



ANSI E1.2 - 2012
Entertainment Technology —
Design, Manufacture and Use of Aluminum
Trusses and Towers

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Entertainment Technology — Design, Manufacture and Use of Aluminum Trusses and Towers

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The PLASA Technical Standards Program

The PLASA Technical Standards Program was created to serve the PLASA membership and the entertainment industry in technical standards related matters. The goal of the Program is to take a leading role regarding technology within the entertainment industry by creating recommended practices and standards, monitoring standards issues around the world on behalf of our members, and improving communications and safety within the industry. PLASA works closely with the technical standards efforts of other organizations within our industry, including USITT and VPLT, as well as representing the interests of PLASA members to ANSI, UL, and the NFPA. The Technical Standards Program is accredited by the American National Standards Institute.

The Technical Standards Council (TSC) was established to oversee and coordinate the Technical Standards Program. Made up of individuals experienced in standards-making work from throughout our industry, the Council approves all projects undertaken and assigns them to the appropriate working group. The Technical Standards Council employs a Technical Standards Manager to coordinate the work of the Council and its working groups as well as maintain a “Standards Watch” on behalf of members. Working groups include: Control Protocols, Electrical Power, Floors, Fog and Smoke, Followspot Position, Photometrics, Rigging, and Stage Lifts.

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The Rigging Working Group, which authored this Standard, consists of a cross section of entertainment industry professionals representing a diversity of interests. PLASA is committed to developing consensus-based standards and recommended practices in an open setting.

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Interest category codes:

CP = custom-market producer	DE = designer
DR = dealer rental company	G = general interest
MP = mass-market producer	U = user

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An asterisk (*) next to a clause number indicates that there is a matching explanatory clause in the informative Appendix A.

FOREWORD (This foreword is not part of the standard. It contains no mandatory requirements.)

Prior to the original 2000 version of this standard, there were no specific American National Standards covering the design, manufacture and use of aluminum trusses in the entertainment industry. In an attempt to improve safety and standards in the industry, the Entertainment Services and Technology Association (ESTA) (now PLASA) convened a series of meetings to prepare a draft standard. Columbus McKinnon Corporation kindly hosted these meetings at their facilities in Buffalo, New York and Abingdon, Virginia,

It is the intention of PLASA that this standard be put forward as the basis for an American National Standard to the American National Standards Institute. It should be noted that other ANSI Standards may be relevant, depending on the application and intended use of the aluminum trusses.

The preparation of the standard was entrusted to the Truss Team working as part of the Rigging Work Group for the Technical Standards Council (TSC) of PLASA. The Truss Team is generally comprised of manufacturers and their structural engineering advisors.

It has been assumed in the drafting of this standard that the execution of its design provisions are entrusted to appropriately qualified and experienced people, and that the fabrication and use is carried out by qualified and suitably experienced people and organizations.

This standard presents a coordinated set of rules that may serve as a guide to government and other regulatory bodies and municipal authorities responsible for the guarding and inspection of the equipment falling within its scope. The suggestions leading to accident prevention are given both as mandatory and advisory provisions; compliance with both types may be required by employers of their employees.

Safety codes and standards are intended to enhance public safety. Revisions result from committee consideration of factors such as technology advances, new data, and changing environmental and industry needs. Revisions do not imply that previous editions were inadequate.

Compliance with this Standard does not of itself confer immunity from legal obligations.

1 Scope

This document describes the design, manufacture and use of aluminum trusses, towers and associated aluminum structural components such as head blocks, sleeve blocks, bases, and corner blocks in the entertainment industry. It does not cover individual, separate rigging hardware such as 1/2 couplers and shackles.

The standards described herein are for a variety of uses that are confined to the entertainment industry and apply to a range of structures subjected to normal atmospheric conditions.

The standards described herein do not cover aerospace alloys, the detail design of castings, curved shell structures or structures subjected to severe thermal or chemical conditions. They are not intended to be used for the design of containment vessels, airborne structures or vessels or for any application where a specific standard exists.

If "truss" is referred to in a particular clause in this standard, then it shall equally apply to 'tower' and vice versa. It shall also apply to associated aluminum hardware.

2 Definitions

2.1 abrasion: loss of material due to wear.

2.2 allowable load: maximum static equivalent load that can be safely imposed on truss / tower in addition to the self-weight.

2.3 ancillary: supplementary

2.4 AWS: American Welding Society.

2.5 bent member, truss or tower: component or assembly that has permanent deviation from the intended center line.

2.6 bolted connection: a connection of two modules using bolts.

2.7 camber: intended vertical deviation of a truss, usually radiused.

2.8 chord: the element of a module that will carry the axial forces associated with flexural, axial, or combined flexural and axial loading.

2.9 competent person: a person who is capable of identifying existing and predictable hazards in the workplace and who is authorized to take prompt corrective measures to eliminate them.

2.10 components: parts of a whole.

2.11 connecting plates: plates welded to the end frames of a module that are used to connect adjacent modules together.

2.12 consumables: items that require regular replacement with use.

2.13 CPL (center point load): a concentrated load that is applied at the midspan of a truss or tower.

2.14 crack: a crevice type discontinuity in the material.

2.15 damage: condition that adversely affects the intended use of a module (usually load carrying capacity).

2.16 dent: localized permanent deformation in the surface of member or element.

2.17 design strength: the capacity of a structural element or module determined using a recognized design manual.

2.18 diagonal: an element of a module that is not at a 90 degree angle to the main chords.

2.19 dye penetrant testing: a standard NDT using dye to highlight cracks in welds.

2.20 dynamic loading: forces caused by the acceleration or deceleration of an object.

2.21 flare test / drift test: a test on drawn, seamless aluminum round tubes to check structural integrity of the tube wall. Refer to ASTM B210-04.

2.22 incident: occurrence where damage to one or more modules has or may have been sustained.

2.23 manufacturer: person or company that fabricates modules or systems.

2.24 module: singular trussed structure that is stable under load and can be used alone or assembled interchangeably into larger assemblies as defined in this standard.

2.25 NDT (non-destructive test): a method for testing one or more aspects of structural integrity while leaving the tested material or piece intact.

2.26 pinned connector: chord end connector that uses a removable pin to effect a connection between modules.

2.27 qualified person: a person who, by possession of a recognized degree or certificate of professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve problems relating to the subject matter and work.

2.28 repetitive use: the assembling and dismantling of the same specific modules or assemblies on multiple occasions.

2.29 single use: the assembly and installation of modules or assemblies specifically intended to either be permanently left in place or scrapped after being dismantled.

2.30 shall: indicates that the rule is mandatory and must be followed.

2.31 should: indicates that the rule is a recommendation, the advisability of which depends on the facts and conditions in each situation.

2.32 skin: a material cover to a truss structure (usually on a roof system).

2.33 span: the distance between support points.

2.34 static equivalent load: a static load whose magnitude equals the peak force reached by a dynamically applied load.

2.35 sweep: intended lateral deviation of a truss, usually radiused.

2.36 temporary: not permanent. Reference shall be made to local building codes for relevant definitions.

2.37 tower: one or more modules assembled vertically to carry primarily axial load; usually square or triangular in cross section.

2.38 truss: one or more modules assembled to carry load over a distance, generally horizontal, and primarily acting in flexure.

2.39 user: person or company who assembles or uses modules or systems, or who assembles and uses modules or systems.

2.40 UDL (uniform distributed load): a load that is evenly spread over the length of a truss or tower.

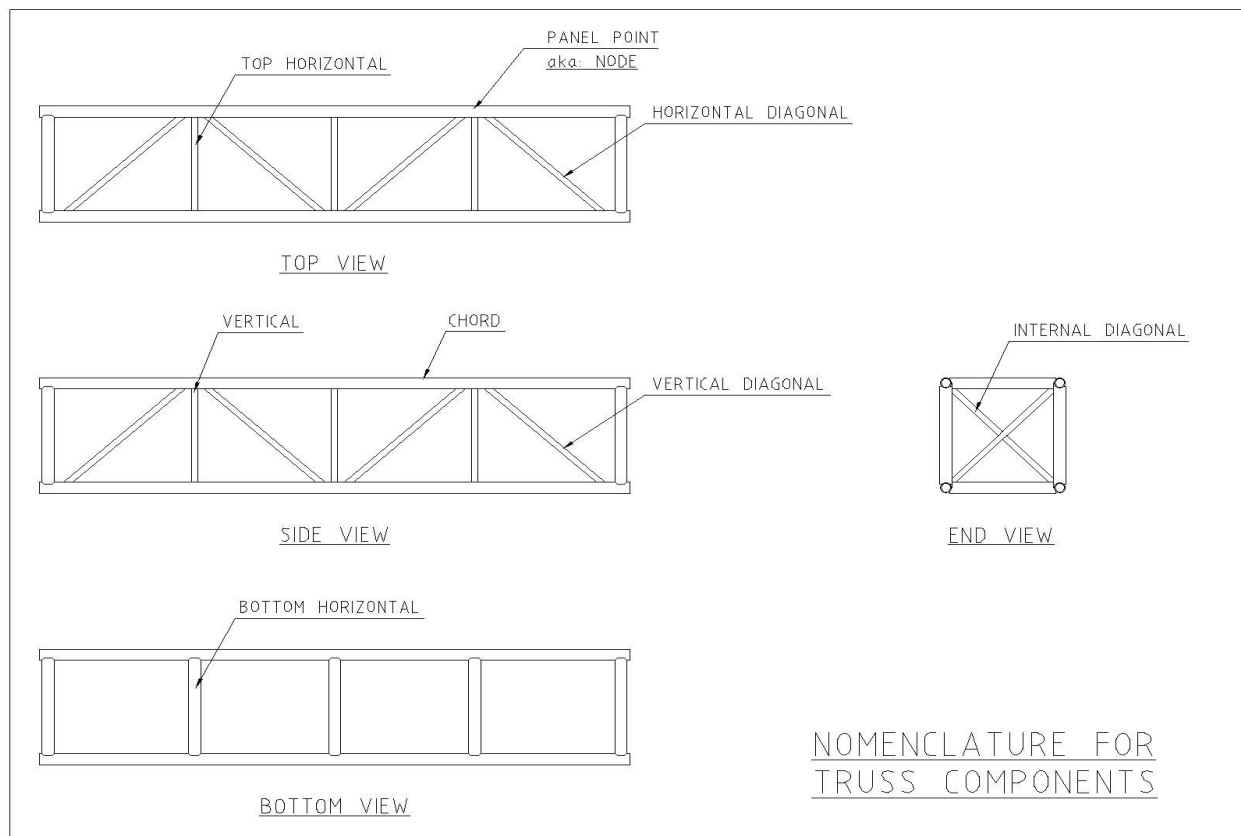


Figure 1

3 ENGINEERING

3.1 Intent

The intent of this section is to provide the engineer with the minimum basis on which aluminum trusses and towers shall be designed.

3.2 Design

3.2.1 Design shall be performed in accordance with established engineering practice.

3.2.2 All relevant standards shall be used in the design of the structure and shall be dependent on the intended conditions of use. These shall include the following:

3.2.2.1 Aluminum Association:

ASM1-10 Aluminum Design Manual 2010: Part I-A Specification for Aluminum Structures, Allowable Stress Design; Part I-B Specification for Aluminum Structures, Load and Resistance Factor Design

3.2.2.2 American Welding Society (AWS):

D1.1/D1.1M:2010, Structural Welding Code – Steel
D1.2/D1.2M:2008, Structural Welding Code - Aluminum

3.2.2.3 American Society of Civil Engineers:

ASCE 7-10 Minimum Design Loads for Buildings and Other Structures

3.2.2.4 ASTM International:

ASTM B210-04 Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes

3.2.2.5 American Institute of Steel Construction:

“Manual of Steel Construction 14th Edition”

3.2.2.6 PLASA NA:

ANSI E1.21 - 2006, Entertainment Technology – Temporary Outdoor Structures

a. Welds shall be designed and detailed per D1.2/D1.2M-03.

b. Fasteners and other components composed of material other than aluminum shall be designed per ASM1-10 and Manual of Steel Construction 14th Edition.

c. Design loading including wind shall be in accordance with ASCE 7-10.

3.2.3 All conditions of use considered in design shall be outlined in the engineering documentation. Design strength may be established using either Load Factor Resistance Design, Allowable Stress Design methods or by physical testing as outlined in ASM1-10.

3.2.4 Two engineering design categories of trusses and towers are defined as follows:

a. Design of truss or tower structures for single use: Such structures shall be designed in accordance with the provisions of the standards cited herein.

b. Design of truss or tower modules for repetitive use: The design strength determined in accordance with the standards cited herein shall be multiplied by a factor of 0.85 when the components will be subjected to repetitive use. This reduced design strength shall be greater than or equal to the maximum demand on the module from the intended loading conditions.

3.3 Engineering Analysis

3.3.1 Engineering analysis of the truss or tower structures for the intended loading conditions shall be performed by calculation, modeling, or physical testing or by a combination of two or more of these methods.

3.3.2 Engineering analysis shall consider the worst combination, application, and configuration of loads and effects possible within the use guidelines.

3.3.3 The design shall be structurally stable for the intended applications.

3.3.4 The structure shall be designed for the effects of eccentricities in element and module connections.

3.3.5 Truss and tower deflections shall be calculated for load conditions provided in the User Information.

3.3.6 The design shall address any coating or surface finishing techniques used in manufacturing that affect the structural properties and load-bearing capabilities of the truss or tower structures.

3.4 Engineering Documentation

3.4.1 Engineering drawings of the truss or tower designs shall be developed and maintained. Engineering drawings shall include dimensions, components, subassemblies, material types, fastener types and specifications, weld sizes and types, and welding consumables.

3.4.2 All weld types and sizes shall be indicated in accordance with the AWS Standards D1.1/D1.1M-04 and D1.2/D1.2M-03. All welding procedures that are not prequalified under AWS shall be documented in accordance with AWS procedures.

3.4.3 Engineering calculations, design notes and/or test results that demonstrate compliance with this standard for the intended load conditions and uses shall be developed and maintained.

3.4.4 Where it is claimed in the User Information that designs have greater margins or factors of safety than required by this standard, engineering documentation that supports the claims shall be maintained.

3.4.5 If the User Information includes a statement about the design factor, commonly called the safety factor or factor of safety, then the manufacturer shall clearly state to what condition the design factor refers.

4 MANUFACTURING

4.1 Intent

The intent of this section is to ensure that all manufacturers maintain a satisfactory level of quality throughout the manufacturing process and that each and every module is traceable back to the manufacturer in the event of defect.

4.2 Material

4.2.1 The aluminum used shall comply with ASM1-10. Component dimensions shall be within the set limits and tolerances given therein.

4.2.2 Drawn or extruded aluminum round tubes shall be flare tested as per ASTM B210-04.

4.3 Welding

4.3.1 All welders involved in producing modules through the welding process shall be certified in accordance with AWS Standards D1.1/D1.1M-03 and D1.2/D1.2M-04.

4.3.2 All welding processes shall be carried out in accordance with the AWS Standards listed in 3.2.2.2.

4.4 Inspection

4.4.1 After the welding process has been fully completed, all welds shall be visually inspected.

4.4.2 Any welds that do not appear sound shall be tested further by using the NDT method of dye penetration and repaired as required.

4.4.3 Inspection during and after fabrication shall verify the product has been built in accordance with design drawings.

4.5 Coatings and Surface Finishes

4.5.1 Coatings and surface finishes shall be applied only in accordance with 3.3.6.

4.5.2 The application of powder coating shall use processes during which modules are heated only in accordance with ASM1-10.

4.5.3 All preparations for painting or coating using a chemical process shall include a procedure to completely flush out or neutralize all corrosive materials that have entered the tubes.

4.5.4 Chemical removal of coatings and surface finishes shall be carried out only after consulting with the chemical manufacturer to ensure that the chemical will not affect the mechanical properties of the aluminum. Abrasion-blasting shall not be used on aluminum less than or equal to 1/8 inch (3mm) thick.

4.6 Identification

4.6.1 The manufacturer shall mark each module with an identification mark unique to that manufacturer and to that module. The mark shall be easily recognizable. The mark shall be durable and difficult to remove. The identification mark shall include the manufacturer's name and the date of manufacture.

4.6.2 The manufacturer shall be responsible for keeping records relating to module identification marks.

4.7 User Information

4.7.1 For each type of truss and tower, Manufacturers shall produce User Information Sheets or documentation which shall include the following minimum information:

- the maximum truss span into which modules may be assembled and safely used;
- the maximum allowable load, UDL and CPL, for a range of truss spans;
- theoretical maximum truss deflection expected at each given load and span combination;
- the maximum height to which a tower may be safely erected;
- the maximum allowable load for a range of tower heights;
- the standards to which modules have been designed and to what extent, if any, dynamic loading has been considered in the design-;
- the proper way to store, handle, transport, and erect the truss and towers;

- the correct method of making connections;
- requirements for regular inspections, specific inspection criteria, and routines for each size and type of truss and tower in accordance with Section 6.
- that full engineering documentation exists and where to obtain it.

4.7.2 It is stressed that the above list of information, instructions and cautions is the minimum information that a Manufacturer shall provide for each type and size of truss and tower.

5 USE AND CARE

5.1 Intent

The intent of this section is to provide the end-user with sufficient information to ensure that modules are handled correctly during storage, transportation, erection, and dismantling, and that the assembled truss and tower systems are used on site within the limitations of the User Information provided by the Manufacturer.

5.2 User Information

5.2.1 User shall obtain, read and keep on file User Information Sheets from the manufacturer for each type and size of truss and tower as specified in Section 4.7.1.

5.2.2 It is stressed that the requirements in Section 4.7.1 are the minimum information that a User shall receive and file for each type and size of truss and tower.

5.3 Coatings and Surface Finishes

5.3.1 Coatings and surface finishes shall only be applied after consultation with the coating or finish manufacturer or other party qualified to evaluate the possible effects of the coating or surface finish on the structural properties and load-bearing capabilities of the module.

5.3.2 The application of powder coating shall use only a low cure process. The heating of truss and tower modules shall only be done in accordance with Table A.3.2 in ASM1-10 (see 3.2.2.1 for full reference.)

5.3.3 Records shall be kept detailing the application of any coating or surface finish with particular attention to processes requiring the application of heat.

5.3.4 Chemical removal of coatings and surface finishes shall be carried out only after consulting with the chemical manufacturer to ensure that the chemical will not affect the mechanical properties of the aluminum. Abrasion-blasting shall not be used on aluminum less than or equal to 1/8 inch (3mm) thick.

5.4 Applied Loads

5.4.1 When assessing loads on the fully assembled system, the weight of all equipment, including, but not limited to, any motors, light and sound equipment, multicore cables, follow-spot chairs, temporary personnel occupancy, and reactions from fall protection systems shall be considered.

5.4.2 Consideration shall be given to the following:

a) disposition of the loads on the trusses, and whether the loads are evenly balanced beneath the centerline of the truss or are mainly concentrated on one side or the other.

b) the increase in weight of the multicore cables towards the point of entry of those cables onto the trussing.

- c) the possible dynamic effects on the trusses from the raising and lowering of the suspended equipment, or from the raising and lowering of the completed truss system.
- d) the wind forces that could load the truss system during erection and after completion in both the unloaded and fully loaded state.
- e) any additional windage attached to the system such as banners, roof skins, sound and lighting equipment, projection screens, scenery, etc.
- f) the effects of changes in temperature during the use of the system, of the weight of snow that may lie on the system or any covering, of seismic action that might affect the overall stability of the system, and of accidental impact damage occurring during the period in which the system is operational. The requirements of the local building codes and regulations shall be adhered to in all cases.

5.4.3 Consideration for all loads related to truss and tower systems used outdoors shall be in accordance with Section 3.5 of ANSI E1.21.

5.5 Handling

5.5.1 Individual modules and assembled trusses and towers, together with any ancillary components which form part of a complete system, shall not be subjected to impact damage and abrasion during handling.

5.5.2 The modules, trusses, and towers shall not be dragged around, but shall be carried or moved on dollies or trolleys; the modules and assemblies shall not be dropped, but shall be set down without damage or abrasion.

5.5.3 The modules, trusses, and towers shall be adequately secured and supported during transportation, and shall be stacked with sufficient spacers between successive heights and adjacent stacks to prevent abrasion.

5.5.4 End connections shall be protected from damage.

5.5.5 Attaching hardware shall be applied in a manner that does not cause damage.

5.6*Erection

5.6.1 Proper layout drawings and calculations shall be prepared for each use of the system and shall include the following minimum information:

- a) accurate overall dimensions,
- b) the locations of applied loads,
- c) the locations of suspension points and ground support points,
- d) the reactions at each suspension point and ground support point with supporting calculations.

5.6.2 Modules shall be inspected before assembly in accordance with Section 6 (User Inspection) and shall be assembled, joined together, and erected in accordance with the layout drawings and calculations by competent persons.

5.6.3 If the trusses are to be supported on towers which form part of the complete system, then a qualified person shall make a full assessment of the load bearing capabilities of the ground on which the towers are to be erected. If stipulated by the qualified person after their assessment, the ground shall be

improved to provide a suitable bearing surface or load bearing spreader plates of sufficient capacity and size shall be provided beneath the tower bases to adequately distribute the tower loads.

5.6.4 The completed system shall be inspected by a competent person prior to each use in accordance with Section 6 User Inspection

6 USER INSPECTION

6.1*Intent

The intent of this section is to establish minimum required inspection routines and guidelines for the module user. While every effort is made to provide a thorough listing of situations and inspection criteria, complete listings are beyond the scope of this standard. Specific advice shall be sought by the user for specific inspection routines from the manufacturer or a qualified person.

6.2 Inspection Classifications

Inspection procedures are divided into two primary classifications:

Frequent Inspections — Visual inspections with records not required to be kept. Frequent inspections shall be performed in accordance with Section 6.4 Frequent Inspection Procedures

Periodic Inspections — Visual inspections with records to be kept. Periodic inspections shall be performed in accordance with Section 6.5 Periodic Inspection Procedures.

6.3 Inspection Intervals

6.3.1 Initial Inspection

When purchased or acquired, whether new from the manufacturer or used, all modules shall be inspected in accordance with Section 6.4 with the difference that records shall be kept and maintained for the duration of possession. Such action shall establish the basis for the record keeping requirements.

6.3.2 Modules in regular service

Modules in regular service shall be subjected to both Frequent and Periodic Inspections as described in Sections 6.4 and 6.5.

6.3.3 Modules not in regular service

Frequent Inspections shall be performed on all modules not in use for a period of one month or more. Periodic Inspections shall be performed on all modules that have not been in service for a period of one year or more.

6.3.4 Permanent installations, stationary

Periodic inspections shall be performed on all modules permanently installed in a stationary and non-movable configuration. The frequency for such inspections shall be determined based upon the exposure to prevailing environmental conditions and consultation with the manufacturer or qualified person.

6.3.5 Permanent installations, moving

Periodic Inspections shall be performed every three months on all modules installed in a permanent configuration where movement of all or part of the system is an integral part of its use.

6.4 Frequent Inspection Procedures

Frequent inspections shall be performed by a competent person on behalf of the user. The inspections shall be conducted prior to each use and immediately after any incident that might have in any way caused damage to the system or any individual modules. Inspection criteria and routines shall be provided by the manufacturer.

The following items shall be inspected as described:

Geometry of trusses and towers for:

- twisting of the truss or tower
- racking of the truss or tower
- bending of the truss or tower

Chords for:

- dents
- bends
- abrasion

Diagonals for:

- dents
- bends
- abrasion
- being missing

Connecting plates (if used) for:

- flatness
- deformation or excessive wear of holes

Pinned connector Forks (if used) for:

- deformation

Fasteners for:

- proper grade - must be matched
- deformation
- excessive wear

Welds for:

- breaks, cracks, or deformation by visual inspection

6.5 Periodic Inspection Procedures

Periodic Inspections shall be performed by a qualified person on behalf of the owner at least once each year. Inspection criteria and routines shall be provided by the manufacturer. Truss shall be taken out of service during inspection. For permanent installations, whether fixed or moving, inspections shall be permitted during non-show times, with the units remaining in place.

The following items shall be inspected:

Geometry of trusses and towers for:

- twisting of the truss or tower
- racking of the truss or tower
- bending of the truss or tower
- sweep
- camber

Chords for:

- dents
- bends
- abrasion

Diagonals for:

- dents
- bends
- abrasion
- being missing

Connecting plates (if used) for:

- flatness
- deformation or excessive wear of holes
- corrosion
- deformation around fastener holes

Pinned connectors (if used) for:

- excessive abrasion
- deformation of connection pin holes
- method of connection to truss

Fasteners for:

- Proper grade - must be matched
- deformation
- Excessive wear

Welds for:

- Cracks by visual inspection - 100% all welds
- Abrasion by visual inspection - 100% all welds
(The User shall have dye penetration or other form of NDT performed on any weld that is thought to possibly be defective. These tests shall be performed by a qualified person.)

6.6 Records

Records shall be kept on file by the owner for each module and shall be dated and signed by the person conducting the inspection.

6.7 Repairs and Removal from Service

6.7.1 If any module shows significant visible damage or is suspected of containing a damaged element, whether visible or not, it shall be removed from service and marked accordingly. A qualified person shall perform and document an assessment of the module to determine if it can be repaired and subsequently returned to service. The type of repair that will ensure that the structural capacity of the module is maintained shall be stipulated by a qualified person.

6.7.2 Any module deemed to have irreparable damage shall be permanently removed from use or service.

6.7.3 Damaged modules shall be marked in a manner that clearly, visibly, and permanently indicates their condition.

6.7.4 Repairs shall be made by a qualified person.

Appendix A, Commentary

This commentary is not part of the Standard and contains no mandatory requirements. It offers some explanatory information about the clauses in the standard. The relevant clauses have the same clause number, but without the "A" prefix. The clause numbering here is not continuous because no comments are offered on some of the clauses in the Standard.

Since no mandatory requirements are stated in this commentary, if there is any disagreement between the text of this appendix and the requirements stated in the body of the standard, the requirements in the body of the standard shall prevail.

A.5.6 If the trusses are to be suspended from the roof beams or other structure within an existing building or from a framework that is not part of the complete trussing system, then a full assessment should be made by a qualified person of the roof beams or other structure from which the trusses are to be suspended. If necessary the position of the suspension points should be moved to other acceptable locations and/or suitable strengthening measures shall be made to the existing structure.

A.6.1 While every effort is made to provide a thorough listing of situations and inspection criteria, complete listings are beyond the scope of this standard. The user should seek advice on specific inspection routines from the manufacturer or a qualified person.