or length of embedment and properties of the material holding the point. Use factors of safety as recommended by the industry for the material involved.

**Submittals.** Test reports: furnish copies of all certified laboratory test reports required by this section and by the referenced publications. Conduct testing at an approved laboratory or under supervision of an independent engineer. Com-

putations: submit calculations made by a professional engineer registered in any U.S. jurisdiction to show that the basic system meets the uplift requirements. These calculations shall tie the general data from the manufacturer to the specific conditions of this project. References: include the appropriate industry publications for the material of the panel and of the support structure.

### **Commentary**

To ensure that all bidders are using the same design loads (preventing the bravest bidder from designing the project), it is necessary to specify the cladding design pressures rather than to merely reference the code. Cladding loads are much higher than those used for design of the basic structure. Current codes vary, but they typically provide average pressure values for cladding at various locations on the roof, for areas  $0.9 \text{ m}^2$  ( $10 \text{ ft}^2$ ), for periods up to ten seconds. The basic structure uses pressures averaged over a much larger area for a longer time.

Reference the location for uplift design information. There are typically two or three pressure zones on each plane of the roof (four if the slope is below 10 degrees and the height is above 18 m (60 ft)). Multiple zone pressures are easily keyed to a diagram on the drawings; if the roof is simple in shape, a table in the specifications will suffice.

A given system can be installed over many types of support: plywood, wood purlins or sleepers, hot-rolled steel, cold-formed steel framing, or metal deck. Analysis of the strength of fasteners into these basic materials need not be evaluated by static air pressure; the size of the test specimen in the E1592 procedure is too expensive to be used to evaluate the strength of components that can be ana-

lyzed by ordinary means. Screw and bolt strength, for example, is commonly developed through standard pull tests of single fasteners.

With proper allowance for leverage or prying forces from eccentric loading, the anticipated service loads on fasteners can easily be compared with safe pullout values from the actual material involved. This is why the specifications require submittal of engineering calculations to show that the installer is using appropriate fasteners to secure anchor clips. Note that a properly certified load span table can meet the design requirement for the panels and clips. Clip loads are a function of panel width and anchor spacing, but the load on the fastener can vary with the leverage of the specific anchor slip used by the installer.

### **Mock-Ups and System Testing**

Overloading on one portion of a system can produce results significantly different from overloading on another. For example, yielding of a clip can be catastrophic, while yielding of a panel may not be noticeable. Accordingly, the factors of safety on design stresses of different components and modes of loading may range from less than 1.5 to more than 2.5.

A total system test that verifies acceptable results is unlikely to produce an optimum design. Only those properties that are not easily analyzed need to be tested following E1592. For a unique configuration on a monumental structure, only one test may be economically feasible. In such a case, setting different factors of safety for different kinds of distress would be appropriate.

Localized buckles are an example of a type of failure that does not lead to system collapse and that can be tolerated

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at pressures well below those desired to verify that the anchorage is secure. Another factor to consider is that the wind design pressure decreases as the tributary area increases. A bar joist spanning 6 m (20 ft) will typically be engineered for the lower maximum average pressure associated with a 9 m<sup>2</sup> (100 ft<sup>2</sup>) area rather than the higher average pressures associated with the 0.9 m<sup>2</sup> area for the panel attachments.

### Key Provisions

The E1592 test procedure has three key provisions: size, specimen sealing, and load sequence.

**Size.** A prime objective of the procedure is to eliminate the influence of fasteners in panel ends and sides, which can restrict panel deformation from uniform pressure. The arbitrary limits in E1592 are based on prior experience with many materials and panels. *Table 1* summarizes these limits.

The basic test panel length criteria also can be met when measurement of panel distortions along the length of the specimen stays within specified limits. (The testing engineer is required to comment on such deviations from standard procedure.) This criterion may also be useful for evaluating the appropriate size of a test specimen for a system outside the range of those tested to date.

**Sealing the test specimen.** Another important criterion is the proper use of air bags or placement of plastic film on the specimen to control air leakage. With light-gauge sheet metal, the admonition regarding these practices in ASTM E330 is not sufficient to guard against non-conservative results. E1592 is more explicit in film placement (see *Figure A*, page 78) and requires that the test engineer be present during installation of

these seals to see that the test specimen complies.

**Load sequence.** The procedure requires both load deflection and permanent set curves. Each somewhat small increment of load is followed by a return to zero pressure. A break in the set curve reveals onset of progressive failure without need for a fatigue-type test. Some sheet metal interlocks are subject to "unlatching failure" resulting from local deformation that impairs the strength on the next reload. *Figure A* illustrates how a seam can carry a very high pressure if load is continuously applied but can unlatch after release of a low pressure.

### Evaluating Prior Tests

Panel distortion under a given pressure is the most significant measure of compliance. If a specimen length is less than suggested in *Table 1* or if there is some question about the placement of the air film or shape of the air bag because it was not observed by the engineer, the pan deflections or rib spread readings should be compared with a test of the same system that does comply. Since crosswise deformation does not vary significantly with the length of the span tested, a single test can be used to validate several tests at different spans. Some clips may not be as susceptible as others to panel deformation under uniform pressure; nonetheless, any test in which the "loose application" of a plastic film does not produce the same pan deflection as a complying specimen justifies further evaluation. Many such tests have resulted in loads 50 percent or higher than those resulting from tests that comply.

After attending meetings for several years, the Corps of Engineers decided it could not wait for the ASTM committee to agree on a test procedure and mod-

eled one of its own after the procedure under consideration. The Corps' procedure is based on the best information available at the time. As a result, some manufacturers have experienced higher test results from the Corps' procedure for compliance and guidance on appropriate safety factors.

Many manufacturers believe the E1592 procedure produces excessively conservative results when used with current code pressures for claddings. The introduction to E1592 states:

This test method is not to be considered as a wind design standard. It is a structural capacity test to determine a panel system's ability to resist uniform static air pressure. Actual wind pressure is nonuniform and dynamic. When these uniform static test results are used in conjunction with commonly recognized wind design standards, they will yield highly conservative results.

There is considerable disagreement over what this means. E330 has been in use for a number of years. E1592 is more conservative in that its load sequence is designed to detect fatigue and unlatching failures. In actual service, some feel that the exceptionally high corner pressures act over such small areas that they do not have the same effect on a structural panel system as they do over a more flexible membrane. But there are examples of metal roof damage restricted to corner areas. For claddings over solid decking, the codes do not indicate how the load is shared between layers. These subjects are discussed in the appendix, but there are no quantitative answers to these questions.

Insurers hit hard by recent hurricanes are looking for more secure attachment systems for all types of roofing. Investi-

Table 1. Minimum number of spans to comply with 8.3*				
Ends with Crosswise Restraint		2	1	0
Span Length		Number of equal spans		
12 ft-0 in. or more		2	2	2
below 12 ft to 8 ft-0 in.		3	2	2
below 8	6 ft-0 in.	4	3	2
below 6	5 ft-0 in.	5	3	2
below 5	4 ft-0 in.	24/L	3	3
below 4	3 ft-4 in.	24/L	4	3
below 3 ft-4 in.	3 ft-0 in.	24/L	4	4
below 3	2 ft-6 in.	24/L	5	4
below 2 ft-6 in.	2 ft-0 in.	24/L	5	5
below 2 ft		24/L	1 + 8/L	10/L
*Count fractional spans as whole numbers, that is, $24/5 = 4.8 = 5$ spans.				

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gators found a number of metal roofs that failed at the clip-to-panel interface. Rather than blindly increase design loads, the E1592 procedure is aimed at reducing failures that originate at the clip-to-panel interface by reproducing the system deformations that take place from uniform pressure. Wind tunnel research sponsored by some members of the metal roofing industry appears close to developing information that will provide static pressure equivalents for the dynamic and spatially variable fluctuations of real wind situations.

#### A Final Comment

The final product is the sum of all of its parts. Testing and planning is of no value if the installation fails to complete the package. Knowing what is necessary for good performance of the clips and cladding is only part of the process. There needs to be a means of verifying that the quality of the design and installation

through the balance of the load path matches the quality of the product design. ♦

#### Industry Resources

*Specifications for Aluminum Structures*, available from the Aluminum Association, 900 19th Street, N.W., Washington, D.C. 20006.

*Cold Formed Steel Design Manual*, available from the American Iron and Steel Institute, 1101 17th Street, N.W., Washington, D.C. 20036-4700.

*Technical Note E830B, Fastener Loads for Plywood*, available from the American Plywood Association, P.O. Box 11700, Tacoma, Washington 98411.

*Design Specifications for Stress Grade Lumber and its Fastenings*, available from the American Forest and Paper Products Association (formerly the National Forest Products Association), 1111 19th Street, N.W., Suite 800, Washington, D.C. 20036.

**RICHARD C. SCHROTER, P.E., CDT, CSI**, is an independent consultant specializing in metal building products. Mr. Schroter is chairman of ASTM task group E06.21.04 on metal roof uplift testing.