Table of Contents

3 PREFACE
   A. Disclaimer
   B. Acknowledgements
   C. About NGA

6 CHAPTER 01
   Introduction
      A. Glazing Used in Laminates
      B. Interlayers Used in Laminates
      C. Laminating Processes
      D. Types of Laminated Architectural Glass

15 CHAPTER 02
   Characteristics of Laminated Glass
      A. General
      B. Weight of Laminated Architectural Flat Glass
      C. Weathering
      D. Durability
      E. Coated Glass Lamination
      F. Optical Distortion in Laminated Glass
      G. Limitations
      H. Marking and Labeling of Architectural Laminated Glass

24 CHAPTER 03
   Applications
      A. Introduction
      B. Safety
      C. Structural Performance
      D. Windstorms and Hurricane Resistance
      E. Earthquake Resistance
      F. General Security
      G. Forced Entry Resistant Laminates
      H. Detention and Institutional Glazing
      I. Bullet Resistant Laminates
      J. Blast Resistant Glazing
      K. Multi Threat Resistant Glazing
      L. Solar Control
      M. Ultraviolet Radiation
      N. Glass Properties Pertaining to Photovoltaic Applications
      O. Sound Control
      P. Specialty Applications
CHAPTER 04
Handling, Storage and Glazing
   A. Receiving
   B. Storage
   C. Cutting Laminated Products
   D. Installation

CHAPTER 05
Maintenance and Cleaning

CHAPTER 06
Guide Specifications
   A. General Note

CHAPTER 07
Standards
   A. Glass Quality
   B. Safety
   C. Glass Strength/Resistance to Windborne Debris
   D. Acoustical
   E. Security
   F. Earthquake
   G. Weathering

CHAPTER 08
Surface Nomenclature

CHAPTER 09
NGA Reference Resources
   A. Glazing Manual
   B. Tempering Division Engineering Standards Manual
   C. Sealant Manual
   D. FGMA Fabrication, Erection & Glazing Hours Manual
   E. Heavy Glass Door Design Guide
   F. Glass & Glazing Estimating Essentials (formerly Blue Print Reading & Labor Estimating Course)
   H. Guide To The Glass And Glazing Requirements Of The Model Building Codes
   I. Glass Informational Bulletins
   J. Safety Bulletins

CHAPTER 10
Organizations Publishing Referenced Standards and Information

CHAPTER 11
Guidelines for Reference Manual Submittals
   A. General Laminated Glass
   B. Submittal Guidelines
List of Tables

13  TABLE 1: Typical Interlayer Thickness
19  TABLE 2: Approximate Weights of Interlayers
20  TABLE 3: Approximate Weight - Architectural Flat Glass
21  TABLE 4: Property to Allowable Change Reference Standards
33  TABLE 5: Safety Glazing Minimum Interlayer Thickness
35  TABLE 6: Performance Levels of Glass in Railing Systems, Guards and Balustrades
39  TABLE 7: Typical Protocol for Windborne Debris Impact and Cyclical Tests
42  TABLE 8: Typical Interlayer for Hurricane Performance
43  TABLE 9: Dynamic Racking Performance of Laminated Glass
44  TABLE 10: UL 972 Test Requirements
45  TABLE 10a: ASTM F1233 Forced Entry Sequence of Testing
47  TABLE 11: H.P. White Laboratories Tests
48  TABLE 12: WMFL Requirements
49  TABLE 13: ASTM F1233 Requirements
49  TABLE 14: ASTM F1915 Requirements
50  TABLE 15: CDCR-860 Levels of Performance
51  TABLE 16: UL 752 Ratings of Bullet-Resisting Materials
51  TABLE 17: NIJ Standard 0108.01 Ballistic Resistance Test Variables and Requirements
53  TABLE 18: Typical Thickness and Weights of Bullet Resisting Laminated Glass
53  TABLE 19: Hazard Levels and Descriptions
54  TABLE 20: Specification Levels
56  TABLE 21: ASTM F2395 Generic Requirements
56  TABLE 22: Solar Performance of Basic Laminates
57  TABLE 23: Solar Performance of Basic Laminated Insulating Glass Units
65  TABLE 24: Acoustical Data - Laminates with Standard PVB Interlayer
66  TABLE 25: Acoustical Data - Laminates with Acoustic PVB Interlayer
66  TABLE 26: Acoustical Data - Laminated Insulating Glass with Standard PVB Laminates
67  TABLE 27: Acoustical Data - Laminated Insulating Glass with Standard PVB Laminates
67  TABLE 28: Acoustical Data - Double Laminated Insulating Glass with Standard PVB Laminates
68  TABLE 29: Acoustical Data - Double Laminated Insulating Glass with Standard PVB Laminates
68  TABLE 30: Acoustical Data - UV Curable Resin Laminates
68  TABLE 31: Acoustical Data - UV Curable Resin Laminates
72  TABLE 32: Select Laminated Glazing with 45% or Less Visible Light Transmittance (VLT) for Coastal Apps.
76  TABLE 33: Installation Recommendations for All-Glass Laminates
List of Figures

12  FIGURE 1:  Laminating Line
13  FIGURE 2:  Seamed Edge
13  FIGURE 3:  Polished Edge
14  FIGURE 4:  Laminated Glass – Basic
14  FIGURE 5:  Laminated Glass – Composite
15  FIGURE 6:  Example of Bent Glass
17  FIGURE 7:  Laminated Glass Clad Polycarbonate
17  FIGURE 8:  Organic Coated Glass – Butyral
18  FIGURE 9:  Glass Clad Polycarbonate Laminate
21  FIGURE 10:  Example of Edge Blush
21  FIGURE 11:  Example of Delamination
22  FIGURE 12:  Glass Clad Polycarbonate with Edge Seal Film Applied
23  FIGURE 13:  Coating Applied to No. 2 Interior Surface
25  FIGURE 14:  Surface Nomenclature for Single Unit Laminated Glass
29  FIGURE 15:  ANSI Z97.1 Impact Test
31  FIGURE 16:  Example of Overhead Sloped Glazing
34  FIGURE 17:  Example of Glass in Guards
36  FIGURE 18:  Example of Glass in Stairs
36  FIGURE 19:  Example of Glass in Railings
38  FIGURE 20:  Example of Glass in an Aquarium
38  FIGURE 21:  Example of Glass in a Zoo Enclosure
38  FIGURE 22:  Example of Glass in a Stadium Box
40  FIGURE 23:  Typical Large Missile Impact Locations - Hung Window FBC HVWZ
40  FIGURE 24:  Typical Large Missile Impact Locations - Hung Window ASTM E1996-14; Wind Zone 3 - Level D
40  FIGURE 25:  Typical Large Missile Impact Locations - Hung Window ASTM E1996-14; Wind Zone 4 - Level D
41  FIGURE 26:  Typical Large Missile Impact Locations - Fixed Opening (no mullion) FBC HVWZ
41  FIGURE 27:  Typical Large Missile Impact Locations - Fixed Opening (no mullion) ASTM E1996-14; Wind Zone 3 - Level D
41  FIGURE 28:  Typical Large Missile Impact Locations - Fixed Opening (no mullion) ASTM E1996-14; Wind Zone 3 - Level D
41  FIGURE 29:  Typical Small Missile Impact Locations - Fixed Opening (no mullion) FBC HVWZ
41  FIGURE 30:  Typical Large Missile Impact Locations - Fixed Opening (no mullion) ASTM E1996-14; Wind Zone 3 - Level A
FIGURE 31:  Earthquake Dynamic Racking Test Apparatus
FIGURE 32:  Example of Forced Entry
FIGURE 33:  Bullet-Resistant Glazing Sample
FIGURE 34:  Blast Resistant Testing Sequence
FIGURE 35:  UVA Transmittance of Common Glasses
FIGURE 36:  UV Damage Ratings
FIGURE 37:  Example of Photovoltaic Glass
FIGURE 38:  Acoustical Glass Mock-Up
FIGURE 39:  Sound Transmission Loss Data
FIGURE 40:  STC and OITC Acoustical Ratings
FIGURE 41:  Acoustical Comparison on IGUs
FIGURE 42:  STC and OITC Acoustical Ratings
FIGURE 43:  Cured Resin Laminated Glass
FIGURE 44:  Example of Glass in Furniture
FIGURE 45:  Example of Bird-Friendly Glass Pattern
FIGURE 46:  Recommended Glazing Clearances and Bite
FIGURE 47:  Laminated Glass with Two Glass Lites and Expanded View
FIGURE 48:  Laminated Insulating Glass Unit
FIGURE 49:  Double Laminated Insulating Glass Unit
FIGURE 50:  Single Core Glass Clad Plastic Glazing
FIGURE 51:  Multi Core Glass Clad Plastic Glazing
FIGURE 52:  Asymmetrical Glass and Plastic Glazing
This Laminated Glazing Reference Manual is an updated edition of the original manual developed by the Glass Association of North America (GANA) in 2009. NGA and GANA combined into one association in February 2018.

This manual provides general descriptions concerning the basics of glass and glass performance. The manual does not purport to state that any particular type of glass or glass product should be used in any specific application. It is an educational tool as well as a guide to clarify and assist in the proper selection and specification of laminated architectural glazing materials. It is intended for use by architects, designers, engineers, component manufacturers (e.g., windows, doors, solariums, skylights, shower enclosures), and installers of laminated glazing materials in buildings. This manual provides both a broad-scope and detailed understanding of laminated architectural glazing materials. Laminated glass usage, performance characteristics, engineering information, technical data, and design opportunities, as well as how to handle, install and specify the products are addressed within.

The user of this manual has the responsibility to ensure that competent professionals select and install the glass in compliance with all applicable laws, rules, regulations, standards and other requirements. NGA does not design, develop or manufacture any products, processes or equipment referred to in this manual and, accordingly, makes no guarantee, representation or warranty, express or implied, as to their fitness, merchantability, patent infringement or any other matter respecting their performance. NGA cannot guarantee and disclaims any responsibility for any specific result relating to the use of this manual.

The standards referenced in the Laminated Glazing Reference Manual are under the jurisdiction of third-party organizations and agencies and are constantly subject to review and revision. The standards and similar documents referenced in this manual are those in effect as of the time of publishing. The manual user should refer to, consult and comply with the most recent edition of the referenced standards.

This manual is reviewed and revised on a regular basis by members of the Fabricating Committee. Procedures for submitting new information for consideration during the revision process are contained in Chapter 11, Guidelines for Reference Manual Submittals.

This manual does not contain all of the information available from all sources regarding the subjects presented. Additional information should be sought from manufacturers’ literature and applicable standards, codes and other regulations. Specifically, a review of all national, state and local building codes pertaining to glass safety and proper applications should be completed in order to identify all governing requirements and to assure product compliance. Except where specifically noted (i.e. footnotes, tables, charts), all standards referenced in this document are intended to be the latest available edition of such standards available at the time of publication.

A. DISCLAIMER

This manual was developed by the National Glass Association (NGA) and this disclaimer is made by the NGA (the Provider). The Provider shall not be held liable for any improper or incorrect use of the materials or information described and/or contained in this manual and assumes no responsibility for any user’s use of them.

In no event shall the Provider be liable for any direct, indirect, incidental, special, exemplary or consequential damages (including, but not limited to: procurement or substitute goods for services; loss of use or profits; or business interruption) however caused and on any theory of liability, whether in contract, strict liability or tort (including negligence or otherwise) arising in any way out of the use of this manual or materials and information herein, even if advised of the possibility of such damage.
This disclaimer of liability applies to any damages or injury, including but not limited to those caused by any failure of performance, error, omission, interruption, deletion, defect or under any cause of action.

B. ACKNOWLEDGEMENTS

The National Glass Association would like to thank the individuals and companies that have given their time and resources to updating the Laminated Glazing Reference Manual. We especially wish to thank the following for their contributions:

- Peter Anderson
- Brandon Barker
- Valerie Block
- Herb Buford
- Michael Burriss
- John Bush
- John Colapietro
- Joel Feingold
- Michael Griffin
- Jeff Haberer
- Bernie Herron
- Dan Laporte
- Michael Ondrus
- Julia Schimmelpenningh
- Aaron Thompson
- James Touchette
- Rick Wright

The members of NGA’s Fabricating Committee encourage users of this manual to review all plans and specifications before selecting a specific laminated architectural glazing product. The users of this manual should consider the potential safety hazards for each glass application. The appropriate type of glass should be specified in view of the perceived foreseeable risks of injury. Mere compliance with the applicable safety regulations, federal, state, and local may not be sufficient to avoid liability in all circumstances. These safety regulations represent only minimum standards, specifications and requirements.

C. ABOUT NGA

The National Glass Association (NGA) was founded in 1948. NGA combined with the Glass Association of North America (GANA) on February 1, 2018 to form the largest trade association serving the architectural glass and metals industry supply chain, including glazing contractors, full-service glass companies, glass fabricators, primary glass manufacturers and suppliers to the industry.

It is a technical powerhouse that brings some of the best minds to the table to create technical resources and promote and advocate for glass in buildings through its membership, its Forming, Fabricating and Installing committees and the Glazing Industry Code Committee (GICC).

NGA’s education and training programs—both online at MyGlassClass.com and in-person at association-sponsored events—and its official publication Glass Magazine, keep the industry knowledgeable and well-informed.

NGA produces the industry’s largest annual trade show in the Americas, GlassBuild America. It hosts the Building Envelope Contractors (BEC) Conference, the Glazing Executives Forum, as well as Annual and Fall Conferences. These educational and networking events bring together thousands of industry professionals to help them build more profitable businesses.