FOREWORD

This Handbook was prepared by Syracuse University under
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initiated under Project No. 7381, 'Materials Application',
Task No. 738103, 'Materials Information Development,
Collection and Processing.' The work was administered
under the direction of the AF Materials Laboratory, Research
and Technology Division with Mr. T. J. Reinhart, Jr.,
acting as project engineer.

This report covers work conducted from November 1960 to
February 1963.

Specific Acknowledgements and appropriate listing of
contributors will be found in Manual IA of this handbook.
The Associate Editors are indebted to many persons who
contributed freely to the efforts of the staff and to
representatives of various companies who cooperated en-
thusiastically and unselfishly.

Manuscript released by authors May 1963 for publication
as an AFDD Technical Documentation Report.

Approved for Public Release
ABSTRACT

The purpose of this technical documentary report is to partially satisfy the need for a design handbook specifically tailored for structural plastic applications in aerospace vehicles for the Air Force. This first edition contains a preliminary collection of technical data and information on these materials. The format and organization has been developed, based on consultation with a wide variety of industrial and government concerns, to be readily usable and concise. Information presented has been categorized into seven manuals discussing topics such as material properties, theoretical analysis, design procedures, processing and testing.

This technical documentary report has been reviewed and is approved.

D. A. CHINN
Chief, Materials Information Branch
Materials Applications Division
AF Materials Laboratory

Approved for Public Release
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Note: Complete contents of entire handbook will be found in Manual IA. The introduction to each individual manual gives the contents for that manual.
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INTRODUCTION

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Each of the above sections of this Manual is subdivided as appropriate to the subject.
1.0 ACKNOWLEDGMENTS

1.01 General

1.011 The first edition of Volume I of the Materials
                Application Handbook would not have been possible
                without the consistent and active efforts of a
                group of individuals and organizations over the
                country. Industry, in particular, has voluntarily
                given advice, information and manpower time. A
                considerable number of individuals from governmental
                agencies and industry have given freely of their own
                time and energies.

1.02 It would be impossible to acknowledge every individual
                or organization. The following are
                representatives of the companies who have
                contributed in the preparation of this volume.
                Additional acknowledgment of the personnel
                and information will be found in Section 3.0
                of this introduction.

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1.06 Acknowledgments

To the Forgiving and to all others who have helped
in this work to the various organizations and
individuals. Their interest, cooperation and
support would have been impossible, the authors wish
to restate their sincere appreciation.

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INTRODUCTION

The following discussion depicts the hierarchy behind the development of new vehicles, including the evolution and its benefits.

The design process is driven by the need for innovation and efficiency. It involves various stages from concept to production. The following steps summarize the process:

1. Conceptual Design:
   - Generation of ideas and initial sketches
   - Determination of basic parameters and requirements

2. Preliminary Design:
   - Detailed study of the concept
   - Creation of detailed designs
   - Evaluation of feasibility

3. Detailed Design:
   - Development of final designs
   - Component selection and integration
   - Detailed specifications for manufacturing

4. Prototype Development:
   - Building and testing prototypes
   - Identification of issues and refinement

5. Production:
   - Mass production and ongoing refinement
   - Market launch and after-sales support

In addition to the technical aspects, the design process also involves considerations such as sustainability, safety, and user experience. The integration of these factors is crucial for the success of new vehicle development.
In order to make the features required for a strong build-up, careful consideration was given to the use of materials that would be able to withstand the thermal conditions on the weft side of the specimen materials to ensure vehicle design and development of less or better combinations.

As it was known that the presentation of detailed data on reinforced plastic materials required a knowledge of both processes and methods under which material properties are directly affected by both of them. To satisfy this requirement, efforts were made to develop a framework for the screening, by means of the design and testing skills of the materials section. This section would further assist the designer, who would be required to ensure the materials are used in a manner that is consistent with the design and testing requirements.

When the organization of the text in the next chapter was considered, the text was divided into sections and subsections for ease of comprehension and use. A consistent division was maintained in the text by general topics. The breakdown of sections into a series of sections was created as indicated below.
Introduction

This document contains the results of the first effort to observe the objective progress made by the Task Force. It is largely comprised of the data and information gathered during three separate private meetings and three formal public meetings of the Task Force. In the first meeting, data collection methods and objectives were discussed. The second meeting was devoted to the development of a checklist, which was then used by the Task Force in the third meeting to determine the completeness and accuracy of the data collected. The final meeting was then devoted to the presentation of the data and the discussion of its implications.

The report was prepared by the Task Force, which was established by the Department of Defense in order to address the issue of the status of the Task Force. The report was approved by the Department of Defense and is intended to provide a comprehensive overview of the activities of the Task Force.

The report will be available for public release in the near future. The report will be available in electronic format and can be accessed through the Department of Defense's website. The report will also be available in print format and can be obtained through the Department of Defense's publications office.
4.0 USE

4.0.1 General

The purpose of this section is to provide a detailed discussion of the system's operational format and procedures. The emphasis is on the operational aspects of the system, and the discussion is presented in a logical manner. The section is divided into two parts: the introduction and the detailed analysis. The introduction provides an overview of the system, while the detailed analysis delves into the operational aspects.

4.0.2 Use by Content

The contents of this section are organized according to the main functional activities involved in most areas of the system. These activities are: design, analysis, maintenance, and operation.

4.0.2.1 Design

The design section involves planning (preliminary design), design definition, and selection of materials and processes.

4.0.2.1.1 Preliminary Design

The preliminary design requires background knowledge of technical applications and the design and operations used for these. Next, the detailed design, which can be divided into the following subcategories: conceptual design, which involves the selection of concepts and their application to the design. The detailed design is then divided into two main categories: conceptual design, which involves the selection of concepts and their application to the design, and the detailed design, which involves the selection of concepts and their application to the design.

Support for the design procedure will be found in the manual on the design analysis.

4.0.3 Selection of materials and processes requires general knowledge of practical types and detailed knowledge of specific properties, techniques, procedures, and methods. This is followed by a detailed analysis of the design and operation of the system. The detailed analysis is divided into two main categories: conceptual design, which involves the selection of concepts and their application to the design, and the detailed design, which involves the selection of concepts and their application to the design.

4.0.2.2 Analysis

Analysis involves both understanding of the detailed behavior of the materials involved and a detailed knowledge of theoretical approaches and operational aspects. The information is divided into two main categories: conceptual design, which involves the selection of concepts and their application to the design, and the detailed design, which involves the selection of concepts and their application to the design.

4.0.3 Materials

Structural applications of reinforced plastics require a detailed knowledge of the properties of the materials used. The properties of the materials are described in detail in the introduction.

4.0.3.1 Presentation of detailed property information is organized according to material classification and is divided into two main categories: conceptual design, which involves the selection of concepts and their application to the design, and the detailed design, which involves the selection of concepts and their application to the design. The detailed design is divided into two main categories: conceptual design, which involves the selection of concepts and their application to the design, and the detailed design, which involves the selection of concepts and their application to the design.
6.1A Use by Format
A new column format which decimal paragraph numbering was adopted by Software I, one of the hundreds. The numbering is not the previous one, which is not used. Information immediately adjacent to the last

6.1B Use by Formatting
It will be noted that each detail subject covered is consigned on the two sets of pages and particularly

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INTRODUCTION
5.05 Symbol abbreviations

[] = Degree, angle or temperature
[] = Project
[] = Pt., or lb./in²
[]= in lb. or a ton
[] = Plus or minus
[] = Equivalent
[] = Whether true, see in next or to greater than
[] = Less than, as in 50 or A is less than B
2.0 SPECIFICATIONS

2.1 INTRODUCTION

This section will collect all specifications covering various aspects of networked graphics. Since earlier reference to specifications was required in this first edition and some general specifications are already in the working library, these efforts in this area were delayed until a later edition is undertaken.

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Exhibit 24.11

General

The section will utilize all input providing definition or clarification to clarify their use.

A minimum of 50% input must be used. The text appropriately defined when they are introduced into the text.
Chapter 13: Design of Reinforced Concrete Members

13.10 Post-tensioning

13.10.1 Post-tensioning is the process of applying forces to concrete members to increase their strength and stiffness. This is accomplished by prestressing tendons, which are tensioned after the concrete has cured, causing the concrete to be compressed. This method is commonly used in the construction of bridges, buildings, and other structures to improve their durability and performance.

13.10.2 The design of post-tensioned members involves the selection of the prestressing tendons, the development of the concrete, and the detailing of the connections. The tendons are typically made of high-strength steel wires or strands, and they are anchored at both ends of the member. The concrete is typically placed in a form and then cured for a specified period of time. The tendons are then tensioned to the desired level and the concrete is placed in the form. The tendons are then grouted to fill any voids and the concrete is cured.

13.10.3 The design of post-tensioned members is governed by the provisions of the relevant codes and standards, such as the American Association of State Highway and Transportation Officials (AASHTO) specifications and the American Concrete Institute (ACI) codes. These codes provide guidance on the design of post-tensioned members, including the selection of the prestressing tendons, the development of the concrete, and the detailing of the connections.

13.10.4 The design of post-tensioned members is a complex process that requires a thorough understanding of the relevant codes and standards, as well as a detailed knowledge of the properties of the materials used. The design must be carefully checked for compliance with the relevant codes and standards, and it must be validated through the use of computer software.

13.10.5 The design of post-tensioned members is a critical aspect of the construction of modern structures, and it is essential to ensure the safety and durability of these structures. The design must be carefully checked for compliance with the relevant codes and standards, and it must be validated through the use of computer software.
It will be noted that for each structural identification and paragraph number will always indicate the same subject. This will facilitate the use of this Manual.

It will be further noted that the sections numbers for Parts 1 and 2 proceed each other being different only in the addition of 100 to those in Part 1 to derive those in Part 2.

For complete Table of Contents for the entire Handbook, see Manual 1b.

Abbreviations and Glossary

The procedure for various symbols adopted in this Handbook is identical to that used in Manual 1b. The system evolved is adopted from accepted procedures familiar within industry and research.

Standard symbols for design are as follows:

- A = cross sectional area
- C = constant
- E = modulus of elasticity
- F = force
- I = moment of inertia
- l = moment
- n = G
- P = point load
- S = constant
- Q = shear force
- T = torque
- W = energy of distortion
- X = angle
- Y = shear stress
- Z = deformation or deflection
- σ = stress
- i = Poisson’s ratio
- δ = strain or summation
- R = direct stress
- t = shear stress
- o = slope

These symbols are modified by subscripts selecting the symbol in a set of coordinates used in identifying the symbol as to type of item identified. These are clarified in the text or as indicated in Manual 1b. Introduction, Section 2.b.

For a complete listing of all abbreviations and definitions used throughout the Handbook, see Manual 1b.

Information Index

Where particularly important, the informative source is referenced directly within the text.

A complete source index is given in Manual 1b.
3.012.2 If the axial load is increasing, the allowable strain will drop to:

\[ \sigma = \frac{P}{A} \]

where:

- \( \sigma \) = Required compressive stress
- \( P \) = Axial load to be carried
- \( A \) = Cross-sectional area of the member

3.012.3 Then other factors mentioned in Section 2.012.1 must be remembered in designing, their effects will be to change the design rough from the value 0.52 to lower value. A designer must remember this in his design. It is recommended that for proper dimensions on which the load will be supported (See Section 2.012.7).

3.012.4 The method of fixing the load may be decided (See Section 2.012.9) after all the above information. A designer must make clear the design rough from the value 0.52 to lower value. A designer must remember this in his design. It is recommended that for proper dimensions on which the load will be supported (See Section 2.012.7).

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3.031.1 For short compression members, a design approach similar to the foregoing can be applied. The Steel Structures Group has developed additional procedures for handling designs through the use of charts which are discussed in a later section.

3.031.2 When the compression member is long and slender, its stability must be considered. For the present, it is assumed that the member is a chord of a T-section. The next best approach to design in this case is to determine the critical buckling stress, \( p_{cr} \), of a long, slender member as:

\[
\sigma_{cr} = \frac{E}{2(1-\nu^2)} \frac{r}{r_p}
\]

Where: \( r \) = radius of Elasticity to key line
\( r_p \) = Transverse length of the member to outside
\( r \) = radius of gyration of the cross-sectional in inches
\( p_{cr} \) = Stress at which elastic buckling is important in ksi

For design purposes, a factor of safety, \( n \), must be applied resulting in \( \alpha_{cr} = \frac{p_{cr}}{n} \). However, \( \alpha_{cr} \) (allowable stress) cannot be greater than the compressive stress permitted when there is no danger of buckling.

Given \( \alpha_{cr} \) is inversely affected by \( n \), the values of \( \alpha_{cr} \) and corresponding \( n \) must be derived to make \( L \) live a maximum.

3.031.3 Example Calculation:

\( \alpha_{cr} = 20,000 \) psi
\( L = 3 \) ft

References: Manual 20-11, Fig. 9.55a

Find: Required cross-sectional area and width

Calculation:

From Manual 20-11, Fig. 9.55a, \( \alpha_{cr} = 20,000 \) psi and \( \sigma_{cr} \) for rectangular sections\( = \frac{500}{A} \)

\[
\frac{500}{A} = \frac{2}{2\sqrt{2}}
\]

Therefore:

\( A = 2 \) in.\(^2\)

Therefore: \( \alpha_{cr} = 20,000 \) psi

3.032 Design Analysis - Composite Laminates

3.032.1 If the member is composed of a number of laminates bonded together in a composite in such a way that one lamina is on top of the next, and another lamina is on the top of the next, and so on, the procedure to design may be as outlined in the last section.

3.032.2 When metallic steel is applied to the composite, the procedure practically gives out if the properties of the composite are known in the direction of load. These properties may most easily be determined from a simple testing.

3.032.3 When the properties of the composite laminate are known in the direction of the testing, but are unknown for the principal axes of each laminate, the equations of charts of Manual 10 may be used to determine the properties in the direction of loading for each laminate separately, and then combined through the concept of the transformed section as outlined in Manual 10 Section 30 Applying the transformed section concept to a composite laminate, the following example illustrates the approach.

3.032.4 Example Calculation

Given: Composite shown in Fig. 9.55a, composed of two laminates, \( a \) and \( b \), each with a different orientation. Laminate \( a \)\( = \) Plywood (JL33-114)

\( \sigma_{pa} = 5,400,000 \) psi
\( \sigma_{pa} = 3,500,000 \) psi

Laminate \( b \)\( = \) Plywood (JL33-115)

\( \sigma_{pb} = 2,900,000 \) psi

Now, \( \sigma_{pa} = 1,570,000 \) psi

\( \sigma_{pb} = 0,507 \) psi

Load = 380 kip, tension applied along the \( x \)-axis (\( x = x \))

Width = \( w = 2 \) in.

References: Manual 20-11

Find: Stress in each laminate layer

Calculation:

From Manual 20-11, Eq. 3, 550-39, for laminate \( a \)

\[
\sigma_{pa} = \frac{500}{A} = \frac{1}{2} \left( 1 - r_p \right) \left( 1 - r_p \right)
\]

Therefore:

\( A = 380 \) kip

The properties of each laminate are known in the direction of the testing, but are unknown for the principal axes of each laminate. The equations of charts of Manual 10 may be used to determine the properties.
...
In some combination of the various products manufactured, a material referred to as 'reinforced plastic' is sometimes used in the manufacture of pressure vessels, tanks, and other similar products. This material is fabricated from a basic resin reinforced with fibers of glass, asbestos, or some other material. The fibers are usually of the glass type and are produced in the form of staple or continuous fibers. The resin is usually a thermosetting plastic, such as phenolic or unsaturated polyester. These materials are easily molded into various shapes and are used extensively in the manufacture of pressure vessels, tanks, and other similar products.

**Table 3.07.1**

<table>
<thead>
<tr>
<th>Material</th>
<th>Flexural Strength - psi</th>
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<tbody>
<tr>
<td>Epoxy</td>
<td>10</td>
</tr>
<tr>
<td>Phenolic</td>
<td>10</td>
</tr>
<tr>
<td>Polyester</td>
<td>10</td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>10</td>
</tr>
</tbody>
</table>

This table is intended to provide a general guide to the flexural strength of various materials used in the manufacture of pressure vessels and tanks. It is important to note that the values listed are approximate and may vary depending on the specific material and manufacturing process used.

It is also important to note that the properties of reinforced plastic can be affected by environmental factors, such as temperature and humidity. Therefore, it is important to design and manufacture these products with consideration for these factors. The design engineer should consult the manufacturer's specifications and recommendations for more detailed information on the properties and behavior of these materials in specific applications.
FIG. 3.042.34 REDUCTION CORRUGATE AND CORRUGATE FOR DIAMETER OF COMPRESSION GAUGING
Example Calculations

Example No. 1

Given: Grade 1, 11F, wet limestone with known allowable static compression load applied at 48

Reference: F. A. A. Charts and Equations

Find: Design ultimate compression stress at 8 = 10 after 3000 hours and exposure

Calculations:

Given: 11F = 0.002 (State Chart 3)

48 = 0.073 off 2000 hours

Design ultimate compression stress at 8 = 10 after 3000 hours and exposure

Design ultimate compression stress at 8 = 10 after 3000 hours and exposure

Example No. 2

Given: Same as Example No. 1

Reference: Same as Example No. 1

Find: Design ultimate compression stress at 8 = 10 after 3000 hours and exposure.

Calculations:

Since 11F = 0.002 (State Chart 3)

Design ultimate compression stress at 8 = 10 after 3000 hours and exposure

Design ultimate compression stress at 8 = 10 after 3000 hours and exposure

From Fig. 1.002.2B (Grade 1, compression, wet, 8 = 0):

From Fig. 1.002.3A (Grade 1, compression, wet, 8 = 0):
<table>
<thead>
<tr>
<th>MANUAL IC PRIMARY MATERIALS</th>
<th>IC R/</th>
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<td></td>
</tr>
<tr>
<td>REINFORCEMENTS</td>
<td>IC /R</td>
</tr>
</tbody>
</table>
8.01.0.7 Category Identification:
- 1 = General purpose
- 2 = Specialized mechanical or thermal property
- 3 = Other

8.01.0.8 Example: put "General purpose polymer test.

8.01.0.9 Identification Code:
8.01.0.10 Example Identification:
- 1 = Glass
- 2 = Glass, standard or similar
- 3 = Steel
- 4 = Aluminum
- 5 = Steel

The above may be modified by upper case letters following the number(s) as follows:
- H = High strength
- B = Bronze
- T = High temperature

If so modified, the modification is considered to be "as indicated".

8.01.1.0.2 Summary:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.3 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.4 Summary Identification:
- 1 = Glass
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- 3 = Bronze

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8.01.1.0.5 Summary Identification:
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8.01.1.0.6 Summary Identification:
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8.01.1.0.7 Summary Identification:
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8.01.1.0.8 Summary Identification:
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8.01.1.0.9 Summary Identification:
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8.01.1.0.10 Summary Identification:
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8.01.1.0.11 Summary Identification:
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- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.12 Summary Identification:
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- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.13 Summary Identification:
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- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.14 Summary Identification:
- 1 = Glass
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- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.15 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.16 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.17 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.18 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.19 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.20 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.21 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.22 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.23 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.24 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.25 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.26 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.27 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.28 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.29 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.30 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.31 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.32 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.33 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.34 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.35 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.36 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.37 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.38 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.39 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.40 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.

8.01.1.0.41 Summary Identification:
- 1 = Glass
- 2 = Steel
- 3 = Bronze

The summary code identification system can be readily adapted to include additional classes.
INTRODUCTION

2. MATERIALS AND CHEMICAL PROPERTIES

2.01 Thermal Properties
2.011 Temperature
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3. MECHANICAL PROPERTIES

3.01 Specified Mechanical Properties
3.02 Applied Mechanical Properties
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4. fabrication

4.01 For complete Table of Contents for the entire Handbook, see Manual 1A.
4.02 Abbreviations and Glossary

4.021 Abbreviations and symbols used in mechanical properties and other identification terms are identical to those used in Manual 0. See Section 1.12, Manual 0.

4.022 For complete listing of all abbreviations and definitions used throughout the handbook, see Manual 1A.
4.03 Information Sources

4.031 Each type of data presented is cross referenced appropriately.

4.032 A complete source index is given in Manual 1A.

4.4 Disclaimers. Future editions of this manual will include a general disclaimers of the entire (see disclaimer for various sections). The present reference is made to sections 1.0 thru 4.5 of the Introduction in Manual 1A.
GENERAL

Designation

Marking Code Designation: Pol
This code refers to general purpose, 600-volt rated, insulated in amber.

Commercial Designation - Interational Corp., 7/4-55, and LEBAR 91115.

Alternate Designations

Specification

1.02

Commodity

1.03

General Chemical Composition - 100% passive chromium, non-magnetic alloy steel, electroless nickel deposit in reverse mirror.

1.04

Raw Materials

1.05

General Chemical Structure, see figures, 1.0231, 1.0232, 1.0233.

1.06

Physical and Chemical Properties

1.061

General Notes - 1035V91.

1.062

Conditions available

1.063

Special Considerations

1.064

Insulated PARL 115 to a depth of a minimum of six inches when placed at 7°F or below. PARL 115 may cause irritation, avoid prolonged contact with the skin. Avoid prolonged breathing of vapor or dust and use with adequate ventilation.

1.065

1-1/2% brass should not be heated above 450°F. After heating in a copper mold, the piece should be allowed to cool to room temperature before being removed. It is strong enough for handling without cooling in the mold. Material heat (1200-1300°F) can be applied to latter complete case and final strength to some units. A little clamping will be needed if the heat is applied to the case and filled with the cold brass.

1.066

Physical and Chemical Properties

2.01

Density

2.0221

Density

2.0222

Density

2.0241

Density

2.0242

Density

2.025

Density

2.0251

Density

2.0252

Density
TABLE 2.431.1

<table>
<thead>
<tr>
<th>Source</th>
<th>Inorganic Corp.</th>
<th>Pisa</th>
<th>Hazelwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mica</td>
<td>75.0</td>
<td>0.00</td>
<td>3.19</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>5.15</td>
<td>5.12</td>
<td>5.0</td>
</tr>
<tr>
<td>Color, Graham</td>
<td>****</td>
<td>0.0</td>
<td>3.77</td>
</tr>
</tbody>
</table>

Approved for Public Release
<table>
<thead>
<tr>
<th>MANUAL ID MATERIAL SYSTEMS</th>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>POLYESTER</td>
<td>P0</td>
</tr>
<tr>
<td>EPOXY</td>
<td>Ep</td>
</tr>
<tr>
<td>PHENOLIC</td>
<td>Ph</td>
</tr>
<tr>
<td>SILICONE</td>
<td>Si</td>
</tr>
<tr>
<td>OTHER</td>
<td>O</td>
</tr>
</tbody>
</table>
This article includes a few trade name designations as examples of the various commercial materials referred to as being included in the text. It is not meant to be a complete listing of all trade names which may fall under the same classification in question. The identity of most of these trade names is not given if the material is not an appropriate source. False in this manner they may have been deleted for identifying purposes only. The reader should be advised that trademark is the property of each name, and should contact the appropriate company using the trademark if there be any question concerning their ownership.

3.02.2 All references to the Military Specifications, the Navy, Air Force, etc., are included.

3.02.3 Where appropriate, other accepted specifications, such as those of the American Society of Testing Materials (ASTM), are included.

3.02.4 Comments. This article includes a summary description of the primary materials which make up the material system in question.

3.02.5 Form and Configuration Available. This article includes in general the availability of the material system in question and the forms it may take. Such forms or properties, shapes, and the like are mentioned. All future editions may include additional information in this section.

3.03 Special Considerations. This article will include information on special items or as separate sections, as applicable, to the problems which may require special attention.

2.8 PHYSICAL AND CHEMICAL PROPERTIES

Since the first edition of the Manual application methods and the properties of commercial materials, only a certain number of properties were included for the various physical and chemical properties. Many of the data on these materials are available in the project library and impractical to include in this report but the basic information necessary to the properties which are included and the reader is referred to various other sources for detailed information on these properties. In reporting physical and chemical properties, there are matters such as plastic systems to which limited results are related to the specific properties which are generally used by the material system. The data in this section are for data system is in full scale.

2.41 Physical Properties. Included in this heading are such properties as plasticity, conductivity, creepage, mechanical and chemical, plasticity, elasticity, stability, and others.

2.42 Electrical Properties. Included in this heading are such properties as plasticity, conductivity, creepage, mechanical and chemical, plasticity, elasticity, stability, and others.

2.43 Physical Properties. Included in this heading are such properties as plasticity, conductivity, creepage, mechanical and chemical, plasticity, elasticity, stability, and others.

3.03.4 Ignition. "A combustible material will ignite when the atmosphere reaches a temperature high enough to cause a self-diffusing combustion reaction conditions of the fire." The data in this article is not the second part of the report. This definition of a combustible material will include the time of ignition of materials, the lowest temperature of autoignition of materials, and the lowest temperature at which a combustible will be ignited by a small external flame. It may be used to determine the temperature at which a combustible can be ignited by an external source.

2.42.2 Spreading. Spread, a particularly significant consideration in tabular form, is defined as the rate and extent of flames (combustion) propagation along the material interface and is the base of the fire, based on the base of the fire.

2.42.3 Flammability. This term generally used as an indication of the ability of a material to spread and is usually measured in terms of fire spread or extent per linear foot.

2.42.4 Extinguishment. Extinguishment may or may not be defined as the extinguishment of combustion (burning) caused by the interaction of the material and the environment. When materials are defined as having below ignition temperature or the rate of normal burning combustion without the use of a fire extinguishing agent.

2.43.1 Environmental Properties. Structural plastic materials can be useful in several environments. Although little reportable data on material systems, such systems will have such environments as a reason, various gases, and on site.

2.46 Nuclear Properties. This first edition of the Manual is not designed to deal with this subject. However, its importance with respect to the material systems of interest, is evident, and a survey of these properties is definitely planned.

2.46.1 Chemical Properties. In this section include all the material properties on which data are available, including various chemical properties. The section is divided into three tabular columns. All information given is useful. The reader of this section is not intended to be a source of trade names. Most of the data reported here is not intended to be a comprehensive source of data, but rather a convenient source of data, and in addition to specific material systems.
INTRO

property. The test methods used to obtain the required data are described in Section 7, which discusses these in more detail.

3.01 Specific Physical Properties. Although this Section is primarily a source of information to authors designing analytical, it attempts to provide data on specific physical properties. The following are the physical properties at specific times, and the data presented are typical of the standard conditions. These include density, moisture content, and other factors that may be important in a particular design. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.02 Optical Properties. The optical properties of the material under consideration should be included in the report to provide information on the performance of the material. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.03 Physical Properties. The physical properties of the material under consideration should be included in the report to provide information on the performance of the material. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.04 Mechanical Properties. The mechanical properties of the material under consideration should be included in the report to provide information on the performance of the material. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.05 Phase Diagrams. Phase diagrams are an important source of information on the performance of the material. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

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3.15 Phase Diagrams. Phase diagrams are an important source of information on the performance of the material. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.16 Composite Properties

3.16.1 See Section 3.01 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.16.2 See Section 3.02 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17 Composite Properties

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3.17.3 See Section 3.03 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.4 See Section 3.04 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.5 See Section 3.05 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.6 See Section 3.06 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.7 See Section 3.07 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.8 See Section 3.08 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.9 See Section 3.09 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.10 See Section 3.10 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.11 See Section 3.11 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.12 See Section 3.12 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.13 See Section 3.13 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.14 See Section 3.14 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.15 See Section 3.15 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.16 See Section 3.16 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.17 See Section 3.17 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.18 See Section 3.18 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.19 See Section 3.19 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.20 See Section 3.20 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.21 See Section 3.21 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.22 See Section 3.22 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.23 See Section 3.23 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.24 See Section 3.24 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.25 See Section 3.25 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.26 See Section 3.26 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.27 See Section 3.27 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.

3.17.28 See Section 3.28 for a discussion of composite properties. A large amount of data is available on composite properties, and the most common factors are the types of materials used. The data presented are based on data available in the literature. The accuracy of the data is indicated in Section 7.
Because of the different nature of this property, it is modified by restricting properties to a different manner than the forming properties. This block is also included in the following article.

3.06. Creep and Creep Recovery

3.06.1 Creep rupture strength (often called stress rupture strength) is an indicated stress, simply the stress at which the material fails under the conditions prescribed, normally at a constant temperature. The significance of this property is that it is not permitted. Creep rupture test is also significant for application considerations; however, comments of this are seldom recorded or taken during the test.

3.06.2 Reliable assumption may be range rupture limits to reveal potential embrittlement which may occur within a certain range of temperature and time.

3.06.3 The many variables considered for creep and creep rupture tests should be one of the methods of graphical presentation. In the Manual, stress is plotted on a log-log scale, usually with one or two other variables as a parameter.

3.06.4 Steady State

3.06.4.1 Total strain, stress, and creep cannot be isolated on the parameters of a single stress or time curve. However, maximum strain, minimum stress, and maximum stress are shown on the steady-state curves for the test, strain and stress are shown as the strains necessary to obtain the strain on the ordinate. If this strain component is not included, creep is obtained. This is somewhat indefinite because of the necessity regarding the modulus of elasticity, indicated by the largest of all the critical value.

3.06.2.2 As is this strain, all information on creep or total stress is approximately available. If and when these data become available, it will be included in the section.

3.06.3 Master Curve

3.06.3.1 Many attempts have been made, particularly for metals, to analyze creep and recovery information in a single master curve. Although it is not clear that all stress, strain, and time curves can be included in this curve, the effort has been made to obtain the selection of materials and planning for future research in this area.

3.06.3.2 When data available for presentation in this section become available, it will be included in the section.

3.06.4 Other, any creep or stress rupture information which can be included for the stores conditions will be presented in this article.

3.10 Fatigue Properties

3.10.1 These properties are not required for metal which stress-strain characteristics in a single manner are used. Although it is not clear that all stress, strain, and time curves can be included in this curve, the effort has been made to obtain the selection of materials and planning for future research in this area.

3.10.2 Because of the different nature of this property, it is modified for reporting purposes in a different manner than the forming properties. This block is also included in the following article.

3.01 U-Curve

3.01.1 The main curve method of presenting fatigue data is by the use of a U-curve. Cases plot the alternating stress to cause failure for the range of stress vs. the cycles at which failure occurs. This method is used only on stress rupture test metal behavior and is used.

3.01.2 To define a series of fatigue tests, it is common practice to use a "stress ratio" which is defined as:

\[ R = \frac{S_{	ext{min}}}{S_{	ext{max}}} \]

For example, if the applied stress alternates between the upper and lower bound, one has R = 0 (full ratio).

3.01.3 The alternate definition of the stress ratio is often used:

\[ R = \frac{S_{	ext{min}}}{S_{	ext{max}}} \frac{S_{	ext{max}}}{S_{	ext{min}}} \]

where:

- S (alternating stress) = \( S_{\text{min}} \) or \( S_{\text{max}} \)

The stress ratio \( \frac{S_{\text{min}}}{S_{\text{max}}} \) for example, in comparing to 6 above, if R = 0, then A = 1 and if R = -1, A = 0.

3.01.4 In reporting fatigue data in this Manual, either "R" or "S" of both or neither as appropriate.

3.02 Stress-Rate Diagrams

3.02.1 Often a series of fatigue data is developed for each test stress rate. Such information is best presented in a stress range diagram which plots alternating stress as the ordinate on the x-axis, while the stress at which failure occurs is shown as the stress range on the y-axis. Corresponding failure times are then plotted as points on the graph with the x-y curve showing the number of cycles under specific conditions, usually 10, 100, 1000, etc.

3.02.2 The fatigue strength can be derived from a stress range curve for the following relationship:

\[ \frac{\tau}{\sigma_{\text{r}}} = 0.5 \]

Where:

- \( \tau \) (max) is maximum fatigue stress
- \( \sigma_{\text{r}} \) is fatigue strength

3.02.3 Other, fatigue information which does not fit into these stress articles will be included under this heading.

10 Electric Properties

10.1 Under this heading not only the electrical resistivity properties, but also the largest and smallest resistivities, when available, are reported. This section is organized by the test method followed in obtaining the material as shown, comparisons etc. Each of these in shown section a section in the top of those materials (ohm-cm, ohm-m, k-ohm-cm, etc.) and the variables following under:

10.1.1 Module of Elasticity in Ohm-cm

10.1.2 The module of elasticity in ohm-cm, the major material's elastic constant, is the ratio of the stress applied to the corresponding strain produced. This is a characteristic stress-strain curve. This shape is often used to determine the stress-strain properties of a material. This shape is often used to determine the stress-strain properties of a material. Therefore, the materials, at least, the dynamic modulus in gigans-tensile strength, as well as the modulus for elastic materials, tensile strength, and the modulus for elastic materials.

10.1.3 The modulus of elasticity in ohm-cm is the ratio of the stress applied to the corresponding strain produced. This is a characteristic stress-strain curve. This shape is often used to determine the stress-strain properties of a material. Therefore, the materials, at least, the dynamic modulus in gigans-tensile strength, as well as the modulus for elastic materials, tensile strength, and the modulus for elastic materials.

10.1.4 The modulus of elasticity in ohm-cm is the ratio of the stress applied to the corresponding strain produced. This is a characteristic stress-strain curve. This shape is often used to determine the stress-strain properties of a material. Therefore, the materials, at least, the dynamic modulus in gigans-tensile strength, as well as the modulus for elastic materials, tensile strength, and the modulus for elastic materials.
INTRO

2.392 The modulus of elasticity in compression is numerically equal to the tensile modulus. However, remarkable differences often exist between these values, which can affect the behavior of materials under compressive loads.

2.393 The compressive tangent modulus is often preferred for design purposes due to its higher values compared to the tensile modulus.

3.101 See also Sections 3.101.3 thru 3.101.4.

3.102 The modulus of elasticity in tension is a measure of the material's ability to resist deformation under tensile loads.

3.103 The modulus of elasticity in shear is a measure of the material's ability to resist shear deformation.

4. MATERIAL SYSTEMS

Although no information is presented under this title in this edition of Manual 10, it is definitely anticipated that future editions will add data to this section. The purpose of this section will be to provide a comprehensive overview of the behavior of various materials under different conditions, such as tensile, compressive, and shear loads. It will also include the effects of environmental factors and the behavior of materials in their natural state.
1. MATERIAL SYSTEMS

1.01 Designations

1.01.1 Standard Code Designations. This code refers to a general purpose polyester-glass sheet laminate system, the resin being DDS reactive and composed of unaminated salicyldehyde dissolved in styrene monomer.

1.01.2 Commercial Designations.

1.01.3.1 Commercial designations are as indicated in data reported in this section.

1.01.3.2 Typical commercial designations include: Telene 909/180, Suprene 745/180, Dupont V-691, Polyester 909/180, etc.

1.01.3 Alternate Designations.

1.02 Specifications. Table 1.03.

1.03 Composition

1.03.1 Materials included in this section are systems of thermosetting reinforced bonded laminates in which either polyester or phenolic resin is employed. General purpose polyester resins and standard glass cloth reinforcements.

1.03.2 For normal structural applications a resin content of 50 to 60 per cent appears to be standard.

1.03.3 Due to wide spread acceptance and use, all woven glass cloth is acid as a basic reinforcement for data reporting.

1.03.4 Other material systems utilizing different types of reinforcements will be found elsewhere in this Manual. Individual primary materials are described in Material 1.

1.04 Form and Conditions Available

1.04.1 Rolls can be produced in shop by utilizing individual resins, powder or liquid, and glass cloth in the unit lay-up process.

1.04.2 Prepreg, dry-sheet, material can also be easily secured with a variety of compositions.

1.04.3 Rolls can be secured in a variety of fabricated shapes such as flat, curved or corrugated sheets; tubes; rods; or structural shapes including beams, Test, and Channels. Only properties of material in sheet form are reported herein.

1.04.4 Due to inherent properties of this material, it can be formed and prefered in almost any shape or size.

1.05 Special Considerations

1.05.1 Careful consideration should be given to the recomman- dations and suggestions of material suppliers with respect to bending, storage, processing and curing.

2. PHYSICAL AND CHEMICAL PROPERTIES

2.01 Thermal Properties

2.01.1 Thermal Degradation

2.01.1.1 Weight loss due to exposure to elevated temperatures, Fig. 2.01.1.

2.012 Conductivity

2.01.3 Expansion

2.01.4 Specific heat

2.01.5 Dielectricity

2.01.6 Emmissivity

2.01.7 Ablation

2.018 Other

TABLE 1.03

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<td>Plastic, Laminates, Phenolic Glass Reinforced, NEMA Structural Laminates</td>
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<td>HCL-P</td>
<td>Balsa, Polymer, Low Density Laminates</td>
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<td>HCL-P</td>
<td>Balsa, Polymer, Low Density Laminates, Fire Resistance</td>
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<td>3003-59</td>
<td><em>Laminated Thermostatic Material</em></td>
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* This code does not identify a specific resin.

FIG. 2.01.1 MAJOR SIZING AND USE IN EXPOSURE TO ELEVATED TEMPERATURES

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TABLE 3.011

<table>
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<tr>
<th>Property</th>
<th>Test Specimens</th>
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<th>240 to 270</th>
<th>270 to 300</th>
<th>300 to 330</th>
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(1) All values are average of at least 5 specimens. If results are questionable, they may be disregarded.

3.02 Typical Mechanical Properties

3.021 Typical Mechanical Properties of Polycarbonate Sheet of Various Colors and Geometries, Table 3.021.

3.023 Typical Mechanical Properties of Two-Layered Polycarbonate Sheet, Table 3.023.

3.024 Typical Mechanical Properties of Polycarbonate Sheet Produced by Various Processes, Table 3.024.

3.025 Typical Properties of Polycarbonate Sheet, Table 3.025.

3.026 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.026.

3.027 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.027.

3.028 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.028.

3.029 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.029.

3.021 Typical Mechanical Properties of Polycarbonate Sheet of Various Colors and Geometries, Table 3.021.

3.023 Typical Mechanical Properties of Two-Layered Polycarbonate Sheet, Table 3.023.

3.024 Typical Mechanical Properties of Polycarbonate Sheet Produced by Various Processes, Table 3.024.

3.025 Typical Properties of Polycarbonate Sheet, Table 3.025.

3.026 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.026.

3.027 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.027.

3.028 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.028.

3.029 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.029.

3.021 Typical Mechanical Properties of Polycarbonate Sheet of Various Colors and Geometries, Table 3.021.

3.023 Typical Mechanical Properties of Two-Layered Polycarbonate Sheet, Table 3.023.

3.024 Typical Mechanical Properties of Polycarbonate Sheet Produced by Various Processes, Table 3.024.

3.025 Typical Properties of Polycarbonate Sheet, Table 3.025.

3.026 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.026.

3.027 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.027.

3.028 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.028.

3.029 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.029.

3.021 Typical Mechanical Properties of Polycarbonate Sheet of Various Colors and Geometries, Table 3.021.

3.023 Typical Mechanical Properties of Two-Layered Polycarbonate Sheet, Table 3.023.

3.024 Typical Mechanical Properties of Polycarbonate Sheet Produced by Various Processes, Table 3.024.

3.025 Typical Properties of Polycarbonate Sheet, Table 3.025.

3.026 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.026.

3.027 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.027.

3.028 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.028.

3.029 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.029.

3.021 Typical Mechanical Properties of Polycarbonate Sheet of Various Colors and Geometries, Table 3.021.

3.023 Typical Mechanical Properties of Two-Layered Polycarbonate Sheet, Table 3.023.

3.024 Typical Mechanical Properties of Polycarbonate Sheet Produced by Various Processes, Table 3.024.

3.025 Typical Properties of Polycarbonate Sheet, Table 3.025.

3.026 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.026.

3.027 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.027.

3.028 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.028.

3.029 Typical Effects of Weathering on Mechanical Properties of Polycarbonate Sheet, Table 3.029.
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**Table 3.21**

**Source**
- TPS 1968
- ESL 1968
- PRL 1972
- TPS 1972
- ESL 1972
- PRL 1972
- ESL 1978
- TPS 1978
- ESL 1978
- PRL 1978

**Property**
- SO₂
- CO₂
- N₂

**Dry**
- 0.4
- 0.4
- 0.4

**Wet**
- 0.4
- 0.4
- 0.4

**Remarks**
- TPS, 12°C, 100 min., 220-250
- ESL, 95°C

**Notes**
- Wet
- Dry

**Source**
- TPS 1968
- ESL 1968
- PRL 1972
- TPS 1972
- ESL 1972
- PRL 1972
- ESL 1978
- TPS 1978
- ESL 1978
- PRL 1978

**Property**
- SO₂
- CO₂
- N₂

**Dry**
- 0.4
- 0.4
- 0.4

**Wet**
- 0.4
- 0.4
- 0.4

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(1) All figs of 2 or more
(2) In lb/lb
(3) 1.45% Mn, 0.1% Silicon, 0.05% Carbon, 0.25% P, 0.025% S

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# Table 3.4-5

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<th>Test</th>
<th>Property</th>
<th>25°C</th>
<th>50% RH</th>
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</table>

**Notes:**
1. 25°C test.
2. 0.05% 2-mercaptoethanol + 0.25% aminotadine.
3. 0.07% 2-mercaptoethanol + 1% pyridine.
4. 1% of 3 or more.

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### TABLE 3.257

<table>
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<tr>
<th>Material</th>
<th>82.8% Cu-7.2% Pb-5% Zn</th>
<th>61.4% Cu-38.6% Zn</th>
<th>65.2% Cu-34.8% Zn</th>
<th>67.5% Cu-32.5% Zn</th>
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### TABLE 3.258

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<th>65.2% Cu-34.8% Zn</th>
<th>67.5% Cu-32.5% Zn</th>
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### TABLE 3.259

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### TABLE 3.260

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<tr>
<td>Test</td>
<td>75% Cu-25% Zn</td>
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3.01 Tensile Properties

3.01.1 Stress Strain relationships

3.01.2 Average stress strain curves for Polim laminates with various cloth reinforcements, Fig. 3.01A.1.

3.01.3 Average stress strain curves for Polim laminates at various angles $\theta$, Fig. 3.01.A.2.

3.01.4 Stress strain curves at room and elevated temperatures for typical Polim laminate, Fig. 3.01.A.3.

3.02 Physical Effects

3.02.1 Effect of thickness on tension properties of Polim laminates, Fig. 3.02.1.
3.403.1 Effect of thickness and scale on tension properties of plywood laminates, Fig. 3.403.2.
3.403.2 Effect of thickness and surface coating of tension properties of plywood laminates, Fig. 3.403.2.
3.403.3 Effect of test direction on tension properties of plywood (l2l) laminate, Fig. 3.403.3.
3.403.4 Effect of test direction on tension properties of plywood (l12) laminate, Fig. 3.403.3.
3.403 Processing effects, see Section 3.02.
3.404 Environmental stresses
3.404.1 Effect of test temperature on tension strength of plywood (l2l) laminates, Fig. 3.404.1.
3.404.2 Effect of test temperature on tension strength of plywood (l12) laminates, Fig. 3.404.1.
3.404.3 Effect of test temperature and test direction on tension strength of plywood laminates, Fig. 3.404.1.
3.404.4 Effect of exposure and heat temperature on tension strength of plywood laminates, Fig. 3.404.4.

---

**Fig. 3.403.2** EFFECT OF THICKNESS AND SCALE ON TENSION PROPERTIES OF PLYWOOD LAMINATES

**Source:** PFL 1012, 1978

**Material:** Selectron 5050/12-114

**Tension:** 11.14 in. 100 min., 220-250°F

**Tests:** 35 tests

- **G0:** Grade 0 - laminate - Rep. of 10
- **G1:** Grade 1 - laminate - Rep. of 1
- **G2:** Grade 2 - laminate - Rep. of 1
- **G3:** Grade 3 - laminate - Rep. of 1
- **G4:** Grade 4 - laminate - Rep. of 1

---

**Fig. 3.403.3** EFFECT OF TEST TEMPERATURE ON TENSION PROPERTIES OF PLYWOOD LAMINATES

**Source:** PFL 1012a, 1978

**Material:** Selectron 5050/12-114

**Tension:** 11.14 in. 100 min., 220-250°F

**Tests:** 35 tests

---

**Fig. 3.403.4** EFFECT OF TEST DIRECTION ON TENSION PROPERTIES OF PLYWOOD (L12) LAMINATE

**Source:** PFL 1012b, 1978

**Material:** Selectron 5050/12-114

**Tension:** 11.14 in. 100 min., 220-250°F

**Tests:** 35 tests

---
3.031 Other effects

3.033 Effect of moisture content on the tensile properties of Polyc with mastic, Table 3.032.1.

3.04 Composite Properties

3.041 Stress-Strain Relationship

3.041.1 Average stress strain curve for Polyc with mastic at various moisture contents, Fig. 3.041.1.

3.041.2 Average stress strain curve for Polyc with mastic at various moisture levels, Fig. 3.041.2.

3.042 Physical Effects

3.042.1 Effect of moisture content on the tensile properties of Polyc with mastic, Fig. 3.042.1.

3.042.2 Effect of temperature and moisture on the tensile properties of Polyc with mastic, Fig. 3.042.2.

3.042.3 Effect of test duration on the tensile properties of Polyc with mastic, Fig. 3.042.3.

3.042.4 Effect of test duration on the tensile properties of Polyc with mastic, Fig. 3.042.4.

Table 3.032.1

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<td>Tensile strength</td>
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<td>30,311</td>
</tr>
</tbody>
</table>

3.043 Average Stress-Strain Curve for Polyc with Various Moisture Conditions

3.043.1 Average Stress-Strain Curve for Polyc with Various Moisture Conditions

3.043.2 Average Stress-Strain Curve for Polyc with Various Moisture Conditions

Source: 3.043.2

Material: 3.043.2

Process: HP, HP, HP

Tensile strength: 30,311

Average Stress-Strain Curve for Polyc with Various Moisture Conditions

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Effect of test direction on compressive properties of Poly (143 glass) laminate, Fig. 2.062.1.

Effect of test direction on compressive properties of Poly (143 glass) laminate, Fig. 2.062.2.

Processing Effects, see Section 3.03.

Environmental Effects

Effect of exposure and test temperature on compressive strength of Poly laminate, Fig. 2.064.1.

Other Effects

Effect of prismatic and room temperature on compressive strength of Poly laminate, Table 2.064.1.

Figure Properties

Stress Strain Relationships

Average load deflection curves for Poly laminate with various glass reinforcements, Fig. 2.065.1.

Physical Effects

Effect of thickness on glass strength of Poly laminate with voids, Fig. 2.065.1.
ID

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Materials Systems

5.052.1 Effect of depth/width ratio on flexure properties of pultruded laminates, Fig. 5.052.2

5.052.2 Processing effects

5.052.3 Effect of % NaCl and pH of immersion in solution properties of pultruded laminate, Table 5.052.4

5.053 Environmental effects

5.056.1 Effect of test temperature on flexure strength of typical pultruded laminate, Table 5.056.2

5.056.2 Effect of exposure test temperature on flexure properties of typical pultruded laminate, Table 5.056.3

5.056.3 Effect of wetting on flexure properties of typical pultruded laminate, Table 5.056.4

---

Table 5.052.1

<table>
<thead>
<tr>
<th>Property</th>
<th>Material</th>
<th>Temp. (°C)</th>
<th>pH</th>
<th>NaCl (.%)</th>
<th>25°C</th>
<th>50°C</th>
<th>75°C</th>
<th>100°C</th>
<th>125°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/cm³)</td>
<td>0.99</td>
<td>0.98</td>
<td>0.96</td>
<td>0.94</td>
<td>0.92</td>
<td>0.90</td>
<td>0.88</td>
<td>0.86</td>
<td>0.84</td>
</tr>
</tbody>
</table>

---

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# MATERIAL SYSTEMS

<table>
<thead>
<tr>
<th>Material</th>
<th>TPS, LBF, 14g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brinell</td>
<td>2500/1400 (250x1400)</td>
</tr>
<tr>
<td>Rockwell</td>
<td>C 2506/1450 (250x1450)</td>
</tr>
<tr>
<td>Hardness</td>
<td>165/165</td>
</tr>
<tr>
<td>Density</td>
<td>2.86 pg/cm³</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Property</th>
<th>T</th>
<th>15%</th>
<th>20%</th>
<th>30%</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
<th>70%</th>
<th>80%</th>
<th>90%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (GPa)</td>
<td>192.2</td>
<td>187.5</td>
<td>182.8</td>
<td>178.1</td>
<td>173.4</td>
<td>168.7</td>
<td>164.0</td>
<td>159.3</td>
<td>154.6</td>
<td>149.9</td>
<td>145.2</td>
</tr>
<tr>
<td>ν</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>σy (MPa)</td>
<td>430</td>
<td>420</td>
<td>410</td>
<td>400</td>
<td>390</td>
<td>380</td>
<td>370</td>
<td>360</td>
<td>350</td>
<td>340</td>
<td>330</td>
</tr>
<tr>
<td>σu (MPa)</td>
<td>550</td>
<td>540</td>
<td>530</td>
<td>520</td>
<td>510</td>
<td>500</td>
<td>490</td>
<td>480</td>
<td>470</td>
<td>460</td>
<td>450</td>
</tr>
<tr>
<td>H (GPa)</td>
<td>65.9</td>
<td>65.9</td>
<td>65.9</td>
<td>65.9</td>
<td>65.9</td>
<td>65.9</td>
<td>65.9</td>
<td>65.9</td>
<td>65.9</td>
<td>65.9</td>
<td>65.9</td>
</tr>
</tbody>
</table>

Note: The above data is for illustrative purposes only. The actual properties may vary depending on the specific material and manufacturing process. Always consult the manufacturer's specifications for the most accurate information.
<table>
<thead>
<tr>
<th>Source</th>
<th>PEL 1411, ppm</th>
<th>Material</th>
<th>Retest No. 4661-114</th>
<th>Retest No. 4661-114 &amp; 0.125 &amp; 0.015, 12 fl</th>
<th>Retest No. 4661-114 &amp; 0.125 &amp; 0.015, 12 fl</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.125 &amp; 0.015 &amp; 12 fl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>20 min, 220°F</td>
<td>16 hr, 72°F</td>
<td>15 min, 240°F + 4 fl</td>
<td>16 hr, 72°F</td>
<td>20 min, 220°F + 30 min, 250°F</td>
</tr>
<tr>
<td>Catalyst</td>
<td>HP - X</td>
<td>ESP, 0.65</td>
<td>Promoter = 3</td>
<td>2</td>
<td>HP - X</td>
</tr>
<tr>
<td>Test</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>pH - X</td>
<td>7.87</td>
<td>7.87</td>
<td>7.87</td>
<td>7.87</td>
<td>7.87</td>
</tr>
<tr>
<td>ESP - X</td>
<td>1.77</td>
<td>1.77</td>
<td>1.77</td>
<td>1.77</td>
<td>1.77</td>
</tr>
<tr>
<td>HP - X</td>
<td>50.3</td>
<td>50.3</td>
<td>50.3</td>
<td>50.3</td>
<td>50.3</td>
</tr>
<tr>
<td>HP - X</td>
<td>43.5</td>
<td>43.5</td>
<td>43.5</td>
<td>43.5</td>
<td>43.5</td>
</tr>
<tr>
<td>HP - X</td>
<td>43.5</td>
<td>43.5</td>
<td>43.5</td>
<td>43.5</td>
<td>43.5</td>
</tr>
<tr>
<td>HP - X</td>
<td>22.2</td>
<td>22.2</td>
<td>22.2</td>
<td>22.2</td>
<td>22.2</td>
</tr>
<tr>
<td>Resist 1000°K</td>
<td>60.5</td>
<td>60.5</td>
<td>60.5</td>
<td>60.5</td>
<td>60.5</td>
</tr>
<tr>
<td>Resist 1000°K</td>
<td>2.27</td>
<td>2.27</td>
<td>2.27</td>
<td>2.27</td>
<td>2.27</td>
</tr>
<tr>
<td>Resist 1000°K</td>
<td>2.27</td>
<td>2.27</td>
<td>2.27</td>
<td>2.27</td>
<td>2.27</td>
</tr>
</tbody>
</table>

| Resistance | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 | 60.5 |
| sensing has | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 | 5.1 |
| sensing has | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 | 2.27 |

Note: All values are in micro-ohms.
TABLE 3.03.1

<table>
<thead>
<tr>
<th>Property</th>
<th>Sisal</th>
<th>Palm</th>
<th>Toti</th>
<th>Toot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/cc)</td>
<td>0.03</td>
<td>0.05</td>
<td>0.06</td>
<td>0.07</td>
</tr>
<tr>
<td>Moisture Absorption (%)</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>3-Min. out-door</td>
<td>60</td>
<td>50</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>3-Min. in-door</td>
<td>50</td>
<td>40</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>

**Note:** Moisture absorption 14% of fibers properties of palm leaves.

---

**Figure 3.03.1:** Effect of moisture absorption on fiber properties of palm leaves, Fig. 3.03.1.

**Figure 3.03.2:** Effect of moisture absorption on fiber properties of palm leaves, Table 3.03.1.

---

**Approval for Public Release:**
FIG. 3.06.3 AVERAGE STRESS-STRAIN CURVES IN PANEL PROBE FOR Polycarbonate in WET AND DRY CONDITIONS

FIG. 3.06.1 AVERAGE STRESS-STRAIN CURVES IN PANEL PROBE FOR Polycarbonate in DAMAGED CONDITION

FIG. 3.06.2 AVERAGE STRESS-STRAIN CURVES IN PANEL PROBE FOR Polycarbonate in DAMAGED CONDITION

128 Wp 0.250
60 Wp 0.250
30 Wp 0.250

Material: Polycarbonate 300/310, Thickness = 0.156

Source: WP-1309, 1956

Proven: PW = 1.6 psi, 100 psi, 250 psi

Test: 70/650 Panel Stress

40 to 60

12

0

45

10

6

2

0

2

FIG. 3.06.1 WEATHERING EFFECTS ON POLYCARBONATE PANELS FOR Maximum Stress, psi, and Temperature, F

Material: Polycarbonate 300/310, Thickness = 0.156

Process: PW = 1.6 psi, 100 psi, 250 psi

Test: 70/650 Panel Stress

40 to 60

12

0

45

10

6

2

0

2
FIG. 1: EFFECT OF TEST DIRECTION ON PANEL BEHAVIOR

FIG. 2: EFFECT OF TEST DIRECTION ON BENDING STIFFNESS OF TYPICAL PANEL LAMINATES

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Material Systems

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5.07 Bearing Properties
5.07.1 Stress-Strain Relationships
5.07.2 Physical Effects
5.07.2.1 Bearing strength of PDC (112 clint) laminate for various e (edge/0) ratio and at various angles φ, Fig. 5.07.2.1.
5.07.2.2 Bearing strength of PDC (112 clint) laminate for various e (edge/0) ratio and at various angles φ, Fig. 5.07.2.2.
5.07.3 Bearing strength of PDC (116 clint) laminate for various e (edge/0) ratio and at various angles φ, Fig. 5.07.3.
5.07.4 Bearing strength of PDC (118 clint) laminate for various e (edge/0) ratio and at various angles φ, Fig. 5.07.4.

---

**FIG. 5.07.1 BEARING STRENGTH OF PDC (112 CLINT) LAMINATE FOR VARIOUS e (EDGEd/0) RATIO AND AT VARIOUS ANGLES φ**

---

**FIG. 5.07.2 BEARING STRENGTH OF PDC (116 CLINT) LAMINATE FOR VARIOUS e (EDGEd/0) RATIO AND AT VARIOUS ANGLES φ**

---

**FIG. 5.07.3 BEARING STRENGTH OF PDC (118 CLINT) LAMINATE FOR VARIOUS e (EDGEd/0) RATIO AND AT VARIOUS ANGLES φ**

---

**FIG. 5.07.4 BEARING STRENGTH OF PDC (120 CLINT) LAMINATE FOR VARIOUS e (EDGEd/0) RATIO AND AT VARIOUS ANGLES φ**
Material Systems

3.072.5 Bearing strength of Polio (543-cloth) laminates for various e (edge/edge) ratios and at various angles $\theta$.

3.072.6 Bearing strength of Polio (433 cloth) laminates for various $e$ (edge/edge) ratios and at various angles $\theta$.

3.072.7 Bearing strength of Polio (443 cloth) laminates for various $e$ (edge/edge) ratios and at various angles $\theta$.

3.072.8 Bearing strength of Polio (433 cloth) laminates for various $e$ (edge/edge) ratios and at various angles $\theta$.

3.072.9 Bearing strength of Polio (443 cloth) laminates for various $e$ (edge/edge) ratios and at various angles $\theta$.

3.072.10 Bearing strength of Polio (433 cloth) laminates for various $e$ (edge/edge) ratios and at various angles $\theta$.

3.072.11 Bearing strength of Polio (543 cloth) laminates for various $e$ (edge/edge) ratios and at various angles $\theta$.

Source: PFI 1500, 1993
Material: Selection 1993/150-110 0.85 RSP
Process: PM-10 pat, 100 min, 225-250$^\circ$C
Test ID: 06.031

FIG. 3.072.6 BEARING STRENGTH OF POLIO (543-CLOTH) LAMINATES FOR VARIOUS EDGE/EDGE RATIOS AND AT VARIOUS ANGLES $\theta$.

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FIG. 3.041.1 - 8-8 CIRCLE FOR STATIC AND CYCLIC LOADS

Material: Steel 500/150-115, 25 psi, 2.21
Process: EDM plus, 150 min, 220-225V
Test: 100,012 - Antal

FIG. 3.042.1 - ENDS FACE DIAMETER FOR CYCLIC LOADS

Material: Steel 500/150-115, 25 psi, 2.21
Process: EDM plus, 150 min, 220-225V
Test: 10,013 - Antal

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3.10 Elastic Properties

3.10.1 Module of Elasticity in Tension

3.10.1.1 Module of elasticity in tension for Pulu laminate with various shear sublaminates and at various angles $\theta$, Fig. 3.102.1.

3.10.1.2 Effect of thickness on module of elasticity in tension for Pulu laminate, Fig. 3.102.2.

3.10.1.3 Effect of thickness and voids on module of elasticity in tension for Pulu laminate, Fig. 3.102.3.

3.10.1.4 Effect of thickness and surface quality on module of elasticity in tension for Pulu laminate, Fig. 3.102.4.

3.10.1.5 Effect of cure temperature on strain modulus in tension for Pulu laminate, Fig. 3.102.5.

3.10.2 Module of Elasticity in Compression

3.10.2.1 Module of elasticity in compression for Pulu laminate with various shear sublaminates and at various angles $\theta$, Fig. 3.102.1.

3.10.2.2 Effect of thickness on module of elasticity in compression for Pulu laminate, Fig. 3.102.2.
FIG. 3.10.1 EFFECT OF HUMIDITY, BASED ON DATA FOR WINDY LEATHER FOR P-42 LEATHER

FIG. 3.10.2 EFFECT OF HUMIDITY ON MODULUS OF ELASTICITY IN LEATHER FOR P-42 LEATHER

FIG. 3.10.3 EFFECT OF HUMIDITY ON MODULUS OF ELASTICITY IN LEATHER FOR P-42 LEATHER
TABLE 1.03

<table>
<thead>
<tr>
<th>Source</th>
<th>Code</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Military</td>
<td>MLY-27186 (1626)</td>
<td>Plastic Material High-Temperature Low Pressure Laminate</td>
</tr>
<tr>
<td>Military</td>
<td>MLY-6-3175</td>
<td>Fiber, Polyester Low Pressure Laminate</td>
</tr>
<tr>
<td>Military</td>
<td>MLY-6-2140A</td>
<td>Fiber, Polyester High Temperature, Low Pressure Laminate</td>
</tr>
</tbody>
</table>

1.02 Composition

1.02.1 Materials included in this section are systems of resins and reinforcement combined into laminates by various processes. The system composition includes special purpose, to improve mechanical properties, polyester resins and standard glass cloth reinforcement.

1.02.2 For normal structural applications a resin content of 30 to 40 percent appears to be standard.

1.02.3 Due to widespread acceptance and use, 161 woven glass cloth is used as a basic reinforcement for data reporting.

1.02.4 Additional information on polymer-glass cloth laminates will be found in Section P-456 which describes the general purpose polymer systems.

Other materials systems utilizing different resins or reinforcements will be found elsewhere in this manual. Individual primary materials are described in Section 23.

1.06 Processing and Handling Procedures

1.06.1 Polymeric resin systems may be processed by utilizing individual resins, powder, or liquid, and glass cloth in the wet lay-up process.

1.06.2 Powder, pre-cure, material can also be readily processed with a variety of resins.

1.06.3 Polymeric resins can be secured to a variety of fabricated shapes, but only properties of the material in sheet form are reported herein.

1.06.4 Due to inherent properties of this material, it can be formed and produced in almost any shape or size.

1.09 Special Considerations

1.09.1 Special consideration should be given to the recommendation of experience of material supplier with respect to handling, storage, processing and handling.

2 PHYSICAL AND MECHANICAL PROPERTIES

2.01 Thermal Properties

2.01.1 Thermal Decomposition

2.02 Conductivity

2.03 Expansion

2.04 Specific Heat

2.05 Diffusivity

2.06 Elasticity

2.07 Emissivity

2.08 Other
2.02 Electrical Properties

2.02.1 Resistivity

2.02.2 Conductivity

2.03 Dielectric Properties

2.03.1 Dielectric constant and loss tangent, Table 2.03.1.

2.02.2 Typical dielectric constants and loss tangents for various PFIs, Table 2.02.2.

2.04 Magnetic Properties

2.04.1 Other

2.05 OTHER Physical Properties

2.05.1 Density

2.05.2 Other

2.05.3 Other Adhesives

2.05.4 Steel-2.5%Cu specified iron absorption after 24 h immersion is 3.5% max increase in weight.

2.05.5 MIL-R-77358, Grade B, specified iron absorption after 24 h immersion is 0.5% max increase in weight.

2.05.6 Other

2.06 Chemical Properties

2.06.1 Chemical Resistance

2.06.2 five resistance Properties

2.06.3 Corrosion rates, MIL-R-23008 and 77358, Grade B, specify a corrosion of 0.01 inch per years as tested by MIL-R-20818.

2.06.4 Environmental Properties

2.07 Nuclear Properties

---

**Table 2.03.1**

<table>
<thead>
<tr>
<th>Source</th>
<th>MIL-R-23008</th>
<th>MIL-R-77358</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>72°C 45% RH</td>
<td>48°C 65% RH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specified Type or Grade</th>
<th>MIL-R-23008</th>
<th>MIL-R-77358</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric Constant</td>
<td>4.5(1)</td>
<td>3.6 ± 0.2</td>
</tr>
<tr>
<td>Wet-Max</td>
<td>4.4(1)</td>
<td>4.5 ± 0.2</td>
</tr>
<tr>
<td>Loss Tangent</td>
<td>3.06(2)</td>
<td>3.06 ± 0.2</td>
</tr>
<tr>
<td>Dry-Max</td>
<td>0.05(2)</td>
<td>0.05 ± 0.2</td>
</tr>
</tbody>
</table>

(1) ± 5% change in value of specified condition over specified.
(2) Impervious range 0.05k over specified temperature range.

**Table 2.03.2**

<table>
<thead>
<tr>
<th>Source</th>
<th>MIL-R-77358 (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>10,000 CC</td>
</tr>
<tr>
<td>cc × 5</td>
<td>3.6</td>
</tr>
<tr>
<td>Constant</td>
<td>4.4</td>
</tr>
<tr>
<td>Dielectric</td>
<td>0.05</td>
</tr>
<tr>
<td>Dry</td>
<td>0.056</td>
</tr>
<tr>
<td>Loss Tangent</td>
<td>0.032</td>
</tr>
<tr>
<td>Wet</td>
<td>0.064</td>
</tr>
</tbody>
</table>

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**Table 2.03.3**

<table>
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<th>Source</th>
<th>MIL-R-23008</th>
<th>MIL-R-77358</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>72°C 45% RH</td>
<td>48°C 65% RH</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Corrosion to Chemical Fluid</th>
<th>MIL-R-23008</th>
<th>MIL-R-77358</th>
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</thead>
<tbody>
<tr>
<td>MIL-R-3338</td>
<td>MIL-R-77358</td>
<td></td>
</tr>
<tr>
<td>MIL-R-3358</td>
<td>MIL-R-77358</td>
<td></td>
</tr>
</tbody>
</table>

(1) Grade B, Tp1. After immersion shall be reported.
(2) Tp1 = 43 h.
### Table 3.013

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Test Condition</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>E' (GPa)</td>
<td>Type 2</td>
<td>25 °C</td>
<td>30.02 GPa</td>
</tr>
<tr>
<td>E'' (GPa)</td>
<td>Type 2</td>
<td>25 °C</td>
<td>2.5 GPa</td>
</tr>
<tr>
<td>tan δ</td>
<td>Type 2</td>
<td>25 °C</td>
<td>0.01</td>
</tr>
<tr>
<td>% change in length</td>
<td>Type 2</td>
<td>25 °C</td>
<td>0.05</td>
</tr>
<tr>
<td>Temperature</td>
<td>Type 2</td>
<td>25 °C</td>
<td>30 °C to 100 °C</td>
</tr>
<tr>
<td>Vickers hardness</td>
<td>Type 2</td>
<td>25 °C</td>
<td>600 H V</td>
</tr>
</tbody>
</table>

### Table 3.012

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Test Condition</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>E' (GPa)</td>
<td>Type 2</td>
<td>25 °C</td>
<td>30.02 GPa</td>
</tr>
<tr>
<td>E'' (GPa)</td>
<td>Type 2</td>
<td>25 °C</td>
<td>2.5 GPa</td>
</tr>
<tr>
<td>tan δ</td>
<td>Type 2</td>
<td>25 °C</td>
<td>0.01</td>
</tr>
<tr>
<td>% change in length</td>
<td>Type 2</td>
<td>25 °C</td>
<td>0.05</td>
</tr>
<tr>
<td>Temperature</td>
<td>Type 2</td>
<td>25 °C</td>
<td>30 °C to 100 °C</td>
</tr>
<tr>
<td>Vickers hardness</td>
<td>Type 2</td>
<td>25 °C</td>
<td>600 H V</td>
</tr>
</tbody>
</table>

### Notes
1. 30 days in water.
2. Samples shall show no significant degradation of mechanical properties, for any level while adhering to the above conditions.
3. Tensile properties (flexural and tensile) are not affected by the above conditioning.

### Table 3.011

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Test Condition</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>E' (GPa)</td>
<td>Type 2</td>
<td>25 °C</td>
<td>30.02 GPa</td>
</tr>
<tr>
<td>E'' (GPa)</td>
<td>Type 2</td>
<td>25 °C</td>
<td>2.5 GPa</td>
</tr>
<tr>
<td>tan δ</td>
<td>Type 2</td>
<td>25 °C</td>
<td>0.01</td>
</tr>
<tr>
<td>% change in length</td>
<td>Type 2</td>
<td>25 °C</td>
<td>0.05</td>
</tr>
<tr>
<td>Temperature</td>
<td>Type 2</td>
<td>25 °C</td>
<td>30 °C to 100 °C</td>
</tr>
<tr>
<td>Vickers hardness</td>
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<td>25 °C</td>
<td>600 H V</td>
</tr>
</tbody>
</table>

### Notes
1. 30 days in water.
2. Samples shall show no significant degradation of mechanical properties, for any level while adhering to the above conditions.
3. Tensile properties (flexural and tensile) are not affected by the above conditioning.


**Tensile Properties**

- Effects of cyclic loading under different cycles on mechanical properties of fiber laminates, Table 3.0.2.

**Physical Properties**

- Physical properties, Table 3.0.3.

**Surface Effects**

- Shear strains in fibers, Page 1.0.2.

**Environmental Effects**

- Environmental effects, Table 3.0.6.

**Other Effects**

- Other effects, Table 3.0.7.

---

**Figure 3.0.1**

Effect of cyclic load on mechanical properties of fiber laminates under different cycles.

---

**Figure 3.0.2**

Effect of cyclic load on mechanical properties of fiber laminates under different cycles.

---

**Table 3.0.1**

<table>
<thead>
<tr>
<th>Source</th>
<th>Material</th>
<th>Stress / Strain</th>
<th>Damage Criteria</th>
<th>Fatigue Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>No data available</td>
<td>No data available</td>
<td>No data available</td>
<td>No data available</td>
<td>No data available</td>
</tr>
</tbody>
</table>

---

**Figure 3.0.3**

Effect of cyclic load on mechanical properties of fiber laminates under different cycles.
Effect of core pressure on flexural strength of fiber (Fig. 4.05.2). (Percent increase of vertical exposure and test temperatures, Fig. 3.01.2.)

<table>
<thead>
<tr>
<th>Core</th>
<th>Core</th>
<th>Temp</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
</tr>
</tbody>
</table>

**Fig. 3.05.2**: Effect of core pressure on flexural strength of fiber (vertical exposure and test temperatures at various core pressures and test temperatures).
3.02.1 Also see Section 3.03.3 for effects of additions and
melt flow on flexural strength.

3.04.2 Effect of exposure and test temperature on various
material systems. Fig. 3.04.2.

3.04.3 Effect of exposure and test temperature on Poly-M
(Venetex 8-1677) laminate. Fig. 3.04.3.

FIG. 3.04.1 EFFECT OF EXPOSURE AND TEST TEMPERATURE
STRENGTH OF POLY-M (Venetex 8-1677) LAMINATE

FIG. 3.04.2 EFFECT OF EXPOSURE AND TEST TEMPERATURE
STRENGTH OF POLY-M (Venetex 8-1677) LAMINATE

FIG. 3.05.1 EFFECT OF EXPOSURE AND TEST TEMPERATURE
STRENGTH OF POLY-M (Venetex 8-1677) LAMINATE
3.005.1 Effect of exposure and test temperature on bond (Vidaxl C-5062) laminate, Fig. 3.005.2.

3.005.2 Other Effects

3.005.3 Effect of various交付 concentrations on flammability strength of PTFE (Vidaxl C-5062) laminate at various exposure and test temperatures, Fig. 3.005.1.

---

**Figure 3.005.1**

- **Source:** NGC (1102), 1974
- **Material:** Vidaxl C-1000/105-1A, 106°C, 50°C
- **Process:** NW, 25 psi, 30 min, 170-240°F
- **Results:** 
  - **DNT:** 63%
  - **HEX:** 48%
  - **TNT:** 40%
  - **PET:** 33%

**Figure 3.005.2**

**Figure 3.005.3**

**Figure 3.005.4**

**Figure 3.005.5**

**Figure 3.005.6**

---

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INTRO

A. 0.90 PHASE PROPERTIES OF POLYMERS

A. 0.91 A theoretical analysis of the effects of temperature on the mechanical properties of polymers is presented in this section. The analysis is based on the assumption that the mechanical properties of polymers are determined by the intermolecular forces acting within the material. The analysis is divided into two parts:

1. Theoretical Model

2. Experimental Verification

The theoretical model is based on the concept of a molecular network, where the intermolecular forces are represented by bonds between the molecules. The model is used to predict the mechanical properties of polymers under various conditions, such as temperature and stress.

The experimental verification is based on the analysis of experimental data obtained from various sources. The results of the experimental verification are compared with the predictions of the theoretical model, and the agreement is found to be satisfactory.

A. 0.92 A complete review of the mechanical properties of polymers is given in Chapter 11.
Theoretical Analysis

2.00 LAMINATES, LAM.L.: Laminae as isotropic materials

2.001 Physical Description

2.001.1 Laminae, class L.: These laminae comprise a panel of resin interlaced with random oriented glass fibers in a matrix of fibrous glass material, which are adhesively bonded to structural parts. Laminae are composed in the form of a sheet or a stack of layers, each of which is a separate sheet of fiber glass, and the reinforcing sheet is arranged in a particular orientation. The bonding of the fibers is accomplished by impregnation with a resin of various possible types, the most common of which are the polyesters, the epoxies, and the polyurethanes. Resin impregnation is frequently accomplished by toasting, or almost certainly to many laminae to provide through the realization of the various materials, e.g., further testing can be determined through the use of combinations of reinforcement in a single laminate.

2.002 Stress-Strain Relations

2.002.1 Structural plastic laminate may be divided into three general types:

2.002.1.1 These laminae whose strength and other mechanical properties are the same in all directions and, correspondingly, are said to be isotropic.

2.002.1.2 These laminae whose properties vary depending on the orientation of the laminae but are based on the properties in two directions on the degree of variation, commonly said to be orthotropic.

2.002.1.3 These laminae built up of combinations of either or both of the first two.

2.002.2 The stress analysis of reinforced laminates is carried out by applying one of two basic approaches to design. The particular approach depends on the assigned characteristics of the laminate as expressed by the type of reinforcement used in its fabrication.

2.003 Since Cora laminate is reinforced with a set of uniaxial oriented fibers, the reinforcing fibers are unidirectionally oriented and they are a material that is essentially isotropic. In other laminates, the fibers may be orientated in all directions in the plane of the plate. Consequently, this method for stress analysis is analogous to the engineering approach used with conventional materials. The application of these standard methods to non-reinforced plastic differs from their application to conventional materials because of the non-linear variations in stress and strain characteristics. Furthermore, it is only necessary to know the strength, modulus of elasticity, and properties of the materials used for the non-linear test.

2.004 Theoretical and experimental studies conducted by the Research Institute of Pennsylvania (R.I.P.) report on the laminate under consideration indicating that two principal axes are at an angle of 45 degrees to each other.

\[
\theta = \frac{\pi}{4} \quad \text{Eq. 2.004}
\]

where:
- \( \theta \) = angle between principal axes of two adjacent layers of orthotropic material
- \( \phi \) = any angle other greater than 45
THEORETICAL ANALYSIS

5.0 LAMINATES, CLASS II

5.0.1 Physical Properties

5.0.1.1 Laminates, Class II, include those laminates composed of more than one layer of composite materials. These laminates are not only applicable to structural parts but also to various kinds of production applications. In general, the thickness of each layer is chosen to be small and filament reinforcement in three directions at right angles to each other or as varying or continuous elements which provide reinforcement in only two principal directions. The bonding of the layers is accomplished by impregnation with any one of several possible resins, the most common of which are: an epoxy, a polyester, a polyurethane, or a phenolformaldehyde. Various resins are thermoplastic or thermosetting. An almost infinite variety of laminates is possible through the combination of the various reinforcements with various resins. Each further variation can be obtained through the use combinations of reinforcements in a single laminate.

5.0.2 Stress Analysis Considerations

5.0.2.1 Structural plastic laminates may be divided into three general types:

5.0.2.1.1 These laminates show strength and/or mechanical properties in one plane only and consequently are orthotropic.

5.0.2.1.2 These laminates show properties varying with the orientation of the laminate but are based on the properties in two directions slightly deviated. Generally said it is orthotropic. (a)

5.0.2.1.3 These laminates built up of combinations of either or both of the first two.

5.0.2.2 The stress analysis of reinforced laminates is carried out by applying one of two basic approaches to design. One approach depends on the mechanical characteristics of the laminate as determined by the general equation for fabrication.

5.0.3 Stiff Class II laminates are fabricated using cloth or taping as the reinforcement, the mechanical properties as given in the conventional design equations are used. Stiff laminates, therefore, are not isotropic; they are orthotropic.

5.0.4 In a laminate, the mechanical properties of the material depend on the orientation of load to the direction of the fiber. The reinforcement, results in a significant improvement in the conventional design equations. Therefore we can conduct a stress analysis on the laminate.

5.0.5 In order to understand the laminate behavior and the stress analysis, we use three assumptions:

5.0.5.1 The first step in the development of the general stress and strain expressions for an orthotropic material is to develop the general equations for the case of plane stress. From this consideration of the plane stress problem, the equations of strain transformation are readily obtained.

5.0.5.2 Thus the first approach is to use the new "anisotropic" equations (4.0.1.5) and (4.0.1.6) for the laminate problem. For the laminate problem, the new "anisotropic" equations (4.0.1.5) and (4.0.1.6) will be used in this chapter for the laminate type described.

5.0.5.3 It is evident, however, that for more complete information on laminate behavior.

5.0.5.4 Approved for Public Release

FIG. 5.0.1.1 ILLUSTRATION FOR DERIVATION OF BASIC SYMMETRY TRANSFORMATION EXPRESSIONS

5.0.6 In Fig. 5.0.1.1, application of the equations of anisotropic (E 11 = 3 and E 22 = 2) to a laminate in the transformation equations (Eq. 5.0.1.5) and (5.0.1.6) results in the transformation equations (Eq. 5.0.1.5) and (5.0.1.6) for the laminate.

5.0.7 In yielding stress theory for the same two axes, the values of 1 1 and 2 2 from Eq. 5.0.1.6 are substituted for 1 1 and 2 2 in Eq. 5.0.1.6. These values result in the new "anisotropic" equations (4.0.1.5) and (4.0.1.6) for the laminate problem.

5.0.8 Collection of terms and application of

5.0.9 Results in Eq. 5.0.1.5.3.

5.0.10 In Eq. 5.0.1.5.3.

5.0.11 In Eq. 5.0.1.5.3.

5.0.12 In Eq. 5.0.1.5.3.

5.0.13 Collection of terms and application of
To find the relationships between the principal stresses in the $x$, $y$ directions and those in the $v$, $w$ directions, apply a stress, $\tau_{xy}$ in the $x$-direction only. The expressions for the variation of intensity of stress on the $x$-axis, $\tau_{xy}$, may be found by using the tractions and normals equations and the relationships previously determined and those for the stress on the $v$-plane. The stress on the $v$-plane is first, and realizing that the stress $\tau_{vw}$ exists, change $\tau_{xy}$ and $\tau_{zw}$ to $\tau_{xy}$ and $\tau_{zw}$, the result is

$$\tau_{xy} = 0, \tau_{vw} = \tau_{vw}$$

The strain in the $x$-direction, $\varepsilon_x$, may be obtained from the strain transformation equations, but it must be noted that in this case the strain $\varepsilon_{xy}$ exists, $1$-plane $\varepsilon_{xy}$ exists, and $\varepsilon_{vw} = \varepsilon_{vw}$. In terms of stress,

$$\varepsilon_x = \frac{\tau_{xy}}{E}$$

Substituting these values of the strains in the equation for $\varepsilon_x$ gives

$$\varepsilon_x = \frac{\tau_{xy}}{E} + \varepsilon_{vw}$$

which may be written as

$$\varepsilon_x = \frac{\tau_{xy}}{E} + \varepsilon_{vw}$$

Performing similar substitutions and simplifications on the equation for $\varepsilon_y$, the result is

$$\varepsilon_y = \frac{\tau_{xy}}{E} + \varepsilon_{vw}$$

The value of Poisson's ratio ($\nu_{xy}$) for strains in the same plane as $\varepsilon_x$ is applied to the equation in

$$\nu_{xy} \varepsilon_y = \frac{\tau_{xy}}{E}$$

The strain in the $y$-direction, $\varepsilon_y$, is obtained from the strain transformation equation as before,

$$\varepsilon_x = \frac{\nu_{xy} \varepsilon_y}{1 - \nu_{xy}}$$

Substituting for the strains in terms of stresses, and replacing $\nu_{xy}$ by the expression for $\nu_{xy}$ results in

$$\varepsilon_x = \frac{\nu_{xy} \frac{\tau_{xy}}{E}}{1 - \nu_{xy}}$$

The shear strain on the $v$, $w$ plane, $\gamma_{vw}$, caused by $\tau_{xy}$ may also be expressed in terms of $E$ and physical constants of the material for the $v$, $w$ plane. Again noting that $\sigma_x = 0$, the shear strains on the $v$, $w$ plane may be expressed from Eq. (5.48) as

$$\gamma_{vw} = -\frac{\sigma_v}{c_v} = \frac{\tau_{vw}}{c_v}$$

Using this expression value for $\gamma_{vw}$ and $\tau_{vw}$ used in previous developments are substituted into Eq. (5.49) simplifying the result in Eq. (5.48).

$$\nu_{vw} \varepsilon_w = \frac{\tau_{vw}}{E}$$

The expression for $\varepsilon_w$ may be expressed in simpler form as

$$\varepsilon_w = \frac{\tau_{vw}}{E\nu_{vw}}$$

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Write the known constants of the matrix A in

\[ a_{ij} = \left( \begin{array}{cc} a_{11} & a_{12} \\ a_{21} & a_{22} \end{array} \right) \]

\[ \cos \theta \left( 1 + \frac{2}{\varphi} \right) \]

3.6.1.4 The shear stress, \( \tau \), may be used to compute the bending moments on the shear plane, and the principal stresses for the section under consideration. For untreated materials, the shear stress is computed as:

\[ \tau = \frac{M}{I \cdot b} \]

3.6.1.5 The section of the beam is shaped to give the desired bending moment and shear stress. The bending moment is computed as:

\[ M = \frac{1}{2} b \left( \frac{d}{2} \right)^2 \]

3.6.1.6 In order to derive a relationship that will be used to determine the function of the stress, \( \sigma \), in the stress-strain relationship, the principal stresses for the section under consideration are determined. The principal stresses are the largest and smallest stresses that occur in the section, and are used to determine the stress-strain relationship. The relationship is given by the following equation:

\[ \sigma = f(\epsilon) \]

3.6.1.7 In order to derive a relationship that will be used to determine the function of the stress, \( \sigma \), in the stress-strain relationship, the principal stresses for the section under consideration are determined. The principal stresses are the largest and smallest stresses that occur in the section, and are used to determine the stress-strain relationship. The relationship is given by the following equation:

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3.6.1.8 In order to derive a relationship that will be used to determine the function of the stress, \( \sigma \), in the stress-strain relationship, the principal stresses for the section under consideration are determined. The principal stresses are the largest and smallest stresses that occur in the section, and are used to determine the stress-strain relationship. The relationship is given by the following equation:

\[ \sigma = f(\epsilon) \]

3.6.1.9 Because of the difficulty of determining \( \sigma \) experimentally, it is necessary to use a more convenient method of determining \( \sigma \). This method is based on the assumption that the stress-strain relationship is linear. The relationship is given by the following equation:

\[ \sigma = E \epsilon \]

3.6.1.10 This method of determining \( \sigma \) is convenient. The relationship is given by the following equation:

\[ \sigma = E \epsilon \]

3.6.1.11 This method of determining \( \sigma \) is convenient. The relationship is given by the following equation:

\[ \sigma = E \epsilon \]

3.6.1.12 This method of determining \( \sigma \) is convenient. The relationship is given by the following equation:

\[ \sigma = E \epsilon \]
3.9-2 The number of layers of the different treatments or equiva-
enent orientation indings are determined from a com-
parison of the final laminate to fabricating several intermediate pla-
s. The two most important points to consider are: the total number of plyme and, instead of building
3.9-3 Together, these two factors have contributed to the
fact that the laminate is fabricated by building layers of
different thickness and orientation to obtain the desired
properties. This has been shown to be an effective
method because it allows for the different layers to be
3.9-4.1 To analyze a composite laminate for stress
3.9-4.2 The following notation is used:
\[ a_n \] - Thickness of laminate \( n \)
\[ r_{nx} \] - Direct stress in laminate \( n \) parallel to \( x \)-axis
\[ t_{nx} \] - Direct stress in laminate \( n \) parallel to \( y \)-axis
\[ t_{nx} \] - Direct stress in laminate \( n \) parallel to \( z \)-axis
\[ e_{nx} \] - Electric field of laminate \( n \) in the direction of the natural axis

![Diagram of laminate notation](image)

**Fig. 3.9-4.2 Diagram Notation for Composite Laminates**

3.9-4.3 The stress in each direction for each laminate is
3.9-4.4 Therefore, the following equations can be used to
3.9-4.5: Finally, for the bending stiffnesses (\( k_{xy} \) and \( k_{yz} \))

\[ k_{xy} = \frac{E_{xy} h}{(1+\nu) (1-\nu)} \]
\[ k_{yz} = \frac{E_{yz} h}{(1+\nu) (1-\nu)} \]

We have:

\[ \sigma_{yx}^{n+1} = \frac{E_{xy} h}{(1+\nu) (1-\nu)} \]
\[ \sigma_{yx}^{n+1} = \frac{E_{yz} h}{(1+\nu) (1-\nu)} \]

Note that the coefficient \( A_n \) is:

\[ A_n = \frac{E_{xy} h}{(1+\nu) (1-\nu)} \]

And again note that \( A_n = A_n \) for the bending stiffnesses (\( k_{xy} \) and \( k_{yz} \)).
THEORETICAL ANALYSIS

3.06.1.3 If the laminate of Fig. 3.06.2.1 is subjected to an external strain, $\varepsilon_1$, uniformly distributed along its edges, the strains $\varepsilon_2$ and $\varepsilon_3$ result in the same set of equations of stress equilibrium as those indicated in Example 3.03.1.

\[ \begin{align*}
\varepsilon_{11} & = \varepsilon_{22} + \varepsilon_{33} + \gamma_{23} \varepsilon_{12} \\
\varepsilon_{22} & = \varepsilon_{22} \\
\varepsilon_{33} & = \varepsilon_{33} \\
\gamma_{23} & = \gamma_{23}
\end{align*} \]

3.06.2 The coefficients $A_{ij}$, $A_{ij}$, etc. in Eq. 3.06.2-10 serve the same purpose as $A_{ii}$, $A_{ij}$, etc. in Example 3.03.1. In each case the set of equations is changed. The substitutions and manipulations that must be performed to arrive at the final set of equations are exactly similar to those performed to obtain Eq. 3.03.1-12 in their final form. We obtain:

\[ \begin{align*}
A_{11} & = \frac{E_1}{1 - \nu_{12} \nu_{13}} \\
A_{22} & = \frac{E_2}{1 - \nu_{21} \nu_{23}} \\
A_{33} & = \frac{E_3}{1 - \nu_{31} \nu_{32}} \\
A_{12} & = A_{12} \\
A_{21} & = A_{21} \\
A_{3} & = \frac{E_3}{1 - \nu_{31} \nu_{32}}
\end{align*} \]

An isolated, $A_{11} = A_{22} = A_{33}$, and $A_{ij} = A_{ij}$. 3.06.2-7 The results obtained for $A_{ij}$, acting alone and $A_{ij}$ acting alone may be used to obtain the equations for the general state of stress, i.e., when $A_{11}$, $A_{22}$, and $A_{33}$ are acting simultaneously. The results of these computations are:

\[ \begin{align*}
A_{11} & = \frac{E_1}{1 - \nu_{12} \nu_{13}} \\
A_{22} & = \frac{E_2}{1 - \nu_{21} \nu_{23}} \\
A_{33} & = \frac{E_3}{1 - \nu_{31} \nu_{32}} \\
A_{12} & = A_{12} \\
A_{21} & = A_{21} \\
A_{3} & = \frac{E_3}{1 - \nu_{31} \nu_{32}}
\end{align*} \]

3.06.2-10

3.06.3 Failure of orthotropic laminated materials under constant stress and the dynamic development of stress have received extensive study at the Boeing Propulsion Laboratory. Although there is based on the energy of distortion theory developed for isotropic materials, agreement between failure strengths determined by test and by analysis is good.

3.06.3.1 For orthotropic laminated materials, the theory may be applied directly when the strains sometimes referred to as the natural strains are specified. The natural strains should be taken to determine identical stress for this case, however, by use of Eq. 3.06.2-7 or their modifications, since failure may occur from this type of stress with which could not be considered otherwise in the generalized theory. Orthotropic laminated composites, since the state of stress of the individual laminates may be mutually different, the strains of the laminates are a study. The preferred procedure is to use Eq. 3.06.2-7 and check for failure under its own stress condition as developed by these equations.

3.06.4 The stress of the laminate equation states that failure in the laminate will occur when the energy of distortion exceeds the value of the state of stress under consideration exceeds a maximum value that is independent of the state of stress. Expressing in symbolic form, an isotropic material subjected to a state of distortion will have for the energy of distortion:

\[ \varepsilon = \frac{1}{2} \left( \varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2 + \gamma_{23} \varepsilon_{12}^2 + \gamma_{31} \varepsilon_{13}^2 + \gamma_{12} \varepsilon_{23}^2 \right) \]

Where $\Delta_0$, $\Delta_1$, and $\Delta_2$ represent direct and second invariant of stress and $\Delta_3$, for the element of each orientation respectively.

3.06.4.1 In the above equations may be applied to elements taken from the laminate at various differing orientations. The state of stress, $\varepsilon_1$, $\varepsilon_2$, and $\varepsilon_3$ for the element at each orientation is determined using Hooke's law of the given equations, Eq. 3.03.1-1 before applying Eq. 3.06.2-7.

3.06.4.2 The above analysis of equations may be applied to elements taken from the laminate at various differing orientations. The state of stress, $\varepsilon_1$, $\varepsilon_2$, and $\varepsilon_3$ for the element at each orientation is determined using Hooke's law of the given equations, Eq. 3.03.1-1 before applying Eq. 3.06.2-7.
Theoretical Analysis

LH

\[ a_\varepsilon = \frac{1}{2} \left[ (c_0 - c_\varepsilon)^2 + (c_\varepsilon - c_\varepsilon)^2 + (c_\varepsilon - c_\varepsilon)^2 \right] \]

2.9.1.3 For orthotropic materials, the equations have the additional symmetry of the different structural properties expressed in the form of an orthotropic material. The general relationship of a set of equations proposed by many researchers is given by Eq. 2.9.1.4. This set of equations can be expressed in the form:

\[ \varepsilon_{xy} = \varepsilon_{yx} \]

2.9.1.4 The relationship of failure criteria Eq. 2.9.1.4 is divided into two categories: linear and non-linear. The linear model, which is most suitable for low-stress levels, is given by Eq. 2.9.1.5. This equation describes the stress state when the material is under biaxial stress. However, for high-stress levels, the non-linear model is more appropriate, which is given by Eq. 2.9.1.6. This equation describes the stress state when the material is under triaxial stress.

\[ \sigma_{xx} = \sigma_{yy} = \sigma_{zz} = \sigma_{xy} = \sigma_{yz} = \tau_{xz} = \tau_{yz} = \tau_{xz} = 0 \quad \text{Eq. 2.9.1.5} \]

3.9.1.4 The equation of failure criteria Eq. 2.9.1.5 is given by Eq. 2.9.1.6. This equation describes the stress state when the material is under biaxial stress. However, for high-stress levels, the non-linear model is more appropriate, which is given by Eq. 2.9.1.7. This equation describes the stress state when the material is under triaxial stress.

\[ \sigma_{xx} = \sigma_{yy} = \sigma_{zz} = \sigma_{xy} = \sigma_{yz} = \tau_{xz} = \tau_{yz} = \tau_{xz} = 0 \quad \text{Eq. 2.9.1.6} \]

3.9.1.5 The relationship of failure criteria Eq. 2.9.1.6 is divided into two categories: linear and non-linear. The linear model, which is most suitable for low-stress levels, is given by Eq. 2.9.1.7. This equation describes the stress state when the material is under biaxial stress. However, for high-stress levels, the non-linear model is more appropriate, which is given by Eq. 2.9.1.8. This equation describes the stress state when the material is under triaxial stress.

\[ \sigma_{xx} = \sigma_{yy} = \sigma_{zz} = \sigma_{xy} = \sigma_{yz} = \tau_{xz} = \tau_{yz} = \tau_{xz} = 0 \quad \text{Eq. 2.9.1.7} \]

3.9.1.6 The relationship of failure criteria Eq. 2.9.1.7 is divided into two categories: linear and non-linear. The linear model, which is most suitable for low-stress levels, is given by Eq. 2.9.1.8. This equation describes the stress state when the material is under biaxial stress. However, for high-stress levels, the non-linear model is more appropriate, which is given by Eq. 2.9.1.9. This equation describes the stress state when the material is under triaxial stress.
Theoretical Analysis

Figure: Multiple Layer laminate subjected to axial tension, T.

A second way of approaching the problem could be to determine the relationship between areas of the two materials in order that they be capable of sustaining the same load. In Eq. 3.01.1 when \( T = T_2 \), then

\[
\frac{A_1}{A_2} = \frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{\sigma_1}{\sigma_2} = \frac{V_1}{V_2}
\]

A further extension of this principle may be obtained from a consideration of hoop cross-sections, for in this case the effect of the load is to cause a bending moment. It is necessary that the moments of inertia of the two cross-sections be related similarly to the areas related to the actual loaded member, i.e.,

\[
\frac{I_1}{I_2} = \frac{A_1}{A_2}
\]

When an orthotropic material made up of lamina with different moduli is transformed to the use of Eq. 3.01.1 and Eq. 3.01.2, the resultant section may be considered isotropic, and for many design purposes the equations for isotropic materials may be used to grasp adequate design and analysis results. This approach is limited to the determination of stress components for uniform and beam design.
FIG. 1, PHYSICAL CONSTANTS FOR POLYETHYLENE/GLASS LAMINATE

Note: Data from [source], curves derived by [method].

FIG. 2, PHYSICAL CONSTANTS FOR POLYETHYLENE/GLASS LAMINATE

Note: Data from [source], curves derived by [method].

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Laminae, Class I III

Buckling of Laminate

6.02 Physical Description

6.02.1 The physical description of fiber laminates in the case of plates for laminates, Class II (Section 6.03), and in repeated sets are commonplace.

6.02.2 Laminate, Class I III, include class laminate composites, which are especially applicable to structural parts.

6.03 Analysis

6.03.1 Stresses in laminates, Class I III (Section 6.04), and in repeated sets are commonplace. The reinforcement for these class I III structural laminates takes the form of a layer cloth, which is the matrix of which it is made, and the reinforcing fibers are embedded in the matrix as shown in Fig. 6.03.1.

6.03.2 Stress Analysis

6.03.2.1 The stresses in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement. The stresses in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement.

6.03.2.2 These laminates whose properties vary depending on the orientation of the laminate axis are based on the properties of the two directions, usually degree apart, aligned (6.03.1).

6.03.2.3 These laminates built up by combinations of another or both of these three basic types.

6.03.3 The stress analysis of reinforced laminates is carried out on the assumption that the laminate is a homogeneous material. The particular approach depends on the mechanical behavior of the laminate, i.e., the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement.

6.03.4 Since Class I III laminates are fabricated using cloth of various orientations of fabric reinforcement, the mechanical properties of the laminate are determined by the orientations of the fabric, i.e., the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement.

6.03.5 The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement. The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement.

6.03.6 Considering a differential element of the plate, and summing up the stress components on each face for a skin with the skin results in Eq. 6.03.1.

6.03.7 The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement. The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement.

6.03.8 The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement. The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement.

6.03.9 The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement. The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement.

6.03.10 The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement. The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement.

6.03.11 The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement. The strains in the laminate are due to the fact that the laminate is a composite of several plies, each composed of a matrix material and a different reinforcement.

6.03.12 During investigations for this work the term "orthotropic" was used synonymously with "anisotropic." For this study the stress-strain relations of a homogeneous anisotropic laminate were given.

6.03.13 The stress-strain relations of a homogeneous anisotropic laminate were given.

8.03.14 During investigations for this work the term "orthotropic" was used synonymously with "anisotropic." For this study the stress-strain relations of a homogeneous anisotropic laminate were given.
THEORETICAL ANALYSIS

4.025 For an orthotropic material, the equations relating
forces \( P \) above are taken from Section 3.6.1.2, 
revised as follows:

\[
\begin{align*}
\sigma_x &= \frac{P_{xx}}{A} \\
\sigma_y &= \frac{P_{yy}}{A} \\
\tau_{xy} &= \frac{P_{xy}}{A}
\end{align*}
\]

Substituting the first two of these equations for \( \sigma_x \) and \( \sigma_y \) 
and rearranging the third results in

\[
\begin{align*}
\sigma_x &= \frac{P_{xx}}{A} \left( \frac{E_x}{E_y} + 1 \right) \\
\sigma_y &= \frac{P_{yy}}{A} \left( \frac{E_y}{E_x} + 1 \right) \\
\tau_{xy} &= \frac{P_{xy}}{A} \left( \frac{E_x}{E_y} + \frac{E_y}{E_x} + 2 \right)
\end{align*}
\]

Substituting the values for \( E_x \) and \( E_y \) from Eq. 4.025.3 
to the above expressions for \( \sigma_x \), \( \sigma_y \), and \( \tau_{xy} \) results in

\[
\begin{align*}
\sigma_x &= \frac{P_{xx}}{A} \left( \frac{E_x}{E_y} + 1 \right) \\
\sigma_y &= \frac{P_{yy}}{A} \left( \frac{E_y}{E_x} + 1 \right) \\
\tau_{xy} &= \frac{P_{xy}}{A} \left( \frac{E_x}{E_y} + \frac{E_y}{E_x} + 2 \right)
\end{align*}
\]

\[
\sigma_x = \frac{2P_x}{A} 
\]

\[
\sigma_y = \frac{2P_y}{A} 
\]

\[
\tau_{xy} = \frac{2P_{xy}}{A}
\]

4.026 The values obtained for \( \sigma_x \), \( \sigma_y \), \( \tau_{xy} \) in Eq. 4.025.4 
may now be substituted into Eqs. 4.025.5 with the following results:

\[
\begin{align*}
\sigma_x &= \frac{P_{xx}}{A} \left( \frac{E_x}{E_y} + 1 \right) \\
\sigma_y &= \frac{P_{yy}}{A} \left( \frac{E_y}{E_x} + 1 \right) \\
\tau_{xy} &= \frac{P_{xy}}{A} \left( \frac{E_x}{E_y} + \frac{E_y}{E_x} + 2 \right)
\end{align*}
\]

\[
\begin{align*}
\sigma_x &= \frac{2P_x}{A} \\
\sigma_y &= \frac{2P_y}{A} \\
\tau_{xy} &= \frac{2P_{xy}}{A}
\end{align*}
\]

4.025.6 The expressions for \( E_x \) and \( E_y \) may be simplified as follows:

\[
\begin{align*}
E_x &= \frac{E_x}{E_y} \\
E_y &= \frac{E_y}{E_x}
\end{align*}
\]

\[
\begin{align*}
E_x &= \frac{E_x}{E_y} \\
E_y &= \frac{E_y}{E_x}
\end{align*}
\]

\[
\begin{align*}
E_x &= \frac{E_x}{E_y} \\
E_y &= \frac{E_y}{E_x}
\end{align*}
\]

4.025.7 To simplify the above, constants may be collected as follows:

\[
\begin{align*}
E_x &= \frac{E_x}{E_y} \\
E_y &= \frac{E_y}{E_x}
\end{align*}
\]

\[
\begin{align*}
E_x &= \frac{E_x}{E_y} \\
E_y &= \frac{E_y}{E_x}
\end{align*}
\]

\[
\begin{align*}
E_x &= \frac{E_x}{E_y} \\
E_y &= \frac{E_y}{E_x}
\end{align*}
\]

4.026.1 In the case of an orthotropic plate with coordinates 
and parallel to the natural axes of the laminate, 
the axes corresponding to \( x \) and \( y \) axes.

4.026.1.1 Therefore, substituting an orthotropic plate to an axial 
compression, \( P_{x} \), in the direction of the plate and 
parallel to the \( x \) axis, as shown in Fig. 4.026.1.1, Eq. 
4.026.1 becomes:

\[
\begin{align*}
P_x &= \frac{1}{A} \left[ \frac{E_x}{E_y} P_{xx} + \frac{E_y}{E_x} P_{yy} + 2 \frac{E_x}{E_y} \frac{E_y}{E_x} P_{xy} \right]
\end{align*}
\]

\[
\begin{align*}
P_x &= \frac{1}{A} \left[ \frac{E_x}{E_y} P_{xx} + \frac{E_y}{E_x} P_{yy} + 2 \frac{E_x}{E_y} \frac{E_y}{E_x} P_{xy} \right]
\end{align*}
\]

\[
\begin{align*}
P_x &= \frac{1}{A} \left[ \frac{E_x}{E_y} P_{xx} + \frac{E_y}{E_x} P_{yy} + 2 \frac{E_x}{E_y} \frac{E_y}{E_x} P_{xy} \right]
\end{align*}
\]

\[
\begin{align*}
P_x &= \frac{1}{A} \left[ \frac{E_x}{E_y} P_{xx} + \frac{E_y}{E_x} P_{yy} + 2 \frac{E_x}{E_y} \frac{E_y}{E_x} P_{xy} \right]
\end{align*}
\]

\[
\begin{align*}
P_x &= \frac{1}{A} \left[ \frac{E_x}{E_y} P_{xx} + \frac{E_y}{E_x} P_{yy} + 2 \frac{E_x}{E_y} \frac{E_y}{E_x} P_{xy} \right]
\end{align*}
\]

\[
\begin{align*}
P_x &= \frac{1}{A} \left[ \frac{E_x}{E_y} P_{xx} + \frac{E_y}{E_x} P_{yy} + 2 \frac{E_x}{E_y} \frac{E_y}{E_x} P_{xy} \right]
\end{align*}
\]
THEORETICAL ANALYSIS

4.01.2. If all angles of the plate are simply supported, and it is assumed that the blocks have a half-circumscribed length of 0.696, the equation for the flexure will be:

\[ w = \frac{8}{3} \pi^2 \frac{EI}{12} \frac{1}{t^2} \]  

4.01.3. For the value of the critical buckling stress, \( \sigma_c \), may be obtained by plugging the equations and substituting into the equations for \( \sigma_c \) (Ref. 1,2) as follows:

\[ \sigma_c \approx \sqrt{\frac{T^2}{E}} \]  

4.01.4. To find the minimum value for the buckling stress for the above condition of loading, the equation of Eq 4.01.1 is used, and it is noted that the function above was equal to zero, and it is noted that:

\[ \sqrt{\frac{T^2}{E}} = \sqrt{\frac{V^2}{E}} \]  

4.01.5. Solving Eq 4.01.4 for \( T \) and substituting this value into the following equation for elastic values of the critical buckling stress for simply supported plate, the following equation for an elastic-composite stress is obtained:

\[ T = \sqrt{\frac{V^2}{E}} \]  

4.01.6. For other plates which fall into the above case, the buckling stress will be higher. The stress can be found by using Eq 4.01.4 accurately as follows:

\[ T = \sqrt{\frac{V^2}{E}} \]  

4.01.7. Eq 4.01.6, there, may be put into a more variable form for convenience of calculation:

\[ T = \frac{V^2}{E} = \frac{V^2}{E} \]  

4.01.8. Using the above equation for \( T \) in Eq 4.01.8, it will return to the following expression for the critical stress in a plate with simply supported edge, loaded parallel to the \( x \) direction only:

\[ \sigma_c = \frac{4 \pi^2}{12} \frac{

4.01.9. Values of \( T \) for the above equation can be compiled by using Eq 4.01.9, for various values of \( T \) and using chart plots for design purposes. Figure 1 is a typical chart for \( T \) values.

**Stress Analysis Charts**

Applications of buckling theory to analysis can be considerably simplified by the use of approximate charts to determine the critical stress for the critical buckling stress.

4.02.1. All edges simply supported, Fig. 4.02.1.

Values of \( T \) in Fig 4.01.9 are plotted against corresponding values of \( T \) from Eq 4.01.8. For typical design purposes, values of \( T \) for two half-plates are plotted, and it may be noted that the maximum value of \( T \) is the same regardless of the value of \( T \). The use of this maximum value of \( T \) for \( T = 0 \), can result in a maximum value of critical buckling stress of approximately 4.45 when \( T = 0 \), but only half that value when \( T = 0.5 \). The larger value is recommended for most composite calculations.

The equation for \( T \), Eq 4.01.9, is repeated below for convenience.

\[ T = \frac{V^2}{E} = \frac{V^2}{E} \]  

4.02.2. Layed edges simply supported, other edges fixed, Fig. 4.02.2.

Again only data for \( n = 1 \) and \( 2 \) are provided. When \( n = 1 \), one of the maximum values of \( T \) will result in a lower value of \( T \) than \( T \) for \( n = 2 \). Eq 4.01.9 will be repeated below for convenience. However, by using other methods, it may be approximated by the following expression.

\[ T = \frac{V^2}{E} = \frac{V^2}{E} \]  

4.02.3. Layed edges fixed, other edges simply supported, Fig. 4.02.3. These are full half-plates are, but should be noted that values of \( T \) for different combinations and means can be obtained by direct integration, but may be approximated by the following expression.

\[ T = \frac{V^2}{E} = \frac{V^2}{E} \]  

4.03. MC-17, Part 3

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For $n = 3$, 3.711 $b_0 q < 1.002$, $b_{1/2}$ at $q = 0.335$

$$b = \frac{1.32}{0.6} \cdot q^3 + 204.4$$

For $n = 4$, 3.672 $b_0 q$ with $q$ taken to the minimum value for $b$, which occurs at $q = 0.335$

$$b = \frac{204.4}{0.4} \cdot q^3 + 364.4$$

4.002, 4.002

All edges fixed. Fig. 5, 6.002, 6.002. As in 4.002, 7 above, data for 4 half-waves are provided and successive half-waves have different vibration modes. Again, values of $b$ cannot be obtained by direct integration, but can be approximated by the following expressions (1).

For $n = 5$, 4.002, 4.002, $b_{1/2}$ at $q = 1.003$

$$b = \frac{1.003}{0.4} \cdot q^3 + 364.4$$

For $n = 7$, 6.002, 6.002, $b_{1/2}$ at $q = 1.065$

$$b = \frac{1.065}{0.4} \cdot q^3 + 364.4$$

For $n = 3$, 1.002, 1.002, $b_{1/2}$ at $q = 1.002$

$$b = \frac{1.002}{0.4} \cdot q^3 + 364.4$$

For $n = 4$, 1.002, 1.002, $b_{1/2}$ at $q = 1.002$

$$b = \frac{1.002}{0.4} \cdot q^3 + 364.4$$

For $n = 5$, 1.002, 1.002, $b_{1/2}$ at $q = 1.002$

$$b = \frac{1.002}{0.4} \cdot q^3 + 364.4$$

For $n = 6$, 1.002, 1.002, $b_{1/2}$ at $q = 1.002$

$$b = \frac{1.002}{0.4} \cdot q^3 + 364.4$$


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20.031.3 When a single helical spring is used, balanced strength is provided when the helix angle, \( \gamma \), is determined so that the ratio of tension to longitudinal stress is as follows.

\[
\frac{F_T}{F_L} = \sin \gamma
\]

\[
\sin \gamma = \frac{p}{E} \left( \frac{D}{t} \right)^2
\]

\[
s = \frac{3}{8} \sqrt{\pi E t^3} \quad \ldots \ldots \quad \text{Eq. 20.031.3}
\]

20.031.4 Fig. 20.031.4a shows the relative proportions of a tension to the hoop and longitudinal directions as the helix angle, \( \gamma \), varies.

![Diagram showing tension to the hoop and longitudinal directions as the helix angle varies.]

20.031.5 When the cylinder is subjected to internal pressure alone, \( \sigma_p = \frac{p}{t} \), and in order to achieve balance, Eq. 20.031.3 reduces to:

\[
u = \frac{3}{8} \sqrt{\pi E t^3}
\]

20.031.6 An optimal angle may be derived in a similar fashion for any other ratio of hoop to longitudinal stresses.

20.032 The equations for a complex spring system are now developed.

20.032.1 When pressure cylinders are constructed with integral and polished steel, it becomes imperative to use the optimum winding angle of 30\(^\circ\). Experiments show that the longitudinal stress increases to the point where the smaller angle becomes necessary. By the use of the helical winding to perform at least the optimum strength of the wire, the angle may be determined in the ratio of stress given in terms of wire and the change in the ratio of stress given in terms of wire and the change in the ratio of stress given in terms of wire. Therefore, it is necessary to use a helical winding system with a low helix angle to form the wire and to carry the longitudinal stress. The angle of the winding provides sufficient strength to the hoop direction when the helix bore is of sufficient thickness to carry the longitudinal load. To overcome this deficiency, circumferential windings are provided to carry the remains of the hoop stresses. These windings are actually a smaller angle only since the hoop stresses may be carried by a smaller angle. By using the radicament and a balanced design, this may be achieved by selecting an end and then configuring this to fit the helix angle shown.

20.032.2 The analysis of such a pressure cylinder is based on the following procedure for the general case of two layers with different helix angles. When the layers consist of circumferential windings alone, the general procedure will apply by using the hoop angle \( \theta \), of the inner layer to determine the stress in the outer layer system. When the system is longitudinal tension and compression, the helix layers form the cylindrical portion of the vessel, but only one is extended to form the rest done. The basic equation is that the two systems act independently of each other. Lower 1 has a helix angle of \( \gamma_1 \) and lower 2 of \( \gamma_2 \).

![Diagram showing two layers of a pressure cylinder.]

20.032.3 For unit length:

\[ T_i = F_i + \frac{p}{t} \quad \text{where:}
\]

- \( T_i \) and \( F_i \) are the hoop forces provided by elements of layers 1 and 2 respectively
- \( p \) is internal pressure

Using the previously derived expression, \( \text{Eq. 20.031.31} \), to compute the component of the hoop stress contributed by each helical winding, results in the following:

\[
\sigma_p = \frac{p}{t} \frac{D}{t} \left( \frac{D}{t} \right)^2
\]

\[
\sigma_T = \frac{F_T}{t} \left( \frac{D}{t} \right)^2
\]

\[
E_1 = \frac{E}{t} \left( \frac{D}{t} \right)^2 \quad \ldots \ldots \quad \text{Eq. 20.032.3}
\]
more.

20.032.4 The total longitudinal force resulting from the internal pressure, see Fig. 10.032.2, is:

\[ F_1 = \frac{1}{2} \pi D_2 \cdot \frac{L_2}{L_1} \cdot \frac{P_1}{2} \]

where:
- \( F_1 \) and \( F_2 \) = longitudinal forces provided by the filament in layer 1 and 2 respectively.

Applying the geotextile limited assumption, Fig. 20.032.4, to compute the component of the longitudinal stress generated by each filament, as in a manner similar to 20.032.3 above, results in the following.

\[ \sigma = \frac{P_1}{\pi D_2^2} \]

\[ F_2 = \frac{2}{3} \pi D_2 \cdot \frac{L_2}{L_1} \cdot \frac{P_1}{2} \cdot \frac{3}{2} \pi D_2 \cos \theta_2 \]

\[ p \left( \frac{L_2}{L_1} \right) = \cos \left( \theta_1 + \theta_2 \right) = \cos \left( \theta_1 \right) \cos \left( \theta_2 \right) - \sin \left( \theta_1 \right) \sin \left( \theta_2 \right) \cos \left( \theta_1 - \theta_2 \right) \]

\[ \Delta u = \frac{\Delta L_2}{L_2} = \frac{1}{L_2} + \frac{1}{L_1} + \frac{1}{L_2} \cdot \frac{1}{L_1} \cdot \frac{L_2}{L_1} \]

20.032.5 From the above, it is known that the value of \( \cos \left( \theta_1 + \theta_2 \right) \), the tensile angle of the geotextile, can be approximated to 90° and equations 20.032.3 and 20.032.4 reduce to:

\[ \Delta u = \frac{1}{L_2} + \frac{1}{L_1} + \frac{1}{L_2} \cdot \frac{1}{L_1} \cdot \frac{L_2}{L_1} \]

\[ \sigma = \frac{P_1}{\pi D_2^2} \]

20.032.6 Subtracting \( \sigma \) in these equations results in:

\[ \Delta u = \frac{1}{L_2} + \frac{1}{L_1} + \frac{1}{L_2} \cdot \frac{1}{L_1} \cdot \frac{L_2}{L_1} \]

\[ \sigma = \frac{P_1}{\pi D_2^2} \]

20.032.7 Since \( \sigma \) and \( \Delta u \) are the maximum stresses that can be developed in the helical and non-helix layers respectively, their sum must equal the strength of the filament, \( \sigma_0 \).

\[ \sigma_0 = \sigma + \Delta u \]

20.032.8 If \( \sigma_0 \) is known, \( \Delta u \) may be found from:

\[ \Delta u = \sigma_0 - \sigma \]

20.032.9 The maximum stress, \( \sigma_0 \), between the helical and non-helical layers may be determined by using the above equations and the physical dimensions of the geotextile. The number of helical layers may be determined from:

\[ \Delta u = \frac{1}{L_2} + \frac{1}{L_1} + \frac{1}{L_2} \cdot \frac{1}{L_1} \cdot \frac{L_2}{L_1} \]

20.032.10 When in function 20.032.1 is used, the number of layers \( n \) can be determined by using the above equations and the physical dimensions of the geotextile. The number of non-helical layers may be determined by

\[ \Delta u = \frac{1}{L_2} + \frac{1}{L_1} + \frac{1}{L_2} \cdot \frac{1}{L_1} \cdot \frac{L_2}{L_1} \]

20.032.11 This approach is to be applied to all horizontal layers to the problem to determine the number of layers in layered geotextile. For helical layers, the method of 20.032.10 must be used. The geotextile can be determined by using the above equations and the physical dimensions of the geotextile. The number of non-helical layers may be determined by

\[ \Delta u = \frac{1}{L_2} + \frac{1}{L_1} + \frac{1}{L_2} \cdot \frac{1}{L_1} \cdot \frac{L_2}{L_1} \]

20.032.12 The stress of a layer of helically wound fibers is given by:

\[ \sigma = \frac{1}{2} \pi D_2 \cdot \frac{L_2}{L_1} \cdot \frac{P_1}{2} \]

20.032.13 The stress of a layer of helically wound fibers is given by:

\[ \sigma = \frac{1}{2} \pi D_2 \cdot \frac{L_2}{L_1} \cdot \frac{P_1}{2} \]

20.032.14 The stress of a layer of helically wound fibers is given by:

\[ \sigma = \frac{1}{2} \pi D_2 \cdot \frac{L_2}{L_1} \cdot \frac{P_1}{2} \]

20.032.15 The stress of a layer of helically wound fibers is given by:

\[ \sigma = \frac{1}{2} \pi D_2 \cdot \frac{L_2}{L_1} \cdot \frac{P_1}{2} \]
In the manner, the axial longitudinal force, $F_z$, may be expressed by the general expression

$$F_z = E_z (x_1 \cos \theta_1 + x_2 \cos \theta_2 + \ldots + x_n \cos \theta_n)$$

$$= x_0 \cos \theta_0 \cdot y_0$$

20.16 Perturbation of Design Formulas

The foregoing analyses result in a number of formulas applicable in the design of filament wound pressure vessels. In addition, various factors are considered in the design procedures. It is the usual practice to assign stress values to certain design conditions which are not considered in the design. Perturbation of design formulas is described in the next section in this chapter.

20.15 Stability Stress Analysis Charts

20.16 Special Considerations

20.16.1 When design conditions become more complicated, or other circumferences of the tube becomes subject to a number of forces, the design of filament wound pressure vessels becomes more complicated. The design criteria and the stress analysis become more complex. This is also valid for other applications, and the design values are dependent on the opening of the analysis. Such an approach will enable the overall properties of the model to be determined.

20.16.2 One of the complexities of loading commonly encountered in that produced by localized loads. In general, this type of loading should be avoided in filament wound structures since it causes stress concentrations and stress fields which are often not predictable. The stress acting on the structure is usually a combination of internal stresses. More concentrated loadings cannot be avoided, many efforts should be made to apply them in an optimal direction to avoid stress concentrations at the external surface of the filament wound structure as a uniformly distributed circumferential load.

20.16.3 Another complexity occurs when local layers of additional material are incorporated in a filament wound structure. This balanced netting system can be used to add a pressure vessel under these circumstances the additional localized material increases the stiffness of the structure in that portion where it is needed. In some cases, however, if the elastic properties of the local reinforcement are similar to those of the original pressure vessel, it is apparent from a consideration of the strain, that the reinforcement cannot be overstressed. However, the locally stiff region will generate secondary bending making in the adjacent shell so that the netting system is to accommodate any discontinuity to avoid stress concentrations produced by the stiffened area of local reinforcement.

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21.0 THEORETICAL ANALYSIS

21.01 Fundamental Stress Formulas

21.01.1 To develop the basic equations for the geodetic, meridian and dome, two procedures are available: one is analytical and the other is semi-empirical. In both approaches, the beta angle $\beta$ is determined by the distance of skin-opening retraction. This distance-beta angle relationship is given in Table 21.01.

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Beta Angle ($^\circ$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.051</td>
</tr>
<tr>
<td>10</td>
<td>0.113</td>
</tr>
<tr>
<td>15</td>
<td>0.131</td>
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<tr>
<td>20</td>
<td>0.137</td>
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<tr>
<td>25</td>
<td>0.144</td>
</tr>
<tr>
<td>30</td>
<td>0.150</td>
</tr>
</tbody>
</table>

21.01.2 Analytically, the hoop and longitudinal stresses from the setting analysis presented in Section 21.01.1 of this manual (Figs. 20.01.1-2 and 20.01.1-3) are applied to the hoop and (longitudinal) stresses for surfaces of revolution.

21.01.3 From the setting analysis:

\[ \sigma_h = \sigma_0 \cos \beta \] and \[ \sigma_l = \sigma_0 \sin \beta \]

21.02 Surface of Revolution

21.02.1 Generalized Gaussian Profile

21.02.2 For surface of revolution:

\[ r = r_0 - a \cos \theta \]

Where:

- $r_0 = \text{radius of curvature of the dome perpendicularr to the meridional line}$
- $a = \text{radius of curvature of the dome in the direction of the major axis}$
- $l = \text{thickness of dome material}$

Note: $r_0$ is the dome inner radius, $a$ is the dome outer radius, and $l$ is the thickness of the dome material.

21.02.3 Combining the foregoing expressions will result in the following:

\[ r = r_0 - a \cos \theta \]

21.03 Formulation of Design Formulas

21.03.1 To develop the general equations of the end dome profile, the rectangle shown in Fig. 21.01.1 is adopted. The rectangle has equal sides and rotates about a small element along the meridional axis to obtain a dome. The dimensions developed from the following equation is used:

\[ r = \text{radius of cylinder} \]

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end from Eq. 21.063.1:

\[ \frac{a}{\mu} = 1 - \cos \theta \]

\[ \sin \theta = \sin \left( \frac{\pi}{2} - \theta \right) \]

\[ \cos \theta = \cos \left( \frac{\pi}{2} - \theta \right) \]

If the expression \( \sin \theta \) is taken as a function of \( \theta \), then the following procedure will result in Eq. 21.064.1 below.

\[ \frac{a}{\mu} = \sin \theta \]

\[ \int \frac{a}{\mu} \, d\theta = \int \sin \theta \, d\theta \]

Resulting that \( \theta = 0 \), \( \alpha = \beta \) and therefore:

\[ \alpha = \theta \]

\[ \frac{a}{\mu} = \frac{1}{\mu} \]

The results represented by Eq. 21.065.1 may be expressed in another form by letting \( \alpha = \theta \) equal the integral portion:

\[ \alpha = \int \frac{a}{\mu} \, d\theta \]

\[ \alpha = \frac{1}{\mu} \]

The other coordinates of the point \( Q \) is found by using Eq. 21.065.15 and the result last obtained:

\[ \alpha = \frac{1}{\mu} \]

and since \( \alpha = \theta \):

\[ \frac{a}{\mu} = \frac{1}{\mu} \]

\[ \int \frac{a}{\mu} \, d\theta = \int \frac{1}{\mu} \, d\theta \]

Integrating and noting that \( \alpha = 0 \) when \( \theta = 0 \):

\[ \alpha = \frac{1}{\mu} \]

21.065.14 Solve 21.064.1 and 21.064.4 and be integrated within various limits of desired limit angle and \( \theta \) using Simpson's rule and a computer. If \( \alpha \) at all times:

\[ \alpha = \frac{1}{\mu} \]

Then the end portion, the integral portion of it. If \( \alpha \) is replaced that \( \alpha \) becomes \( \frac{\pi}{2} \) since \( a/\mu = \theta \)

\[ \int \frac{a}{\mu} \, d\theta = \frac{1}{\mu} \]

\[ \alpha = \frac{1}{\mu} \]

\[ \alpha = \int \frac{a}{\mu} \, d\theta \]

\[ \alpha = \frac{1}{\mu} \]

21.065.15 Solve 21.064.1 and 21.064.4 and be integrated within various limits of desired limit angle and \( \alpha \) using Simpson's rule and a computer. If \( \alpha \) at all times:

\[ \frac{1}{\mu} \]

\[ \alpha = \frac{1}{\mu} \]

Then the end portion, the integral portion of it. If \( \alpha \) is replaced that \( \alpha \) becomes \( \frac{\pi}{2} \) since \( a/\mu = \theta \)

\[ \int \frac{a}{\mu} \, d\theta = \frac{1}{\mu} \]

\[ \alpha = \frac{1}{\mu} \]

\[ \alpha = \int \frac{a}{\mu} \, d\theta \]

\[ \alpha = \frac{1}{\mu} \]
21.04-8 Eqs 21.04.3b and c define a surface of revolution that has the property of zero stress in the hoop direction. Moreover, the solutions are due to Mr. G. L. Taylor for the design of a part of a profile, he felt that a particular in the design of building between 1956 (near loop yields) would provide the greatest weight of material. These solutions are more readily analyzable than the general case previously derived.

21.04-9 Further examination of Eqs 21.04.3b and 21.04.3c is necessary to clarify their application to the design of a dome profile under single cells. For each of the two derivative cones, the derivative fixed at one end and varies smoothly along in a function of $x$ and $y$. Values over the cone surfaces, that difficulty may be resolved approximately by utilizing approximate expressions for $F(x)$ or perhaps slightly increasing the value of selected points in the surface, since the value $F(x)$, or of the DERIVATIONAL point is.

21.05 Numerical integration of the simple solution to Eq. 5.57 may then be computed for each case of values and numerical methods of integration may be used on Eqs 21.04.3b and 21.04.3c.
INTRODUCTION

The primary objective is to provide a comprehensive overview of the processes involved in the manufacture of molded parts. The following sections will cover the general aspects of each process, including the equipment, materials, and the unique characteristics of each process. The information presented is based on extensive research and is intended to provide a clear understanding of the processes covered.

1.0 Purpose of Manual

2.01 The purpose of this Manual is to provide general but detailed information on the processes used in the manufacture of molded parts. The processes discussed in this Manual include those that are commonly used in industry today. The information presented is based on research and is intended to provide a clear understanding of each process.

2.02 The information included in this Manual has been compiled from various sources. The information gathered is based on research and is intended to provide a clear understanding of the processes covered.

2.03 The Manual has been divided into sections as indicated in the Table of Contents. The topics covered include:

- Section 1: General Information
- Section 2: Process Descriptions
- Section 3: Equipment and Materials
- Section 4: Operating Procedures
- Section 5: Troubleshooting

2.04 Each section is divided into subsections as follows:

- Section 1: General Information
  - 1.0 INTRODUCTION
  - 1.1 PURPOSE OF MANUAL
  - 1.2 PROCESS DESCRIPTION
  - 1.3 EQUIPMENT AND MATERIALS
  - 1.4 OPERATING PROCEDURES
  - 1.5 TROUBLESHOOTING

3.0 CONTENTS OF MANUAL

3.01 This Manual is divided into sections as indicated in the Table of Contents. The topics covered include:

- Section 1: General Information
- Section 2: Process Descriptions
- Section 3: Equipment and Materials
- Section 4: Operating Procedures
- Section 5: Troubleshooting

4.0 PRELIMINARY

4.01 The Manual is divided into sections as indicated in the Table of Contents. The topics covered include:

- Section 1: General Information
- Section 2: Process Descriptions
- Section 3: Equipment and Materials
- Section 4: Operating Procedures
- Section 5: Troubleshooting

4.02 Each section is divided into subsections as follows:

- Section 1: General Information
  - 1.0 INTRODUCTION
  - 1.1 PURPOSE OF MANUAL
  - 1.2 PROCESS DESCRIPTION
  - 1.3 EQUIPMENT AND MATERIALS
  - 1.4 OPERATING PROCEDURES
  - 1.5 TROUBLESHOOTING

5.0 SECTION TITLE

5.01 General Information

5.02 Process Description

5.03 Equipment and Materials

5.04 Operating Procedures

5.05 Troubleshooting

6.0 APPENDIX

6.01 Abbreviations and Glossary

6.02 Appendix I: Process Identification Codes

7.0 ACKNOWLEDGMENTS

7.01 Acknowledgments

8.0 CONCLUSIONS

8.01 Conclusions

9.0 REFERENCES

9.01 References

10.0 APPENDIX

10.01 Appendix

11.0 APPENDIX

11.01 Appendix

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In most cases additional information is given, such as an amount of Civex or curing agent or leaching procedure. In summary, 1.5 oz cross-linking is constant to normal parallel laminated.

Grits are used in subsequent applications which are considered to standard, known, or recommended from context. Where appropriate, these are defined in the text.

For complete listing of all references and definitions used throughout this handbook, see Section 1A.

Page 2

A general bibliography of pertinent references was used in compiling this manual includes the following more important listed.


A complete source index is given in Section 1A.
1.0 MOLDING TECHNIQUES

1.01 GENERAL

1.011 General Description. Contact molding was developed in the late 1940's and has been referred to as die...
1.088 Others. Certain additional can be used in the contact molding process to impart desired characteristics such as color, flexibility, resistance to repeated reuses, and the like, to the finished products, as to be indicated from the examples cited above. These materials can be added to the basic material, the mold, or both, and may be added at any time, as long as they are compatible with the materials used and the desired results, and are not detrimental to the finish of the finished product. The addition of such materials can increase the flexibility limits to "baking molding" resilient plastic parts.

1.09 Equipment Used

1.091 Basically, the equipment required for contact molding consists of a cam action and a vacuum system. The vacuum is usually used to speed the baking process, and can also be used to create a vacuum seal on the finished product. This vacuum can be created by either a vacuum pump or a vacuum bag.

1.092 Equipment necessary for spray-coating contact-molded parts is not always used and depends upon the specific application. A vacuum system may be used to create a vacuum seal on the finished product, and the use of a vacuum pump can help to speed the baking process.

1.093 Equipment necessary for the use of contact-molded parts is not always used and depends upon the specific application. A vacuum system may be used to create a vacuum seal on the finished product, and the use of a vacuum pump can help to speed the baking process.

1.094 Equipment necessary for the use of contact-molded parts is not always used and depends upon the specific application. A vacuum system may be used to create a vacuum seal on the finished product, and the use of a vacuum pump can help to speed the baking process.

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1.096 Equipment necessary for the use of contact-molded parts is not always used and depends upon the specific application. A vacuum system may be used to create a vacuum seal on the finished product, and the use of a vacuum pump can help to speed the baking process.
Next the gel coat is spread by either brush or squeegee manner. Before being able to spread it properly, the gel coat must be thinned properly using thinning. This is necessary to achieve the correct consistency before it is allowed to set. The gel coat is applied to a thickness of 0.01 mm. The gel coat should be applied over a period of about 5 minutes. The gel coat should be applied to a thickness of 0.01 mm.

1.344 Other

1.345 Preparing

1.346 Trimming

1.347 Scraping

1.348 Cutting

1.349 Attaching
56.0  PROCESS CODE 2
Bag Molding - General

56.11 General Description. Bag molding follows the procedures used to contact molding (see Section 5.10) except that pressure is exerted onto the two lower mold halves which are separated by either application of vacuum or positive pressure to the bag. Bag molding was developed to minimize the thickness of the bag molding process, thereby improve strength and accuracy and to reduce cooling time. Although a more complex method handling partially cured equipment, this method has been widely accepted in recent years. Bag molding may be sub-classified into two processes based on the method of applying the molding pressure. Positive pressure bag molding, done with the vacuum bag, has been described in Section 5.11, because of the relatively complex and cost of each of these methods, and specifics of each will be discussed under separate Sections later in this book. The following Sections in this volume will describe the general method of bag molding as involved in all three methods.

56.22 Application. Bag molding of reinforced plastic is widely used in the manufacture of automotive bodies and parts, aircraft and aerospace craft components, boats, ducts, tanks, and pressure molds. In aviation specifically to the aerospace industry, bag molding is perhaps the most commonly used process than contact molding because of its basic advantages over the latter.

56.24 Advantages and Disadvantages

56.31.1 Advantages. Next to contact molding, bag molding is perhaps the simplest process for manufacturing reinforced plastic, because the molds are not pressure sensitive or precise, structural parts of much higher strength and lower weight are possible, therefore, larger parts become practical to this method. The reduction in weight is properly reduces or even eliminates the need for expensive material handling equipment. Again, the molds are not as expensive as contact molding molds, and parts normally required to contact molding. A further advantage of this system is the greater efficiency of the finished part created with higher production rates. The reduced possibility of pre-shotting (in contact molding) is almost universal to the bag molding process, and uniformity throughout the finished part are also lessened in this process as compared to contact molding.

56.31.2 Disadvantages. Bag molding does involve many shortcomings that contact molding although this is still considerably less than for the former methods. Also, bag molding is, package, were difficult to secure and requires more accuracy in control. Therefore, bag molding using this method requires careful forging of parts to make feasible and economical, although although dimensions can be more uniformly improved, these are still to be considered in the choice of the various molding techniques.

56.52 Resin Compatibility. Compatibility for contact molding, see Section 5.11.23. Resin release agent is used in bag molding to release film or film forming resins.

56.532 Release Agents. Requirements for contact molding, see Section 5.11.2.2. Release agents are not used in bag molding although application for the final product is of prime importance.

56.533 Bags. Compatible to that for contact molding, see Section 5.11.2.2. Some type of bag is required in bag molding, usually the selected bag of the red product is of prime importance.

56.544 Bags. Compatible to that for contact molding, see Section 5.11.2.2. Some type of bag is required in bag molding although commercially available resins in liquid or dry form are often used. The use of glass materials is more common in bag molding of small parts. All else on this center may be used in bag molding.

56.555 Release Agent. Compatible to that for contact molding, see Section 5.11.2.2. Some type of bag is required in bag molding although commercially available resins in liquid or dry form are often used. The use of glass materials is more common in bag molding of small parts. All else on this center may be used in bag molding.

56.566 Pressure. Compatible to that for contact molding, see Section 5.11.2.2. Some type of bag is required in bag molding although commercially available resins in liquid or dry form are often used. The use of glass materials is more common in bag molding of small parts. All else on this center may be used in bag molding.

56.577 Pressures. Not applicable.

56.588 Others. Compatible to that for contact molding, see Section 5.11.2.2.

56.61 Equipment Used

56.61.1 Heating, Laminating, or Placement of Materials in the mold, is usually accomplished by heat which may be applied through vacuum equipment or that used for contact molding. All bags molding will commonly involve one of spraying materials, the spray stage of a bag molding also necessitates coating, forming, and extrusion (or "fuming") of the material, thereby requiring appropriate tools for same.

56.61.2 Molds. Bag molding involves the use of only one mold which can be either male or female according to which one of the finished parts is required to be smooth, the mold to be used on a female, male or female prototypes, and the cavities be figured by any material of sufficient rigidity to maintain the shape of the molding pressure, and pressure, but must be strong enough to withstand mold pressure and temperature. The mold is all best used necessarily, because alone each molding method is generally different, in the most common mold material, the working surface of the mold should be finished as smoothly as possible, since any imperfection will be evident on the surface of the finished molding. Maintenance for the mold is also essential, the molders should be made. A very important portion of the mold is to provide for cleaning the bag (or as most molds) in place so that we may to ensure a complete seal permitting appropriate application of vacuum or pressure as the case may be.

56.61.3 Pressure. The most important part of equipment in bag molding is the bag itself. The bag is usually made of rubber, benzene-sulfonic acid, or polyvinyl chloride and without glass material which is capable of holding pressure or vacuum. In most cases the bag is made of a material that is quite limp and quite limply closed to the outside edge of the mold, to prevent seams that the bag to be free of leaks and of strong, surrounding the mold, which are sealed together around the perimeter. For applications at pressure, the bag can be made flexible layer permanently attached to a "rigid" layer, associated with the use of the pressure, to provide and control the vacuum or pressure used. The pressures required in bags can be calculated from the selection of material for same.

56.61.4 Venting. Bag molding often involves some kind of cooling. The vent ports should be sealed with a solid material that is strong enough to maintain pressure throughout the process. This solid material is often used, in certain cases penetration is made for heating the mold itself with electric power, but water, or electricity.
10.04 Other, similar equipment when may be necessary includes dies of forms to hold the component parts in shape after removal from the mold and during post-curing. Support and storage equipment, etc., though essential become particularly important if large quantities are worked prior to use in the bag welding process.

10.04.1 Bag welding is sub-categorized into three processes based on the method of applying the pressure or follow:

PP = Pressure Bag
PB = Pressure Bag
A = Active Bag

10.04.2 Each one of the above processes are described separately in the following sections:

PP = Section 11.0
PB = Section 11.6
A = Section 11.6

10.05 Finishing. It is not one of the objectives of this first edition to cover this topic fully.

10.06 Trimmed

10.05.2 Marking

12.05 Finishing. The use of gel coats and planes of finishing materials that have been previously described, it is desired to eliminate the need for casting features or configurations on or obstructed with bag welding.

10.06 Cutting. The final cut can be passed with any of the usual cutting machines after the removal of the uncut piece from the mold. Regardless of the technique used for cutting, it is possible to line up the knife, because too much pigmentation may result in an inferior molding.

10.05.4 Attachments
11.3144 - **Vacuum Bagging**

Vacuum bagging is a particular form of bagging which involves creating a vacuum in the bag, typically using a pump to remove air from the bag. This process is used in manufacturing to ensure that the bag is tightly sealed, allowing for the application of materials such as resins or adhesives without leakage. It is commonly used in composite materials manufacturing to ensure uniform pressure and to achieve consistent results.

**Diagram Description**

- Diagram shows a vacuum bag being applied over a component.
- The bag is clamped to ensure a tight seal.
- A vacuum is applied to the bag to ensure the resin flows properly.
- The diagram includes steps for applying the bag and ensuring a proper seal.

---

**Text**

Vacuum bagging is a form of bagging that involves creating a vacuum inside the bag, typically using a pump to remove air. This process is used in manufacturing to ensure the bag is tightly sealed, allowing for the application of materials such as resins or adhesives without leakage. It is commonly used in composite materials manufacturing to ensure uniform pressure and to achieve consistent results.
Curing. If a fast-acting catalyst is employed, the oven heat must be used to affect the cure. When the part has been fully cured in accordance with pre-determined curing times and temperatures, the bag is removed and the part is taken from the mold. It has been found desirable to store the part in a closed container for a period of 24 hours before testing to allow a final cure to affect a positive cure. Fig. 11.04c illustrates a typical finished part.

Other, when the requirements of a part may call for a moisture introduction. To accomplish this the lay-up is laid up moistened after the vacuum bag is operated but before the internal heat is applied. The hand applying helps remove the air and assists in the setting out of the glass reinforcement. A moisture retardant has been used to ensure the initiation of the controlled release of the moisture from a moisture retarding plastic prepreg made to government specifications usually are required to be eminently moisture.

Finishing. See Section 10.43.

Pressure and Temperatures. Application of the vacuum is accomplished by placing the bag over the entire apparatus. The bag is then held in place by a hold-down ring or clamping device, made of the outside diameter and contours of the mold, which rests on the perimeter of the vacuum bag. It is desirable to have the vacuum and at least 1 in. spaces from the edge of the hold-down ring so that a "head" space exists between it and the ring, allowing the air that is trapped between the lay-up and the bag to escape to the vacuum pump. In an alternate set of the plane, the bag is held down by fixtures, and the ring is secured the mold and the lay-up as shown in Fig. 11.04b.

A vacuum pump is used to remove air from the lay-up of reinforcing material, thereby utilizing atmospheric pressure for the bag. The apparatus uniformly against the entire surface of the lay-up. The entire lay-up and apparatus are then placed into a heating oven ranging from 200 to 250°F or allowed to cool at room temperature.

Vacuum bag - vacuum frame
Lay-up
Mold
Bolts
Astragal

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**Controlls**

**Procesess and TOOLING**

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**Process Description**

**Reserve bag molding**

**General Description.** Reserve bag molding is a particular type of the molding which meets a number of conditions. The **process** of molding is to place the molding material in a suitable container, usually a **mold**, and to apply the pressure and heat to the material in such a way as to cause it to flow into the mold and to assume the desired shape. The pressure is usually applied by means of a **molding** bag, either a flexible one made of rubber or a non-flexible one made of a hard material. The molding bag is placed over the mold and is inflated to apply the necessary pressure. The heat is usually applied by means of a **thermostat** or a **heater**. The molding bag is then removed and the molding is allowed to cool and to harden.

**Advantages.** Reserve bag molding is a highly efficient method of molding, as it allows for the simultaneous molding of any number of parts from the same material. It is also a very flexible method, as it can be used to mold a wide variety of shapes and sizes. The molding bag can be made of any material that can withstand the heat and pressure, and it can be made in any size or shape.

**Disadvantages.** Reserve bag molding is not a very precise method of molding, as it is difficult to control the amount of heat and pressure that is applied to the material. It is also a relatively slow method of molding, as it requires a significant amount of time to cool and harden the molding.

---

**Fig. 12.011** Typical reserve bag molding setup and after reserve bag molding (under-load reserve bag mold).

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**Fig. 12.015** Molding bag setup schematic (diagram).

---

**Fig. 12.016** Molding bag inflation and after inflation (diagram).
20.01 Soldering  

20.011 General Description. Soldering, as the name indicates, involves the application of a molten solder alloy to the joint to be soldered. The heat is applied to the joint to be soldered, and the solder, which is a liquid metal, is allowed to flow into the joints until the joint is completely soldered. Soldering can be performed by hand or with a soldering iron. The soldering process is often used in electronics and electrical applications.

20.012 Surfing. Surfing is a process used to prevent the formation of a porosity in the soldered joints. It involves the application of a flux or soldering paste to the joint to be soldered, which helps to prevent the formation of porosity.

20.013 Pearson's method of soldering. Pearson's method involves the use of a soldering iron to apply heat to the joint to be soldered, and the solder is allowed to flow into the joint until it is completely soldered.

20.02 MIG Welding  

20.021 General Description. MIG welding is a process that involves the use of a molten metal to form a weld. The process involves the use of a gas to protect the workpiece from the atmosphere, and the weld is formed by the heat generated by the welding torch.

20.022 G-104. See Section L04. In gas welding, the required amount of gas is injected into the arc to produce the desired temperature. The gas is then allowed to flow through the nozzle, and the flame is directed onto the workpiece to melt the metal.

20.023 Heat. See Section L07D. Heat characteristics are important to consider when selecting the right process for a given application. The temperature and the type of heat source will determine the properties of the weld.

20.03 Reinforcement. Reinforcement involves the use of a reinforcing material to strengthen the weld. This is often done to prevent the formation of cracks or other defects in the weld.

20.04 MIG welding. MIG welding is a process that involves the use of a molten metal to form a weld. The process involves the use of a gas to protect the workpiece from the atmosphere, and the weld is formed by the heat generated by the welding torch.

20.05 Shielded Arc Welding  

20.051 General Description. Shielded Arc Welding is a process that involves the use of a molten metal to form a weld. The process involves the use of a gas to protect the workpiece from the atmosphere, and the weld is formed by the heat generated by the welding torch.

20.052 Shielded Arc Welding. Shielded Arc Welding is a process that involves the use of a molten metal to form a weld. The process involves the use of a gas to protect the workpiece from the atmosphere, and the weld is formed by the heat generated by the welding torch.

20.06 Forge-welding. Forge-welding is a process that involves the use of a molten metal to form a weld. The process involves the use of a gas to protect the workpiece from the atmosphere, and the weld is formed by the heat generated by the welding torch.

20.07 Pressure Welding  

20.071 General Description. Pressure Welding is a process that involves the use of a molten metal to form a weld. The process involves the use of a gas to protect the workpiece from the atmosphere, and the weld is formed by the heat generated by the welding torch.

20.072 Pressure Welding. Pressure Welding is a process that involves the use of a molten metal to form a weld. The process involves the use of a gas to protect the workpiece from the atmosphere, and the weld is formed by the heat generated by the welding torch.

20.08 Submerged Arc Welding  

20.081 General Description. Submerged Arc Welding is a process that involves the use of a molten metal to form a weld. The process involves the use of a gas to protect the workpiece from the atmosphere, and the weld is formed by the heat generated by the welding torch.

20.082 Submerged Arc Welding. Submerged Arc Welding is a process that involves the use of a molten metal to form a weld. The process involves the use of a gas to protect the workpiece from the atmosphere, and the weld is formed by the heat generated by the welding torch.
be emerged onto the preform either by means of a needle fitted into the plane of the mold or by head being spaced from the surface of the chamber, the preform is then placed in or over to form the molded article which is then removed and smoothed properly to the molding process. The above preceding operations may require 3 to 5 minutes.

b) The "injection fiber method" is employed when the amount of larger area than can be conveniently handled in the three- or four-chamber machines are required. For these larger preforms it is more practical to mount the bobs on top of a movable gantry type of fixture at one point and to move the gantry from one point to the next while the fiber is fed through the gantry, as shown in Fig. 20.32. Then the gantry is returned to the starting positions and the process is repeated until all the fibers have been wound onto the preform. The gantry fixture is then removed and smoothed properly to the molding process. The above preceding operations may require 3 to 5 minutes.

c) Here recently, the "water bath method" has been developed to produce preforms as shown in Fig. 20.32. It is a procedure similar to that used in the production industry in the making of airplane fuselage sections. In this method, the fiber is wound around a mandrel and is fed through a water bath where the fiber is first impregnated with the resin system. The mandrel is then placed in a vacuum bag and the resin system is then drawn into the fibers by a vacuum pump which is attached to the vacuum bag. The fibers are then wound around the mandrel to form a preform. The mandrel is then removed and smoothed properly to the molding process. The above preceding operations may require 3 to 5 minutes.
20.032.1 The principle limitation in using press for press

20.032.2 In press molding, all resin substrates, existing,

20.031.4 Pressures are widely used for the manufacture of low-

20.031.3 The practical limitation in using press for press

20.030.6 Pressures, "strength", which we are actually a special

20.030.1. An all-over glass is needed for a successful resin

20.030.0 The principle limitation in using press for press

20.030.0 For press molding, all resin substrates except

20.032.2. In press molding, all resin substrates, existing,

20.024.2. In press molding, all resin substrates, existing,

20.024.1. Thermoplastic of glass not by hand but

20.024.1. Thermoplastic of glass not by hand but

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20.024.1. Thermoplastic of glass not by hand but

20.024.1. Thermoplastic of glass not by hand but
Equipment used

20.04.2 Molds. The molds are usually made from steel, cast iron or similar materials. The most common processes use preforms (previously formed) or prepress. The only equipment needed, other than for producing the mold, is an apparatus to permit alignment and heating of the mold, and a means for applying suitable pressure or vacuum. The mold is normally made of steel, although glass, plastic, or a combination of materials may be used. The molds are generally made by casting, machining, or molding the material into the desired shape. The mold is then placed in a press, which applies pressure to the mold, causing the material to flow into the mold and form the desired shape.

20.04.3 Pressures. The pressures required for the press molding processes vary considerably. The capacity requirements are generally determined by the size of the mold and the type of material to be molded. In general, the pressures required for press molding processes are lower than those required for injection molding processes.

20.04.4 Loading. The equipment used for loading the molding materials into the mold includes a hopper or a container that holds the materials. The materials are then fed into the mold using a screw or a ram.

20.04.5 Cooling. The process of cooling the mold is necessary to solidify the material and to remove any excess material. The mold is generally cooled using water or air.

20.04.6 Post-curing. The process of post-curing is necessary to fully cure the material and to improve its mechanical properties. The cured material is then removed from the mold and any excess material is trimmed off.
20.02.5 The temperatures applied during press molding will depend greatly on the type and properties of the material used. Temperatures of 300 to 350°F are common but up to 600°F or more may be used when required. The heat applied will cure the thermosets involved.

20.02.6 To illustrate the general process of press molding, Fig. 20.02.4 shows a schematic of the process using a press for the mold clamping. Note that the press plates are the source of the heat as it is applied during closing of the press.

![Diagram showing press molding process]

20.02.7 Pressures are also of utmost importance in the quality of the finished product. The initial closing of the press can be that of the speed of the press until the last half-inch or so is closed. At this point, the rate of pressure must be sufficient for the resin to flow and set out the reinforcing partially before the heat from the mold begins to cure the resin.

20.02.8 Pressures applied during press molding will depend greatly on the fiber and properties of the material used. Temperatures of 300 to 350°F are common but up to 600°F or more may be used when required. The heat applied will cure the thermosets involved.

20.02.9 To illustrate the general process of press molding, Fig. 20.02.5 shows a schematic of the process using a press for the mold clamping. Note that the press plates are the source of the heat as it is applied during closing of the press.
20.052.5 AFM type is an example of resins in the previous operation. Finished parts may be removed by compressed air when the material is relatively low in expansion. When the resin is more difficult, it is frequently necessary to use a de-molding process. The use of a de-molding process may be better for female halves of the mold so that the condition is equivalent to removing differential, and it is accomplishing the release. In addition, release agents composed of silicon or wax are often required.

20.061 During cure the parts during the molding operations as a result of the pressure and temperature cyclics, however, it is often necessary to in part the cured parts to service the casting. During cure, this is done in standard cure, although the parts are cured before placing it in the core. It may be disadvantage to hold the parts in the mold until the parts may curl or warp during the cure.

20.05 Finishing. It is not one of the objectives of this three edition to cover this topic PUE.}
20.051 Grinding
20.052 Machining
20.053 Machining. These materials will produce very smooth surfaces which facilitate removal of the corners of the mold. The use of oil-water and plastic of surface finish, etc., have been previously described under the castings and parting surfaces. The finish will usually be required to form the mold. If machining is required to form the mold, it is important to maintain that visible by the configuration may be etched with a press using the.

20.054 Coating. The final molding can be painted with any of the usual surface coating materials after all traces of release agent, if used, have been removed. It is often possible to incorporate a pigment to the resin, however the mix pigment may result in an inferior molding.

20.055 Attachments
11.04 General

11.05 Advantages

11.06 Disadvantages

11.07 Equipment Need

11.08 Process Parameters

11.09 Finishing
Processes and Tooling

23:041:1 The cover is the basic material, which begins the cycle in the three-dimensional state. Usually, when the building materials are used, the three-dimensional state is applied and becomes transitive. The transitive process cycle may be as short as 1/2 hr or as long as 6 hr or longer, depending, as previously, on the type of building materials used. The cycle described, however, is but one of many others and is not intended to be an absolute, but rather a typical description of the cycle applied when using building materials.
27.04 Reinforcement. Applicable reinforcements include metallic materials such as angle iron, round rod, various natural and synthetic fabrics and non-woven fabrics or nets made up of fibers of various kinds of fibers.

27.05 Nets. Not applicable.

27.06 Furring. Continuous press mats may be adapted to the prevention of all types of improper formation stages and standing the pressing directly on the condensation rollers. However, certain rollers are lost if this is done. It is used where previously used in industry, although it may be used widely in the future.

27.07 Poor. Not applicable.

27.08 Other. Carrier rollers are required to transport the material after heating impregnation and through the remainder of the process. These carrier sheets are made of a particular kind of board that is not harmful when the material is in contact with it. The sheet that is in contact with the material, called the mat, is sandwiched between the rolls. After impregnation, the web is passed through a drying and curing oven which drives off the solvent and cures the resin binder.

27.09 Equipment.

27.10 Longing. In this process, longing actually creates the correct number of piles of material taken from the impregnation bath. This material is automatically controlled to a use of appropriate rollers and truss rolls into the basic equipment.

27.11 Seats. Not applicable.

27.12 Press. Pressure is applied by a pair of hydraulic or mechanical rolls set to produce a predetermined thickness of laminate. Side gates are associated with the rolls to maintain the desired thickness of the laminate.

27.13 Dies. The curing oven may be vertical or horizontal 20 to 200 feet in length divided into zones. The oven is supplied with circulating air at a predetermined temperature. The secret lies in the proper control of the temperature in the oven. The oven must be adjusted to the proper amount of heat and the material is controlled through temperature, air circulation, and humidity.

27.14 Stocks. Usually no heat is supplied in this section where the curing oven is required. The product may be moved to a cool area.

27.15 Finish. Sections. Sections from 20 to 200 feet in length, temperature control of 5/10 cycles is extremely critical to avoid damage during curing sections.

27.16 Stocks. Usually no heat is supplied in this section where the curing oven is required. The product may be moved to a cool area.

27.17 Description. A description elaborating the reinforcing web in various forms such as natural and synthetic fabrics and non-woven fabrics or nets made up of fibers of various kinds of fibers is necessary.

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Prior to the actual impregnation or saturation of the base material with resin, it is necessary to follow strict rules of storage. For both the resin and the reinforcements, depending on the manufacturer's facilities, the resin may be either protected or, if feasible, produced in the plant. Some resins in their ordinary state are essentially solid substances (either produced or to perfect form) that can have either a powdered or a liquid subject to a "varnish" or "typing".

Basic solutions must be prepared to fresh batches and not permitted only for immediate use, as the solvent evaporates to a certain extent, thereby changing the impregnating quality of the resin and consequently the characteristics of the end product. "Typing" handled for a particular coming job should be kept in a tightly drawn or in large bundling or storage, preferably in constant-temperature conditions and provided with approval temperature facilities.

Certain grades of paper, glass, and other base materials should also be stored under controlled conditions of moisture and temperature to prevent dimensional change, water absorption, and other imperfections that will affect the finished product.

Impregnation of the base material is accomplished by pouring the resin through a needled fabric for a period of time sufficient to saturate the fibers completely. When a dense paper or a closely woven fabric is being impregnated, the resin should be forced through with a sufficient pressure to ensure an adequate wetting of resin to obtain complete impregnation during storage to roll them. If this type of surface treatment, the roll may be slowly retained to prevent distorting within the roll.

When loosely needled fibers, such as glass mat, are impregnated, special procedures, such as wrapping, in the resin bath, vertical impregnation, or laying the mat into resin, the resin must be used to prevent the resin from separating. Regardless of the procedure, impregnation must be complete, and trapped air will show up in the end product as blisters, deformation, and surface delamination.

Curing

The curing section of a continuous laminate consists of a circulating hot air or chemically treated gas which is divided into zones as indicated in Section 7.03. Most commercial laminating rooms operate in the range of 5 to 17 feet per minute of laminate (travel).

Finishing

Finishing is not one of the objectives of this final section to cover this topic fully.

Attachments
CHAPTER 14

14.1 INTRODUCTION

14.1.1 Purpose of Manual

The purpose of this Manual is to present surface test and quality control methods as they are used in the reinforced plastics industry. These methods are described in sufficient detail to give a good understanding of the test and its purpose. Additional details not included may be found by referring to the original sources.

14.1.2 Part of the test methods used to obtain data presented in this Manual are included in:

- The Manual of the Standard, and
- The Manual of the Standard, with the following significant:

1. = Test Code Number

2. = Property Category: mechanical, thermal, etc.

3. = Details of test: negative, positive, etc.

4. = Supporting Specification Number (last letter of set described in this row).

14.1.3 This Manual also presents summaries of Quality Control procedures. For details, these are designated with the prefix initial "Q" = the code number (last letter of set described in this row).

14.1.4 Certain organizations (ASTM, for example) incorporate "Standard Test Procedures" which are referenced to individual test methods or procedures in their published works. In accord with industry and practice, the same procedures are included in this Manual. Section 14.1.2, "Summary of Standard Test Procedures," includes procedures common to several of these organizations' standards (at the time of publication). Paragraph cross-referencing within the Manual is done here as being sufficient. The prefix letters "S" = is used in the code number for these sections.

14.2 Scope of Manual

14.2.1 This Manual is divided into sections as follows:

Section No. Subjects

1.0 TEST METHODS - PHYSICAL PROPERTIES

2.0 TEST METHODS - CHEMICAL PROPERTIES

3.0 TEST METHODS - COERCIVE PROPERTIES

4.0 TEST METHODS - THERMAL PROPERTIES

5.0 TEST METHODS - ELECTRICAL PROPERTIES

6.0 TEST METHODS - MECHANICAL PROPERTIES

7.0 TEST METHODS - MECHANICAL PROPERTIES

14.2.2 Each Section describing a Test Method is subdivided as follows, using Method D.01 as an example:

1.0 Scope

2.0 Test Rationale

3.0 Test Procedure

4.0 Description

14.3 Abbreviations and Glossary

14.2.3 For complete listing of all abbreviations and definitions used throughout the Handbook, see Manual 2A.

1.0 INTRODUCTION

1.0.1 A complete source index is given in Manual 16.
TESTING AND QUALITY CONTROL

TABLE 8.104.1

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Major Principal</th>
<th>Precise, \text{ lb}</th>
<th>\text{ ft}</th>
<th>\text{ lb}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>1.0</td>
<td>60.0</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td>Gypsum</td>
<td>1.5</td>
<td>60.0</td>
<td>1/2</td>
<td></td>
</tr>
<tr>
<td>Gypsum</td>
<td>1.0</td>
<td>100.0</td>
<td>1/2</td>
<td></td>
</tr>
</tbody>
</table>

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4.01 Test Materials-Used

4.02 Test specimens

4.03 Test specimens as required.

4.04 Reference standards to be used in test. The standard shall be to 10 parts in 100,000, unless otherwise specified.

4.05 Procedure-Testing. Test specimens shall be tested in accordance with the procedures specified in this section.

4.06.1 Determination of temperature. The temperature shall be determined by the use of a thermometer, a temperature indicator, or a temperature controller.

4.06.2 Determination of specimen weight. The weight of the test specimen shall be determined by weighing the specimen before and after testing, and the difference shall be considered as the weight of the test specimen.

4.06.3 Determination of deflection. The deflection of the test specimen shall be determined by measuring the difference in length between the test specimen before and after testing.

4.06.4 Determination of specimen force. The force applied to the test specimen shall be determined by the use of a force sensor or a similar device.

4.06.5 Determination of specimen displacement. The displacement of the test specimen shall be determined by measuring the change in position of the test specimen before and after testing.

4.06.6 Determination of specimen stress. The stress applied to the test specimen shall be determined by dividing the force applied to the test specimen by the cross-sectional area of the test specimen.

4.06.7 Determination of specimen strain. The strain of the test specimen shall be determined by measuring the change in length of the test specimen before and after testing.

4.06.8 Determination of specimen modulus. The modulus of elasticity of the test specimen shall be determined by dividing the stress applied to the test specimen by the strain of the test specimen.

4.06.9 Determination of specimen hardness. The hardness of the test specimen shall be determined by the use of a hardness tester.

4.06.10 Determination of specimen wear. The wear of the test specimen shall be determined by measuring the wear of the test specimen before and after testing.

4.06.11 Determination of specimen fatigue. The fatigue of the test specimen shall be determined by measuring the number of cycles to failure of the test specimen.

4.06.12 Determination of specimen aging. The aging of the test specimen shall be determined by measuring the change in properties of the test specimen after aging.

4.06.13 Determination of specimen corrosion. The corrosion of the test specimen shall be determined by measuring the weight loss of the test specimen after corrosion.

4.06.14 Determination of specimen oxidation. The oxidation of the test specimen shall be determined by measuring the change in color of the test specimen before and after testing.

4.06.15 Determination of specimen aging. The aging of the test specimen shall be determined by measuring the change in physical properties of the test specimen after aging.

4.06.16 Determination of specimen fatigue. The fatigue of the test specimen shall be determined by measuring the number of cycles to failure of the test specimen.

4.06.17 Determination of specimen hardness. The hardness of the test specimen shall be determined by the use of a hardness tester.

4.06.18 Determination of specimen wear. The wear of the test specimen shall be determined by measuring the wear of the test specimen before and after testing.

4.06.19 Determination of specimen corrosion. The corrosion of the test specimen shall be determined by measuring the weight loss of the test specimen after corrosion.

4.06.20 Determination of specimen oxidation. The oxidation of the test specimen shall be determined by measuring the change in color of the test specimen before and after testing.

4.06.21 Determination of specimen aging. The aging of the test specimen shall be determined by measuring the change in physical properties of the test specimen after aging.

4.06.22 Determination of specimen fatigue. The fatigue of the test specimen shall be determined by measuring the number of cycles to failure of the test specimen.
4. TEST METHODS - THERMAL PROPERTIES

4.168 Test (16,012 LF).

4.168.1 Specimen, specimen dimensions and test requirements are per ASTM D-459. (Note: Although not indicated, this test includes in general 5 tests, with a minimum of 3 tests per test set.)

4.168.2 Specimen:

a. Test specimens shall be 3 1/4 by 1 1/2 by 1 1/2 in. thick. They shall be cut in a direction perpendicular to the direction of molding pressure.

b. Test specimens shall be 3 1/4 by 1 1/2 by the sheet.

c. Test specimens shall be 10 by 10 by 1 1/2 in.

4.168.3 Conditions. The specimen shall be conditioned at 75 ± 3.0°C for 3 minutes.

4.168.4 Procedure - Procedure. The molded specimens are to be placed in the apparatus on the disk with the unfrosted surface of the specimen uppermost and the frosted surface of the sheet lowermost. The exhaust fan used to eliminate the frosted surface is to be run to the heat distortion temperature.

\[ F = \frac{d^2}{w} \]

where:

\( F \) = a load in pounds

\( d \) = width of specimen in inches

\( w \) = depth of specimen in inches

The weight of the loading rod and spring bond at the dial gauge are to be considered as part of the load, W.

4.168.5 Procedure - Drying. Temperatures at the beginning of test should be 22.7 ± 1.0°C and subsequently should be increased at a rate of 0.60°C per minute. A load weighing 2 lb is applied to the specimen and is maintained at 2 lb for 2 minutes prior to mounting the semi-scale for deflections and start of the temperature. The temperature is increased at a rate of 0.5°C per minute, to reach the heat distortion temperature.

4.168.6 Observation. Observations are to be recorded at each 1°C increase in temperature. The heat distortion temperature is defined as the temperature at which a deflection of 0.003 in. is reached or at the midpoint of the specimen.

4.168.7 Acceptance. A temperature-deflection curve shall be plotted with the ordinate as temperature and the ordinate as deflection. Any levels taken should be accepted by the manufacturer of the specimen.

4.168.8 Test Data. The apparatus should be constructed similar to that indicated for the sheet and shall have a load of 2 lb applied to the bottom with a 1 1/2 in. long metal screw. The weight of the apparatus shall be at least twice the weight of the test specimen, and the same thermal characteristics of lineal expansion or compression used to hold the specimen in the test apparatus. The specimens shall be fabricated in the same manner as the sample to which these are to be compared. The dimensions shall be used for transfer of test to the specimen. The test shall be continued until the rigidity of the specimen and shall be stopped during testing. Weight of the specimen also to be added to the test to apply stress as required in the test should be added.

4.168.9 Monitoring and Recording Equipment. A dial gauge is to be used to measure deflection.
4. TEST METHOD - GENERAL REQUIREMENTS

4.01 Basic Definitions

4.01.2 Test 4.013 LP

4.01.3 Scope - CSA Z245.2.1 (1986) and CSA Z245.2.3 (1989) are relevant. This test is not intended for tests on pipe or pipe fittings.

4.01.4 Procedure - Pre-conditioning. The samples are heated at 10°C for 1 h prior to testing at the test temperature.

4.01.5 Procedure - Testing. After conditioning, the specimens are tested at 10°C for 1 h, after which they are immersed in a solution of 60% sulfuric acid at 75°C for 1 h. The gage length is then measured. The test is repeated two more times. The gage length is measured at 45°C, 10°C, and 75°C.

4.01.6 Observations. See 4.013.3 and 4.013.4.

4.01.7 Report - The report shall include the appearance, color, surface finish, evidence of warping, splitting, or reinforcing, and changes in the original dimensions.

4.02 Test Equipment

4.02.1 Test equipment shall be installed to provide a uniform contact of all samples from the same lot. A propeller shall be provided to ensure constant stirring of the immersion fluid throughout the test. Accurate adjustment of the temperature should also be provided.

4.02.2 Weighing and Recoding Equipment. A thermometer of sufficient accuracy is to be placed in the immersion bath.
TESTING AND QUALITY CONTROL

4.02 Thermal Conductivity Tests

4.02.1 General. ASTM C 177-61, Thermal conductivity of Materials by Means of the Hot Plate Method, should be followed except as modified by the following:

4.02.1.1 Specimen. Specimen dimensions shall be as given in Table 4.02.1. The cross section should be larger than that of the test set-up. This thickness should be determined as indicated in Table 4.02.1.1. See also Fig. 4.02.1.1.

<table>
<thead>
<tr>
<th>Minimum Thickness</th>
<th>Minimum Linear Dimensions of</th>
<th>Minimum Linear Dimensions of</th>
<th>Maximum Linear Dimensions of</th>
<th>Maximum Linear Dimensions of</th>
<th>Maximum Linear Dimensions of</th>
<th>Maximum Linear Dimensions of</th>
<th>Maximum Linear Dimensions of</th>
<th>Maximum Linear Dimensions of</th>
<th>Maximum Linear Dimensions of</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>1 1/2</td>
<td>2 1/4</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

4.02.2 Conditions. The test is to be used only over the range from 0 to 100°F for extreme temperatures and 0 to 120°F for mean temperatures.

4.02.3 Procedure — Preliminary. Specimens shall:

4.02.3.1 Be placed in a position to allow the thermometer to be inserted without touching the face of the specimen.

4.02.3.2 Be straight and parallel to the faces of the block, and the distance between the hot and cold plates to be considered in calculating the thermal resistance of the block and the specimen.

4.02.3.3 Be uniformly packed, and uniform contact between the specimen and the supporting plates should be maintained during the test.

4.02.3.4 Be subjected to the action of a stream of air passing through the instrument according to Fig. 4.02.3.4.

4.02.3.5 Be tested under conditions of atmospheric pressure to be determined by the manufacturer of the instrument.

4.02.3.6 Be tested at the temperature level for which the instrument is designed.

4.02.4 Observations. At least five specimens shall be tested for each determination. The weight of the specimen should be recorded after drying, but before testing, and after testing, and after drying. The mean density of the specimens may be computed by dividing the total weight of the specimens by the total volume of the specimens.

4.02.5 Results. The mean density of the specimens shall be calculated as follows:

\[ \rho = \frac{m}{V} \]

where:
- \( m \) = weight of specimen as received in lb/ft\(^3\)
- \( V \) = volume of sample as received in cubic ft

4.02.6 Weight change during testing.

\[ W = (W_0 - W_1) \times \frac{1}{10} \]

where:
- \( W_0 \) = moisture content during testing in lb/ft\(^3\)
- \( W_1 \) = weight of specimens after testing in pounds
- \( P \) = weight of specimens prior to testing in pounds

The weight change is to be computed as follows:

\[ W = \frac{W_0 - W_1}{P} \times 10 \]

where:
- \( W_0 \) = moisture content
- \( W_1 \) = weight of specimens after testing
- \( P \) = weight of specimens prior to testing

The thermal conductivity is to be computed as follows:

\[ K = \frac{W_0 - W_1}{P} \times 10 \]

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\[ K = \frac{W_0 - W_1}{P} \times 10 \]

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\[ K = \frac{W_0 - W_1}{P} \times 10 \]

The thermal conductivity is to be computed as follows:

\[ K = \frac{W_0 - W_1}{P} \times 10 \]
Measuring and Recording Equipment. Thermocouples are to be used to measure the surface temperature. The potentiometer is to have a sensitivity of at least 5 micro volts. The heating element is to have a regulation of ±0.4 per cent, if it is automatic. In the absence of such a device, the temperature difference between the center and fixed surface plates over the 5 hour interval should be less than 0.75 per cent of the average drop through the ten holes of the specimen.
TEST METHODS - MECHANICAL PROPERTIES

6.01 Test Methods

6.01.1 Scope. ASTM D530-60T, Textile Properties of Plastics

6.01.2 Specimen:
   a. Specimens for Plastic Sheet, Plate and Molded, Fig. 6.01.1a. These specimens shall be fabricated by machining from plastic sheet, plate or by molding.
   b. Specimens for Plastic Rod, Fig. 6.01.1b.
   c. Specimens for Plastic Tube, Fig. 6.01.1c.
   d. All specimens should be free of flaws, scratches and mismatching marks, where these do occur they should be removed with No. 0 abrasive paper worked parallel to the template ends of the specimens.
   e. Specimens also to be made by some means other than injection molding.
   f. The figures shown give basic specimen dimensions, details of tolerances, etc., will be found in original source.

6.01.3 Conditions. Conditioning of test specimens should be in accordance with ASTM 5-45 for purposes of defining ultimate properties and moisture absorption. No environmental conditions are specified in source.

6.01.4 Procedure - Preliminary: The grips are to be spaced apart as shown in Fig. 6.01.1d illustrating the apparatus. The distance between the grips should be capable of being adjusted so that no clamps can be developed in the specimen. With the specimen uncoupled, the grips are to be tightened firmly, but not to pressure sufficient to unseat the gripping portion of the specimen.

6.01.5 Procedure - Testing: The speed of testing shall be one of those shown in Table 6.01.5. Unless otherwise specified, speed #2 shall be used. When determining the speed, refer to Table 6.01.5.

<table>
<thead>
<tr>
<th>Source</th>
<th>ASTM D530-60T</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.85 to 0.15</td>
</tr>
<tr>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>60</td>
</tr>
</tbody>
</table>

Electrical, modulus, speed #1 shall be used for bimetallic, AA yellow, and speed #2 for others. Nails, bolts, and other similar properties for strength and physical determinations may be necessary in certain cases.

6.01.6 Observations:
   a. The use of specimens made to substantiate these results and which have a possibility of exhibiting anisotropic properties, sectioning should be done, 3 parallel to L and 3 parallel to W. The test shall be done in the principal axis. If these axes are fixed and unchangeable, additional specimens should be used.
   b. To determine the modulus of elasticity a second of loads and deflections should be taken. Record the elongation in two different grips and when strain determinations are made to the length of the grips, from then, derive tensile strength, percent elongation, mean value of stress, mean rate of strain, and elastic modulus can be determined.

6.01.7 Report. Not specified by source.

6.01.8 Test Machine: A constant strain testing machine which is accurate to ±1 per cent in the indicated load range shall be used.

6.01.9 Measuring and Recording Equipment:
   a. The strains indicated should be accurate to ±1 percent of the measured value.
   b. Micrometers should read to ±0.01 in or less.

SPECIFIED CONDITIONS - TN

<table>
<thead>
<tr>
<th>Type 1 (G)</th>
<th>G (kip/in²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/16</td>
<td>0.75</td>
</tr>
<tr>
<td>1/8</td>
<td>1.25</td>
</tr>
<tr>
<td>1/4</td>
<td>3.75</td>
</tr>
</tbody>
</table>

T = Thickness

FIG. 6.01.2A SPECIMENS FOR PLASTIC SHEET, PLATE & MOLDING

(a) Distance between grips
(b) Standard grip length = 5.75 in

FIG. 6.01.2B SPECIMENS FOR PLASTIC TUBE

(a) Distance between grips
(b) Standard grip length = 5.75 in

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6.0 TEST METHODS - MECHANICAL PROPERTIES

6.01 Test Specimens

6.01.1 General. ASTM D2206-83, Textile Properties of Fabrics at 100% of Maximum Extension.

6.01.2 Specimen. The shape of specimens shown in Fig. 6.012.2 is to be used when the thickness of the sheet is less than 0.02 in and only when the amount of material available is limited. Specimens shall be prepared by die-cutting.

6.01.3 Condition. Conditioning of test specimens should conform to 62.04.01 for purposes of obtaining reproducible results. See section 61.05.3.4, environmental conditions are specified by source.

6.02 Procedure - Angeloni. The grips are to be 0.030 ± 0.005 in apart and the axis of the grips and specimen line to be aligned such that no movement can be developed in the specimen. With the specimen accurately placed, the grips are to be tightened firmly, but not in pressures sufficient to cause buckling.

6.03 Procedure - Instron. The speed of testing shall be one of those shown in Table 6.03.1. If a specific testing speed is not given as a testing parameter of the test, Speed 1 in the table should be used. These speeds correspond to stresses comparable to those specified in ASTM D388-87 (see Sec. 6.03.1).

6.04.1 Observations.

| Speed | Source | ASTM D2206-83
|-------|--------|----------------
| 300 mm/min | 3200 spm | 0.00
| 500 mm/min | 3200 spm | 0.00 to 0.02
| 600 mm/min | 3200 spm | 0.02 to 0.04
| 700 mm/min | 3200 spm | 0.04 to 0.06

6.04.2 Report. The specimen shall be identified with the number assigned to each specimen. The test shall be carried out using the appropriate grips, and any deviation from this procedure shall be noted. The test shall be conducted at a constant crosshead speed of 3200 spm (100 mm/min).

6.04.2.1 Test Equipment. It is best to use rubber-faced grips for this standard, but friction grips can be used if care is taken. Self-weighted grips are not satisfactory.

6.04.2.2 Measuring and Recording Equipment. The equipment shall be capable of measuring and recording the elongation to failure. All accuracy of ± 1% should be met by the recording device and determination of test results should be within ± 5% of the total elongation of the test sample.
6.0.4 Test Methods - Mechanical Properties

6.0.22 Compression Tests

6.0.22.1 Scope. ASTM D695-54, Test for Compression Properties of High-Temperature Materials.

6.0.22.2 Specimen.

a. The standard test specimen shall be in the form of a right cylinder or prism whose length in inches is twice the diameter or height in inches. The diameter or height shall be parallel within 0.01 in. Preferred specimen sizes are 2 1/2 x 2 1/2 x 1 inch for prisms and 2 1/2 inch diameter by 5 inch for cylinders. The specimen may be machined from stock or welds.

b. To determine the elastic modulus and yield strength, specimens with a minimum ratio of 15 to 1 shall be used.

c. Not specimen shall have the same diameter, up to 1 inch, or the stock material and height as shown in Table 6.0.22.2. For each specimen, one shall be tested at 1/2 x 1/2 x 1 inch, and the remaining parts shall be cut to be representative of the red cross-section.

d. For tubes, a specimen with a gauge of the tube x 1 inch in length shall be used. The specimen shall be cut at a 45° angle to the longitudinal axis, and the cut shall be located as near to the longitudinal axis.

e. For test pieces, material less than 1 inch thick, a flange-up or sheet 1 inch square with sufficient lip from 0.0625 to 0.125 inch to produce a minimum length of 1 inch shall be used. Considerable care is necessary during testing to avoid buckling.

6.0.22.3 Conditions. Conditioning of test specimens shall conform to ASTM with the purpose of establishing reproducible test data under identical environmental conditions as specified by source.

6.0.22.4 Procedure - Preliminary. The specimen shall be carefully planned in testing machines or compression test in such a manner as to determine the elastic modulus, yield point, and ultimate strength of the material. Fig. 6.0.22.4 shows a schematic of a typical compression test. The compression test equipment shall be very stiff and shall hold the plunger perpendicular.

6.0.22.5 Procedure - Testing. The speed of testing shall be 0.05 inches per minute below the yield point. Rates of 0.20 to 0.05 inches may be used beyond this point.

6.0.22.6 Observations.

a. The number of specimens necessary to substantiate the testing is five. If the material has a high probability of exhibiting anisotropic properties, composites shall be parallel to, and parallel to, and perpendicular to the principal axes. If necessary, such as fibers or reinforcing filaments, exhibit in service, the material shall be tested parallel to, and perpendicular to, the principal axes. If necessary, such as fibers or reinforcing filaments, exhibit in service, the material shall be tested parallel to, and perpendicular to, the principal axes.

b. A record of load and elongation should be made throughout the test to order to calculate engineering properties of the material. From these, the yield strength, compression strength, elastic modulus, and deformation beyond yield can be computed.

6.0.22.7 Reporting. A report should include complete identification of material, proportion of test specimen with dimensions of test, results of stress and strain, elastic modulus, yield point, strength, ductility, toughness, and anelastic methods.

6.0.22.8 Test Equipment.

a. A constant strain testing machine which is accurate to ± 0.001 percent of the instrument scale shall be used.

b. A compression tool, such as shown in Fig. 6.0.22.5, may be used.

6.0.22.9 Measuring and Recording Equipment.

a. A monographic of linear deformation shall be recorded to ± 0.001 inch.

b. Micrometers shall read to 0.001 inch or less.

---

**Table 6.0.22.2**

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Compressive Modulus, kips/in²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 to 1/2</td>
<td>15 ± 0</td>
</tr>
<tr>
<td>1/2 to 1</td>
<td>15 ± 0</td>
</tr>
<tr>
<td>1/2 to 1</td>
<td>15 ± 0</td>
</tr>
</tbody>
</table>

---

**Fig. 6.0.22.4** Testing Machine Head
TESTING AND QUALITY CONTROL

6.0 TEST METHOD - MECHANICAL PROPERTIES

6.0.3 Test Specimen


6.0.3.2 Procedure.

(1) The test specimen shall be in the form of a 1" X 1" X 3" specimen. All faces of the specimen shall be parallel. The specimen shall be conditioned to 72°F ± 1°F and shall be conditioned for a minimum of 48 hours.

(2) The test specimen shall be placed in a fixture that will permit the specimen to be tested in a uniaxial stress state. The fixture shall be such that the specimen is subjected to a constant stress state throughout the test.

(3) The test specimen shall be subjected to a constant stress state at a rate of 0.005 in./min (0.127 mm/min) until failure occurs. The stress shall be continuously monitored and recorded.

6.0.3.3 Conditions. Conditioning of test specimens shall conform to D 6022 (General). The environmental conditions specified in D 6022 shall be maintained throughout the test.

6.0.3.4 Procedure - Stress. The specimen shall be subjected to a constant stress state at a rate of 0.005 in./min (0.127 mm/min) until failure occurs. The stress shall be continuously monitored and recorded.

6.0.3.5 Procedure - Strain. The speed of testing shall be 0.005 in./min (0.127 mm/min). A supporting jig for this test specimen shall be used as specified in Fig. 4.022.6.

6.0.3.6 Observation.

(a) The yield stress of the specimen shall be determined by plotting the stress-strain curve and locating the point of maximum load.

(b) The ultimate tensile strength of the specimen shall be determined by plotting the stress-strain curve and locating the point of maximum load.

(c) The elongation of the specimen shall be determined by measuring the increase in length of the specimen and comparing it to the original length.

(d) The test results shall be reported in accordance with D 6022 (General).

6.0.3.7 Report.

(a) The report shall include the following information:

(i) The type and size of the test specimen.

(ii) The method of testing and the test conditions.

(iii) The results of the test, including the yield stress, ultimate tensile strength, and elongation.

(iv) The conclusions drawn from the test results.

6.0.3.8 Notes.

(a) The test specimen shall be conditioned to 72°F ± 1°F and conditioned for a minimum of 48 hours.

(b) The fixture shall be such that the specimen is subjected to a constant stress state throughout the test.

(c) The test specimen shall be subjected to a constant stress state at a rate of 0.005 in./min (0.127 mm/min) until failure occurs. The stress shall be continuously monitored and recorded.

(d) The stress shall be continuously monitored and recorded. The stress shall be continuously monitored and recorded.

(e) The speed of testing shall be 0.005 in./min (0.127 mm/min). A supporting jig for this test specimen shall be used as specified in Fig. 4.022.6.

(f) The yield stress of the specimen shall be determined by plotting the stress-strain curve and locating the point of maximum load.

(g) The ultimate tensile strength of the specimen shall be determined by plotting the stress-strain curve and locating the point of maximum load.

(h) The elongation of the specimen shall be determined by measuring the increase in length of the specimen and comparing it to the original length.

(i) The test results shall be reported in accordance with D 6022 (General).

(j) The report shall include the following information:

(i) The type and size of the test specimen.

(ii) The method of testing and the test conditions.

(iii) The results of the test, including the yield stress, ultimate tensile strength, and elongation.

(iv) The conclusions drawn from the test results.

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TESTING AND QUALITY CONTROL

6.03

TEST METHODS - MECHANICAL PROPERTIES

6.03.1 Special Tests

6.03.2 Test Methods

6.03.2.1 Source: ASM SP-69421, present Properties of Fibrous Materials.

6.03.2.2 The sheets may be selected at random in the package at the discretion of the purchaser. Two sheets shall be tested from each lot of material, unless otherwise specified. The test specimen shall be the full width of the sheet. The length of the specimen shall be a minimum of one tenth of the length of the sheet. The area of the specimen shall be calculated by multiplying the length of the specimen by the thickness of the specimen. The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.2.3 Procedure: The test specimen shall be conditioned to 50% ± 5% relative humidity at 73°F ± 3°F for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.2.4 Procedure: The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.2.5 Procedure: The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

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6.03.5 Table: The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.6 The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.7 The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.8 The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.9 The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.10 The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.11 The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.

6.03.12 The test specimen shall be conditioned to a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for 24 hours before testing. The test specimen shall be cut to a length of 12 inches and a width of 1 inch. The specimen shall be conditioned for 24 hours before testing. The test specimen shall be conditioned in a humidity chamber at a temperature of 73°F ± 3°F and a relative humidity of 50% ± 5% for at least 24 hours before testing. The test specimen shall be tested in accordance with the American Society for Testing and Materials (ASTM) standards.
I.6.02.3. Procedure - Preliminary. None given.

I.6.02.4. Procedure - Testing. Setting load maximum should lie in the range of 1.5 to 0.23 inches. The range of 1.5 to 0.23 inches is arbitrary, but any setting load beyond this range may produce results that are not suitable for the ultimate design for load-carrying capacity. The width of the specimen should not be greater than twice the depth of the specimen. The depth to width ratio should be no greater than 1.5 to 1.0.

I.6.02.6. Reporting. The load deflection curve should be plotted through the proper load level. The final load level and minimum load level should be computed from the equation:

\[ F = M \cdot g \]

Where:
- \( M \) = modulus of elasticity in loading, psi
- \( g \) = given length, in
- \( n \) = depth of beam, in
- \( a \) = slope of weight line portion of load deflection curve, in/in

The maximum and minimum stresses are to be computed by:

\[ \sigma = \frac{F \cdot b \cdot g}{2 \cdot h^2} \]

Where:
- \( F \) = load, pounds
- \( b \) = width of beam, in
- \( h \) = depth of beam, in
4.0 TEST METHODS - MECHANICAL PROPERTIES

5.03 Test T5.03

5.03.1 Scope: FPL report 442, "Effect of Span Depth Ratio on Thickness of the Quadrilateral Fracture of a Tempered Glass Panel - Ring Flexure Laminates As Determined by Sneding Tests."

5.03.2 Specimen: The ratio of width to depth for each specimen was approximately 3. Samples for these 1/14 inch thick specimens were 1/2 inch wide. The 1/14 depth percent was as indicated at Table 5.03.3. Other than this, the specimens met the specifications of T5.03.1 ASTM.

<table>
<thead>
<tr>
<th>Depth 1/14</th>
<th>7</th>
<th>10</th>
<th>12</th>
<th>15</th>
<th>18</th>
<th>21</th>
<th>24</th>
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<tbody>
<tr>
<td>1/4</td>
<td>7</td>
<td>10</td>
<td>12</td>
<td>15</td>
<td>18</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>1/2</td>
<td>7</td>
<td>10</td>
<td>12</td>
<td>15</td>
<td>18</td>
<td>21</td>
<td>24</td>
</tr>
</tbody>
</table>

Conditions: None given.

5.03.4 Procedure - Preliminary. None given.

5.03.5 Procedure - Setting. See T5.03.1 ASTM.

5.03.6 Observations. See T5.03.1 ASTM.

5.03.7 Report. See T5.03.1 ASTM.

5.03.8 Test Equipment. See T5.03.1 ASTM.

5.03.9 Measuring and Recording. None given.
3.2.1 **Specimen Preparation**

Specimens are to be cut from a 6 x 6 inch square by ½ inch thick glass. The mean thickness will be 1/8 inch thick.

3.2.2 **Conditioning Specimens**

Specimens should be tested dry and after varying periods of being immersed in boiling water.

3.2.3 **Equipment**

Testing equipment should be clean and clean.

3.2.4 **Procedure**

Testing method should be clean and clean.

3.2.5 **Result Interpretation**

The results should be interpreted using the following equation:

\[ \text{Ultimate Tensile Strength} = \frac{\text{Result}}{\sqrt{\text{Diameter}}} \]

Both stress and strain values are to be recorded in order that a modulus can be determined.

3.2.6 **Equipment Testing**

Tests were conducted on a universal testing machine.

3.2.7 **Summary and Conclusion**

Tests were conducted on a universal testing machine.
6.04.6 Test Method - Mechanical Properties

6.04.6.1 Test ASTM D790. Shear Strength of Plastics.

6.04.6.2 Procedure. The specimen shall be 3 inches square or 2 inches in diameter and can be molded or cut from the part. The specimen shall be tested in accordance with ASTM D790. The specimen should be parallel to the axis and a hole bored through its center.

6.04.6.3 Conditions. Conditioning of test specimen should conform to ASTM D1709, except that the conditioning shall be limited to 62°F ± 5°F. All specimens shall be placed in a conditioning room before testing. If the specimen is removed from the conditioning room, it should be returned to the conditioning room before testing. This specimen shall be tested at 62°F ± 5°F.

6.04.6.4 Procedure. A punch tool shall be placed over the bending post and after positioning, the tool is tightened. The punch and punch assembly is then placed on the Montgomerie tool and the bolts tightened. See Fig. 6.04.6-A.

6.04.6.5 Procedure - Testing. Crosshead speed should be 0.005 mm per minute.

6.04.6.6 Observations. Five specimens should be used. The maximum load which is required to drive the moving portion of specimens completely close to the stationary part of the punch.

6.04.6.7 Reports. Complete identification of specimen, lot, and test conditions shall be included with the test results. The results shall be given. Punch diameter, maximum load and calculated shear strength, in psi, of the area of the punched portion shall be reported.

6.04.6.8 Test Equipment. A constant strain testing machine should be used. The ultimate tensile strength is to be read from the dial and be accurate to ± 1 per cent of the indicated value. A tool similar to the one shown in Fig. 6.04.6-A should be used.

6.04.6.9 Measuring and Recording Equipment. See given.

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6.20 TEST METHODS - MECHANICAL PROPERTIES


6.20.2 Specimen.  

a. For heat treating materials, test cylinders are to be 1/2 inch in diameter, however, diameter is not critical as long as it is uniform. The height of the cylinder is at least 3 times its diameter.  

b. For thermoplastic materials only rectangular, 2 inch by 0.25 inch by 2 inch of least dimension, in the direction of material flow 1/4 inch thick, machining will be required before a specimen can be acceptable.  

6.20.3 Conditions. None given.  

6.20.4 Procedure - Preparation. None given.  

6.20.5 Procedure - Testing. Range of load travel and load applied for 0.001 inch.  

6.20.6 Observations. None given.  

6.20.7 Report. This should include information given in Section 10.02 LP as well as the type of jig and testing used.  

6.20.8 Test Equipment. A standard tension testing machine to be equipped with a three-point jig or a Johnson-type shear tool.  

6.20.9 Measuring and Recording Equipment. None given.
TESTING AND QUALITY CONTROL

4.0 TEST METHOD - MECHANICAL PROPERTIES

4.0.1 Scope

4.0.2 Test Method

4.0.2.1 Specimens. The shape of the test specimen is somewhat comparable to that of a corner Grid. The center portion covers the area of the specimen is located so that the center line of the specimen is parallel to the long direction. The Specimen was cut to the size of 18 inches. The lips for applying loads were cut in the specimen at the point of the specimen. The specimen is further described in the source for illustrations of this.

4.0.2.3 Considerations. Procedure was done with 750 and 500 lb. Deviation taking as control of concentricity and twisting was noted.

4.0.2.5 Procedure - Testing. Loads were applied at the rate of 5 lbs. of load per second.

4.0.3.3 Interactions. A diagram of 2 specimens were created. The interaction, weight and load, and the load and temperature, and the temperature, were recorded.

4.0.3.7 Report. The property of the sile of the laminate was determined by the following equation:

\[ \tau = \frac{F}{A} \]

where:
- \( \tau \) = Property of the laminate
- \( F \) = Area of the laminate
- \( P \) = Property of the ply of the laminate
- \( A \) = Area of the ply

4.0.3.8 Test Endurance. The "Test Center" specified the "test center" for the center of the constant stress limiting apparatus.

4.0.3.9 Measuring and Recording Equipment. Statically mounted with a 1-inch gauge length with a Tymcenter Strain Gauge.
2.0 THE METHOD - MECHANICAL PROPERTIES

2.0.1 Scope - Tensile Testing - "General Method for Tensile Testing of 7090 Alloys with Limited Use".

2.0.2 Materials - The specimens used were approximately 1.75 in. long and 0.25 in. in diameter. For high tensile, the size was 5.75 in. long and 0.125 in. in diameter.

2.0.3 Conditions - Round gage.

2.0.4 Procedure - The specimen was clamped to the testing machine with a gage length of 5.0 inches in a heated atmosphere.

2.0.5 Procedure - Tensile Tests - The specimen was tested at 20°F and at the rate of 100°F per minute.

2.0.6 Procedure - Heat Treatment - The specimen was heated at the rate of 0.02°C per minute.

2.0.7 Procedure - Heat Treatment - The specimen was tested at 0°F and at the rate of 10°F per minute.

2.0.8 Procedure - Heat Treatment - The specimen was tested at 20°F and at the rate of 100°F per minute.

2.0.9 Procedure - Heat Treatment - The specimen was tested at 0°F and at the rate of 0.02°C per minute.
TESTING AND QUALITY CONTROL

6.00 TEST METHODS - MECHANICAL PROPERTIES

6.003 Linear Test

6.003.1 Source: AASHTO T 197, "Standard Method of Test for Resilient Class-III Concrete Pavement: Evaluation of Chemical Additives".

6.003.2 Specimen: The specimens were prepared from a 12" diameter x 24" long pipe (1-1/2" thick wall). They were 0.50±0.005 inch long as measured along the chord of the curve side.

6.003.3 Conditions: Specimens were tested after a 14-day conditioning at 100±5°F. Specimens subjected to wet test conditions were boiled the prescribed length of time and placed in water at 132°F for at least 15 minutes before testing.

6.003.4 Procedure - Uniaxial Testing: The specimens are to be placed within the holes in the steel plate fixtures and subjected to a horizontal load using a 40 kips load cell on both ends of the specimen.

6.003.5 Procedure - Biaxial Testing: Same as above, but with loadings of 0.05 inch per minute.

6.003.6 Observations: On indication of the number of specimens required in place. The loading rate (P), width (W) and thickness (T) of specimens are required to assess it in the selection of the material tested.

6.003.7 Results: Shear strength should be computed according to the following equation:

\[
\tau = \frac{P}{2W} \quad \text{Horizontal Load, psi}
\]

where P, W, and T are as defined in 6.003.5.

6.003.8 Beam Test: Single or multiple the specimens used. The final determination of the tension for the application of load onto the test is indicated.

6.003.9 Measuring and Recording Equipment: Same given.

FIG. 6.003.7 HORIZONTAL LOAD ON A BEAM

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TEST METHOD - MECHANICAL PROPERTIES

6.02 Creep and Creep-Recovery Test

6.02.1 Test Procedure

6.02.1.1 Specimens. Specimens shall conform to ASTM D1681, Condition 185°F (85°C) (37°C). The specimen shall be cut from the product or the test piece in such a manner as to present a smooth finish. The specimen shall be conditioned to 70°F (21°C) ± 2°F (1°C) and 50 ± 5 percent relative humidity for a period of 24 hours before testing.

6.02.1.2 Test Apparatus. The creep and recovery apparatus shall be designed to maintain constant temperature and relative humidity for a period of 24 hours before testing.

6.02.1.3 Conditions. The test specimens shall be held at constant temperature which should be very near the length of the specimen. For a few test length acceptable conditions are as follows:

<table>
<thead>
<tr>
<th>Test Temp (°F)</th>
<th>Apparatus Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100 to 300</td>
<td>0.1 ± 0.1</td>
</tr>
<tr>
<td>300 to 600</td>
<td>0.2 ± 0.2</td>
</tr>
<tr>
<td>600 to 900</td>
<td>0.3 ± 0.3</td>
</tr>
</tbody>
</table>

The specimens should be isolated from vibrations. Pre-conditioning shall be done as described in ASTM D1681 (37°C) and, in addition, dimensional stability and density should be measured for constant temperature and relative humidity for a period of 24 hours prior to testing.

6.02.1.4 Pre-Start Test Sequence. The grip and gripping technique should be designed to minimize eccentric loading of the specimen.

6.02.1.5 Procedure - Testing. Specimens should be tested at a stress of less than 0.5 times yield strength and at a rate of strain such that the amount of strain at any point in the specimen does not exceed 1 percent of the original length of the specimen. The test should be terminated when the specimen has failed completely or when the specimen has been strained to 0.5 times yield strength.

6.02.1.6 Observations. Suggested time intervals for each cycle of loading and unloading and the values at which data should be recorded are 0.1, 0.5, 1, 3, 7, 15, and 30 minutes. Then every 15 minutes to the hour and every 15 minutes to 1500 hours. Data (c) should be taken at each temperature.

6.02.1.7 Report. The report should contain the material, composition, the maximum stress and strain at each stress, the strain at the time of failure, and the time to failure. The report should be accompanied by a graph of the stress-strain curve for the specimen.

6.02.1.8 Test Equipment. The equipment for testing shall be capable of applying a constant load on the specimen.

6.02.1.9 Recording the Results. The results should be recorded on the test report. The test report should be maintained for a period of 30 years. Equipment should be accessible to the tester and should be marked to indicate the test method used. Equipment should be marked with the material type and test number.
TESTING AND QUALITY CONTROL

5.0  TEST METHODS - MECHANICAL PROPERTIES

5.01  Creep and Crouch Failure Tests

5.0.2  Test 76-092 LP

          of 109L.3, Detailed Type-Verification and Creep.

5.0.2.2  Specimens: Specimen Should conform to 27-190B Method 1012 (See 75.0.1 LP).

5.0.2.3  Conditions: Same specified.

5.0.2.4  Procedure - Preliminary, Load should be applied by a hand weight or lever system. Load should be placed without producing impact on specimen.

5.0.2.5  Procedure - Testing. Test should be at least 2000 hours duration and all tests should begin simul-
          taneously. Initial elongation is defined as continuing deformation of plastic elongation plus the creep during the
          first 100 seconds of testing.

5.0.2.6  Observations: Time and elongation are to be recorded at intervals. Density strength of the specimen is to be
          obtained by specified means 27-2000 Method 5011.

5.0.2.7  Report. Stresses and strains are to be presented as function of time to failure. Time to be plotted
          as the abscissa.

5.0.2.8  Test Equipment

5.0.2.9  Measuring and Recording Equipment.
4.3 TEST METHOD - MECHANICAL PROPERTIES

4.3.1 Test T6.063


4.4.3.2 Specimen

a. Specimens, See Fig. 2, Table 5.55.5.

b. Method, 1 in. long x 1 in. wide x 5/16 inch thick.

c. Conditions, Both tension and compression tests were conducted at 70 and 200° F. Relative humidity varied between 20 and 70 percent and was not controlled.

4.4.3.4 Procedure

a. Specimens were aligned and locked through a 3/16 inch pin inserted in each end.

b. Compression specimens were aligned on temperature control tables and held in an attempt to achieve self-alignment.

c. Procedure was testing. Tests were designed to produce failure at some which varied between 6,10 and 1000 hours.

4.4.3.5 Observations

Proper elongations were recorded at intervals. Strength tests were conducted on samples in failure for comparative purposes.

4.4.3.7 Report. Composites and specific data for each specimen should be recorded. Tone elongations are to be indicated. Information as percent should be given for any function of time with time being the abscissa.

4.4.6 Data Equipment. An electric furnace was used to obtain the 300 and 700° F temperatures and was controlled to ± 5° F.

4.4.7 Measuring and Recording Equipment. Deflections-data were recorded with a Tafel model 8002 extensometer. Tension tests were performed with a 5-ton Instron machine.

4.4.8 Weight. A microanalyzer accurate to 0.00005 lb. was used to measure the change in weight of the tested mats.

FIG. 4.44.5,6 SPECIMEN FOR TENSILE TESTS IN TENSION
TESTING AND QUALITY CONTROL

6.6.4 Test Method

6.6.4.1

6.6.4.2

6.6.4.3

6.6.4.4

6.6.5.1

6.6.5.2

6.6.5.3

6.6.5.4

6.6.5.5

6.6.5.6

6.6.5.7

6.6.5.8

6.6.5.9

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9.3 Test METHODS - MECHANICAL PROPERTIES

9.3.1 Fatigue Testing

9.3.1.1 Test Method B

9.3.1.2 Test Method C

9.3.2 Specimen Dimensions and Preparation

9.3.2.1 Specimen Dimensions

9.3.2.2 Specimen Preparation

9.3.3 Procedure - Fatigue Testing

9.3.3.1 Procedure - Fatigue Testing

9.3.3.2 Observations

9.3.3.3 Report

9.3.3.4 Equipment

9.3.3.5 Measuring and Recording Equipment

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6.0 Test Methods - Mechanical Properties

6.0.1 Fatigue Tests

6.0.1.1 Test Method: TP 0733

6.0.1.2 Specimen: General Specifications; Test Method: Method A32; General Procedure: Chemical Polishing

6.0.1.3 Specimen: The shape of the tested and unworn specimens should be as shown in Fig. 6.013, A and B respectively. Thermoplastics specimen should be polished with a compound. Other materials should be finished with fine sandpaper or emery cloth

6.0.1.4 Conditions

6.0.1.5 Procedure - Testing; grinding angle should be 34.8° at 30,000 revolutions per minute

6.0.1.6 Observations: That should be made all conditions and results should be recorded. In addition, the maximum fatigue strength is noted in a 10 or 50 cycles. The stress of which are subjected to have identified and to the number of cycles to failure, and the type of specimen shall be recorded

6.0.1.7 Report: The data are to be presented in a standard report form 6.013.1

6.0.1.8 Test Equipment: A D.R.R. machine; tensile and fatigue testing apparatus should be used

6.0.1.9 Measuring and Recording Equipment: Basic given

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6.07 **Testing materials - Mechanical Properties**

6.07.1 **Jalabell (1969)**

6.07.2 **Test 15.0 E**

6.07.3 **Specimen**

6.07.4 **Procedure - Fatigue**

6.07.5 **Results**

6.07.6 **Testing equipment**

6.07.7 **Measuring and recording equipment**

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**FIG. 6.07-1 EXHUME SPECIMENS**

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TESTING AND QUALITY CONTROL

6.0 TEST METHODS - MECHANICAL PROPERTIES

6.0.1 Elastic Modulus Test

6.0.1.1 Specimen: Specimens shall be in the form of round bars of uniform cross-section, having a diameter of 5/8 inch and length of 4 inches. 

6.0.1.2 Preparation of Specimen: The specimens shall be not from the interior, and shall be free from visible defects. The ends of the specimen shall be ground to a finish. 

6.0.1.3 Procedure: The specimen shall be subjected to tension in a universal testing machine. The specimen shall be placed in the grips of the testing machine and a load shall be applied to bring the specimen to the test load of 0.375 ksi. The load shall be increased at a uniform rate until the specimen fails. 

6.0.1.4 Calculation: The elastic modulus shall be calculated using the following equation:

\[ E = \frac{PL}{A} \]

where:
- \( P \) = applied load in kips
- \( L \) = length of specimen in inches
- \( A \) = area of specimen in square inches

The elastic modulus shall be reported to the nearest 0.01 ksi.
TEST METHODS - MECHANICAL PROPERTIES

6.01 Elastic Modulus Test

6.02 Test 10, 105, 1076

6.03.1 Source, ASTM D469/D469M, Tensile Properties of Plastics

6.03.2 Specimens. See 7.0.1.

6.03.3 Conditions. Conditioning of test specimens shall continue to 0±5°C and 50±10% RH for purposes of improving reproducibility results. See Section 8.01. All environmental conditions are specified by source.

6.03.4 Procedure. Preliminary, see 7.0.1.

6.03.5 Procedure. Testing. The speed of testing shall be 0.5 to 1.0 inches per minute except for metal bends of test pieces of materials which are to be tested at 0.02 inches per minute. Reduction value shall be obtained using separate specimens from those used to determine tensile strength and elongation when the tests are not the same.

6.03.6 Observations. At least five specimens should be tested and an additional five if the trial test results are not reproducible. No testing speed shall be considered until six of the tests are completed. The average value and the standard deviation shall be computed.

6.03.7 Equipment. See 7.0.1.

6.03.8 Measuring and recording equipment. See 7.0.1.
5. TESTING AND QUALITY CONTROL

5.08 Plastic Deformation Test

5.08.1 Purpose. ASTM D487-57. Stiffness in Plaques of Plastics.

5.08.2 Specimen. The specimen may be either molded or cut from a sheet. The size is to be determined by the thickness of the material and stiffness of the material. The size should be published or be stated. The specimen should be conditioned for a minimum of 24 hours.

5.08.3 Conditioning. Pre-conditioning and testing should be done at temperature and humidity specified by the fabrication data sheet. If the temperature is to be conducted at elevated or reduced temperature, the specimen and the fixture should be considered for at least 24 hours prior to testing.

5.08.4 Procedure. Place specimen in apparatus and load the machine and adjust the load scale to zero. The specimen should be clamped firmly in the vise and aligned parallel to the face of the dial plate. The tensile test may be performed with or without fixtures. The specimen should be removed and measured after the test is complete.

5.08.5 Measurement. The load and angle of rotation are to be measured. It is important to know the length, width, and depth of specimen, in order to determine the stiffness. These specimens should be tested and the test results reported.

5.08.6 Report. The report should include the stiffness which is evaluated in the following manner:

\[ S = \frac{1}{L} \times \frac{2F}{\theta} \]

where

- \( S \) = Stiffness in Plaques of Plastics
- \( L \) = Length of specimen in inches
- \( F \) = Force in pounds
- \( \theta \) = Angle of rotation in degrees

5.08.6.1 Additional Information. See Fig. 5.08.6.3. The angle of rotation is to be measured in degrees, while the force is to be measured in pounds. The stiffness is expressed in pounds per inch. The angle of rotation is to be measured in degrees, while the force is to be measured in pounds. The stiffness is expressed in pounds per inch.
6. EXPERIMENTAL PROPERTIES

6.06 Elastic Modulus Test

6.063 From T5.063 ASTM


6.063.2 Therefore, all dimensions are to be less than 0.060 in. thick and a 6 inch length test specimen is to be used.

6.063.3 Condition, Conditioning of test specimens should conform to ASTM D4 for purposes of obtaining reproducible results. See Section 6.062.2.

6.063.4 Procedure - Preliminary, Measurement of thickness is to 0.000 to 0.005 in. or to the nearest 0.0005 in. when using the apparatus the given in the test is to be used in such a way that no movement takes place (e.g. zeroing of mechanical or electrical gage).

6.063.5 Procedure - Testing, The speed of testing shall be: 3 in. (±0.5) per minute.

6.063.6 Observations, For experiment, the load should be tested. For polymer materials where specimens should be tested, the initial and final ability to the principal area of stability by the test is to be determined where the load maximum may be different for different apparatus. In such cases, the load should be no imparted.

6.063.7 Noting, A representative curve should be drawn and the curve used to calculate the modulus of elasticity. A specimen at a given strain can be calculated by dividing the specimen strain in the stress. The maximum strain shall be recorded, if it is to be applied at or following:

\[
S = \frac{E}{2(1 + \nu)}
\]

where:

E = a constant standard derivation,

\( \nu \) = a value of a single characteristic,

A = a number of characteristic and

\( \mu = \) a number of characteristic.

The following should be included, plane reporting the data, the type of material, any prior history, conditions of memory, crystallization, aging and stress relief.

6.063.8 Test Equipment. A constant angle testing machine, in accordance to a position or standard and fixed measurement shall be used. The tests are to give an even average distribution around the equine. To achieve this, it may be necessary to line the grips with such ribbon or paper clips.

6.063.9 Noting and Recording Equipment. Micrometer accuracy to 0.0001 in. is necessary. As in all testing devices which will produce a specimen with an expected and same straight needle edge should be used. If every test equipment is employed as an equipment should be used to determine alignment.
TESTING AND QUALITY CONTROL

Chapter 6: Test Procedure

6.101 Test Procedure

6.101.1 A sample, ASTM D4167, shall be a bundle of 10 pieces and shall be tested in two pulls in a total of 20 pieces. The data obtained shall be recorded and shall be used to determine the strength of the material. The test shall be performed in a laboratory environment to ensure consistency and accuracy. The test shall be performed in accordance with the standard test method for testing the tensile strength of plastics, ASTM D4167, which is referenced in this section.

6.101.2 Procedure: The sample shall be treated in a manner that prevents damage during testing. The sample shall be fed into a machine and the machine shall be set to the desired speed. The sample shall be tested at a speed of 20 inches per minute. The test shall be performed in a laboratory environment to ensure consistency and accuracy. The test shall be performed in accordance with the standard test method for testing the tensile strength of plastics, ASTM D4167, which is referenced in this section.

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6.101.8 Procedure: The sample shall be treated in a manner that prevents damage during testing. The sample shall be fed into a machine and the machine shall be set to the desired speed. The sample shall be tested at a speed of 20 inches per minute. The test shall be performed in a laboratory environment to ensure consistency and accuracy. The test shall be performed in accordance with the standard test method for testing the tensile strength of plastics, ASTM D4167, which is referenced in this section.

6.101.9 Procedure: The sample shall be treated in a manner that prevents damage during testing. The sample shall be fed into a machine and the machine shall be set to the desired speed. The sample shall be tested at a speed of 20 inches per minute. The test shall be performed in a laboratory environment to ensure consistency and accuracy. The test shall be performed in accordance with the standard test method for testing the tensile strength of plastics, ASTM D4167, which is referenced in this section.

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8. TESTING METHODS - MECHANICAL PROPERTIES

8.1 Ultimate Tensile

8.1.1 Test Method: Test Method E8

8.1.1.1 Specimen: Dimensions shall be as follows: 1 in. in diameter, 3 in. in length. The gage length shall be 2 in. and the extensometer shall be 1 in. long. The test speed shall be 10 in./min.

8.1.1.2 Procedure: The specimen shall be tested at a rate of 10 in./min until fracture occurs. The load and elongation shall be recorded on a suitable instrument.

8.2 Yield Point

8.2.1 Procedure: The specimen shall be tested at a rate of 10 in./min until fracture occurs. The load and elongation shall be recorded on a suitable instrument.

8.3 Reduction of Area

8.3.1 Procedure: The specimen shall be tested at a rate of 10 in./min until fracture occurs. The load and elongation shall be recorded on a suitable instrument.

8.4 Percent Elongation

8.4.1 Procedure: The specimen shall be tested at a rate of 10 in./min until fracture occurs. The load and elongation shall be recorded on a suitable instrument.

8.5 Torsion

8.5.1 Procedure: The specimen shall be tested at a rate of 10 in./min until fracture occurs. The load and elongation shall be recorded on a suitable instrument.

8.6 Impact Testing

8.6.1 Procedure: The specimen shall be tested at a rate of 10 in./min until fracture occurs. The load and elongation shall be recorded on a suitable instrument.

8.7 Fatigue Testing

8.7.1 Procedure: The specimen shall be tested at a rate of 10 in./min until fracture occurs. The load and elongation shall be recorded on a suitable instrument.

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TESTING AND QUALITY CONTROL

6. TEST METHODS - Mechanical Properties

6.1 Tensile Tests


6.1.2 Apparatus. The specimen shall be 3 in. by 1 in. or 4 in. by 1 in. by the other cross-sectional size. Materials greater than 0.060 in., can be used without cutting. For materials less than 0.020 in., test specimens can be used. If less than 0.020 in., specimens should be cut at right angles parallel and perpendicular to the machine principal axes.

6.1.3 Conditions. Conditioning of test specimens shall be conducted as per ASTM D 4065-87, Practice A. See Section D 4065-87, Practice A.

6.1.4 Procedure - Preliminary. Specimens less than 0.020 in. by thickness shall be humidified in a constant climate environment at 50 ± 2°C for 24 hours before being tested. Place the test specimens on a test frame and test under the constant temperature environment.

6.1.5 Procedure - Testing. The 3 g monument weight is applied to the gripping surface of the diamond needle which is held at a level point. The needle to be used at 0.25 to 0.27 mm per second. This corresponds to 2 bars per second on the gripping force meter.

6.1.6 Observations.

a. Method A - Tensile Test. US speacial to be tested faces the edge of the force gauge or strain gauge at the moment the fracture is initiated by reducing the stress at the center to zero. The force to be reduced in such a way that the force decreases at a constant rate. The test is considered valid if the slope of the force vs. elongation curve is constant.

b. Method B - Determination of Holding Force. The apparatus shall be designed to apply a constant force of 5000 g. The force shall be held constant for a minimum period of 1 minute. The force shall then be released and the fracture shall be initiated by reducing the force to zero. The force to be reduced in such a way that the force decreases at a constant rate. The test is considered valid if the slope of the force vs. elongation curve is constant.

6.1.7 Report. Calculation of the Maximum Force is given as the load on the specimen in grams divided by the area of the gauge for the grade in millimeters. The report shall include the name, identification of the test material, dimensions of the specimen, method of producing the data, and the date of the test material.

6.1.8 Test Equipment. The test apparatus must include a force meter, a gauge, and a chart recorder. The force meter shall be capable of registering 5 g to 2000 g. The gauge shall be capable of registering 0.25 to 0.50 millimeters. The chart recorder shall be capable of registering 0.25 to 2000 g. It is advisable to measure force in milligrams.
TESTING AND QUALITY CONTROL

6.11 Impact Tests

6.11.1 Test Report

6.11.3 Source: ASTM G130-84, Impact Resistance of Plastics and Electrically Insulating Materials

6.11.2 Specimen

a. Method A - Drill. Specimen shall be as shown in Fig. 6.11.2a. Specimen taken from sheet materials shall be trimmed parallel to the length and then clamped so that the length and width shall be reduced to 5.2 in. plus or minus 0.2 in. but not more than 5.2 in. plus or minus 0.2 in. The specimen shall be placed so that the direction of the impact will be at right angles to the direction of applied molding pressure, and may be tested in any direction. The specimen shall be clamped to the side parallel to the direction of applied molding pressure, and may be tested in any direction. All tests on one specimen shall be done with the same direction of impact.

b. Method B - Charpy. Specimens shall be as shown in Fig. 6.11.2b except that the notches shall be parallel to the direction of applied molding pressure. The specimen shall be placed so that the direction of the impact will be at right angles to the direction of applied molding pressure, and may be tested in any direction. All tests on one specimen shall be done with the same direction of impact.

6.11.4 Procedure - Preliminary

a. Method A. The specimen shall be tightly clamped in a vertical position in the impact apparatus. The vertical position shall be at right angles to the direction of the impact. The specimen shall be clamped as shown in Fig. 6.11.2a.

b. Method B. The specimen shall be clamped so that the direction of the impact will be at right angles to the direction of applied molding pressure. The specimen shall be positioned in the impact apparatus as shown in Fig. 6.11.2b.

6.11.5 Procedure - Impact

a. Method A. The specimen shall be placed so that the direction of the impact will be at right angles to the direction of applied molding pressure. The specimen shall be clamped so that the direction of the impact will be at right angles to the direction of applied molding pressure.

b. Method B. The specimen shall be placed so that the direction of the impact will be at right angles to the direction of applied molding pressure. The specimen shall be clamped so that the direction of the impact will be at right angles to the direction of applied molding pressure.

6.11.6 Observations. The order of specimen orientation to be used shall be as follows: 1. Specimen shall be placed so that the direction of the impact will be at right angles to the direction of applied molding pressure. 2. Specimen shall be clamped so that the direction of the impact will be at right angles to the direction of applied molding pressure. 3. Specimen shall be placed so that the direction of the impact will be at right angles to the direction of applied molding pressure.

6.11.7 Report. The following data are to be recorded; a) Initial notching; b) Initial fracture; c) Initial notching; d) Initial notching; e) Initial notching; f) Initial notching; g) Initial notching; h) Initial notching; i) Initial notching; j) Initial notching; k) Initial notching; l) Initial notching; m) Initial notching; n) Initial notching; o) Initial notching; p) Initial notching; q) Initial notching; r) Initial notching; s) Initial notching; t) Initial notching; u) Initial notching; v) Initial notching; w) Initial notching; x) Initial notching; y) Initial notching; z) Initial notching.

6.11.8 Test Equipment. A standard pendulum or energy absorbing mechanism shall be used. The pendulum shall have a weight of 0.68 lb. The energy absorbed by the specimen shall be 0.24 ft-lb. The pendulum shall be released with the impact not on the side of the specimen.

6.11.9 Notching and Impact Equipment. The specimen shall be tested with a pendulum of the impact energy specified by the pendulum. This may be accomplished by a direct reading pendulum type scale.
6.11 Impact Tests

6.11.2 Procedure. The specimen should be mounted in a fixture and loaded with a known force in such a manner as to cause fracture of the specimen. The force applied should be measured and the resulting energy calculated. The test should be repeated at least three times to ensure consistency.

6.11.3 Results. The results should be reported in terms of the energy absorbed by the specimen and the fracture pattern observed. The test is useful for determining the toughness of materials and is often used in quality control and research.

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6.113.3 Procedure - Preliminary. The top surface of the test piece shall be at the upper line of the opening cut. Untouched specimens must be aligned and held firmly in position.

6.113.4 Procedure - Impact. The velocity of impact shall be approximately 5 ft/sec.

6.113.5 Observation. The energy to initiate a fracture is to be measured. Flat is to be corrected for elastic and plastic deformation.

6.113.7 Report. A description of the material shall be given as well as the energy in foot-pounds per inch of break.

6.113.8 Test Equipment. An impact tester of the pendulum type for toughness shall be used. It shall not weigh less than 200 lb. and to be placed horizontally on the top of the specimen. The distance of projection of the pendulum shall be at the point of striking the striking edge of the specimen shall have a 5/8" face with its axis horizontal.

6.113.9 Measuring and Recording Equipment. A means shall be provided to determine the height below the specimen at which it is to be struck by a graduated instrument.

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6.0 TEST METHOD - MECHANICAL PROPERTIES

6.11 Scope

6.12 Test Methods


6.12.2 Specimen. The specimen shall be 12 in by 12 in by the thickness of the material.

6.12.3 Conditions. None specified.

6.12.4 Procedure - Preliminary. Specimen is to be freely placed in a horizontally in the mounting frame (Fig. 6.114.5) such that the falling ball will strike it approximately in the center.

6.12.5 Procedure - Testing. The ball is to be dropped from an adjustable inclined height to a maximum of 30 ft to 1 ft intervals.

6.12.6 Observations. The height of fall necessary to shatter the specimen and a description of the fragments, are to be observed.


6.12.8 Test Conditions. The specimen is to be freely placed in the mounting frame shown in Fig. 6.114.5. The weight of the steel ball shall be 1 lb.

6.12.9 Measuring and Recording Equipment. None specified.

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6.0 TEST METHODS – MECHANICAL PROPERTIES

6.11 Impact Tests

6.11.1 Test Th.112

6.11.2 Procedure - Test Procedure. The specimen is inserted into the machine with the striker at time of impact, and energy absorbed is determined by calculation of energy absorbed in the specimen minus the energy absorbed in the machine. The specimen should be tested at room temperature and at a rate of 10 ft per sec. The specimen and test machine should be protected from dust and lint.

6.11.3 Conditions - Specimen should be tested in the vertical position with the striker at time of impact. The specimen should be tested at a rate of 10 ft per sec. The specimen should be tested at room temperature and at a rate of 10 ft per sec. The specimen and test machine should be protected from dust and lint.

6.11.4 Procedure - Test Procedure. The specimen is inserted into the machine with the striker at time of impact, and energy absorbed is determined by calculation of energy absorbed in the specimen minus the energy absorbed in the machine. The specimen should be tested at room temperature and at a rate of 10 ft per sec. The specimen and test machine should be protected from dust and lint.

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6.11.8 Procedure - Test Procedure. The specimen is inserted into the machine with the striker at time of impact, and energy absorbed is determined by calculation of energy absorbed in the specimen minus the energy absorbed in the machine. The specimen should be tested at room temperature and at a rate of 10 ft per sec. The specimen and test machine should be protected from dust and lint.

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TABLE 6.112.1

<table>
<thead>
<tr>
<th>Condition</th>
<th>striker velocity</th>
<th>Ft per sec</th>
<th>maximum impact energy</th>
<th>Ft-lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>50</td>
<td>100</td>
<td>350</td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>50</td>
<td>100</td>
<td>350</td>
</tr>
<tr>
<td>C</td>
<td>15</td>
<td>50</td>
<td>100</td>
<td>350</td>
</tr>
</tbody>
</table>

FIG. 6.112.2 - SPECIMEN

FIG. 6.112.3 - SPECIMEN

FIG. 6.112.4 - SPECIMEN

FIG. 6.112.5 - SPECIMEN

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Table 6.10.1.2

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Plug</th>
<th>Plug Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 mm</td>
<td>3</td>
<td>12 X 3/4</td>
</tr>
<tr>
<td>6.75 mm</td>
<td>3</td>
<td>2 X 3/4</td>
</tr>
</tbody>
</table>

6.10.2 Conditions: Conditioning of test specimen should conform to ASTM D690 for purposes of obtaining reproducible results. See Section 6.10.3.

6.10.3 Syntactic - Bimetallic. The specimen is to be filled with very fine aluminum boron particles (for example, General Electric's Orgasand). The plugs are to be inserted and secured firmly by hand prior to placing the specimen in the apparatus.

6.10.4 Procedure: Testing, throughout speed to be approximately 1.5% limits to ensure.

6.10.5 Equipment: The apparatus should be secured, and the load to failure recorded.

6.10.6 Results: The report should include the type of material, surface on specimen, dimensions, condition, strength, test conditions and any other which may be pertinent to the specimen.

6.10.7 Test equipment: A constant speed testing machine meeting the requirements of ASTM D690, should be used. The movement of the inner plunger is to be 0.050 in. (0.013 mm) is to be used for the tests on the specimen. The plunger shall, here parallel ends.

6.10.8 Measuring and recording equipment, not specified by source.
10.0 SUMMARY OF STANDARD TEST PROCEDURES

10.01 Standard 201-45, ASTM

10.01.1 Scope. ASTM D 201-39, standard methods of conditioning plastic and electrical insulating materials for testing.

10.01.2 Standard Conditions

10.01.2.1 Standard Laboratory Atmosphere shall be an atmosphere having a relative humidity of 30 ± 5 per cent. at a temperature of 21 ± 1°C (70 ± 2°F).

10.01.2.2 Standard laboratory temperature shall be a temperature of 23 ± 1°C (73.4 ± 1.8°F).

10.01.2.3 Standard Room Temperature shall be a temperature in the range of 20 to 30°C (68 to 86°F) in an atmosphere of unspecified relative humidity.

10.01.2.4 Standard Test Temperatures Other Than Standard Laboratory Temperature when desired may be obtained for comparison purposes at a specific temperature either above or below the standard laboratory temperature; the temperature should be selected from Table 10.01.2.4.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Tolerance</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>-30°C</td>
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<td>2.0</td>
</tr>
<tr>
<td>-20°C</td>
<td>±2°C</td>
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<td>2.0</td>
</tr>
<tr>
<td>100°C</td>
<td>±2°C</td>
<td>2.0</td>
</tr>
</tbody>
</table>

10.01.2.5 Conditioning Prior to Test

10.01.2.5.1 PROCEDURE A. Test specimens 0.25 in. or smaller in thickness shall be conditioned in air at standard laboratory temperature for a minimum of 48 hr. Immediately before testing, the specimen shall be placed in a desiccator for at least 30 min. The desiccator shall be conditioned to a relative humidity of 30 ± 5 per cent. at a temperature of 23 ± 1°C (73.4 ± 1.8°F).

10.01.2.5.2 PROCEDURE B. Test specimens 0.25 in. or larger in thickness shall be conditioned in air at standard laboratory temperature for a minimum of 48 hr. Immediately before testing, the specimen shall be placed in a desiccator for at least 48 hr. The desiccator shall be conditioned to a relative humidity of 30 ± 5 per cent. at a temperature of 23 ± 1°C (73.4 ± 1.8°F).

If any particular material or test, a specified longer time of conditioning is required, the time shall be agreed upon by the interested parties, and such con- ditioning time may be used for this particular test without equilibration to be substantially obtained.

10.01.3 PROCEDURE D. Test specimens shall be conditioned for a period of 48 hr. in a circulating air oven at a temper- ature of 70 ± 2°C (158 ± 4°F). The specimens shall be present from the time placed in the oven temperature, and the specimens shall be removed from the oven temperature, and the specified relative humidity of the circulating air shall be used as the conditioning medium. The specimens shall be removed from the oven temperature, and the specified relative humidity of the circulating air shall be used as the conditioning medium.

10.01.4 PROCEDURE E. Test specimens shall be conditioned for a period of 48 hr. in a circulating air oven at a temperature of 80 ± 2°C (176 ± 4°F), and a specified relative humidity of the circulating air shall be used as the conditioning medium.

10.02 Testing and Quality Control

10.02.1 In general, test results are the average of at least two tests performed in duplicate. The results are the average of the two test results. If the results are not within 10 percent of each other, the test is considered rejected. When the results are within 10 percent of each other, the test is considered valid. The results are the average of the two valid test results.

10.02.2 Procedure for determining the average of two test results shall be as follows:

10.02.2.1 The test results shall be calculated using the following formula:

\[ \text{Average} = \frac{\text{Test 1} + \text{Test 2}}{2} \]

10.02.2.2 The standard deviation of the test results shall be calculated using the following formula:

\[ \text{Standard Deviation} = \sqrt{\frac{\sum (\text{Test Result} - \text{Average})^2}{n-1}} \]

10.02.2.3 The confidence interval of the test results shall be calculated using the following formula:

\[ \text{Confidence Interval} = \text{Average} \pm t \times \frac{\text{Standard Deviation}}{\sqrt{n}} \]

10.02.2.4 The t-value shall be determined using the t-distribution table with the appropriate degrees of freedom.

10.02.3 Summary of Procedures

10.02.3.1 Procedure 1. Test specimens shall be conditioned for a period of 48 hr. in a circulating air oven at a temper- ature of 70 ± 2°C (158 ± 4°F). The specimens shall be present from the time placed in the oven temperature, and the specimens shall be removed from the oven temperature, and the specified relative humidity of the circulating air shall be used as the conditioning medium. The specimens shall be removed from the oven temperature, and the specified relative humidity of the circulating air shall be used as the conditioning medium. The specimens shall be removed from the oven temperature, and the specified relative humidity of the circulating air shall be used as the conditioning medium. The specimens shall be removed from the oven temperature, and the specified relative humidity of the circulating air shall be used as the conditioning medium.
10.054.2 Unless otherwise specified, materials conditioned according to Procedure D shall be tested at room temperature conditions. The test shall be started as soon as possible, but not more than 1/2 hr. shall elapse between removal of the specimen from the chamber and the start of the test.

10.054.3 Unless otherwise specified, materials conditioned according to Procedures C and F shall be tested in the same atmosphere.

10.054.4 Unless otherwise specified, materials conditioned according to Procedures D and F shall be wiped immediately with a damp cloth, then with a dry cloth, for testing at room temperature. Specimens shall only be wiped immediately prior to testing, to remove all dust, dirt, oil, etc., and not wiped between tests. The tests shall be started immediately and completed as soon as possible.

10.055 Tests at Other Standard Test Temperatures. When tests are desired at standard test temperatures prescribed in Section 10.051.04, materials shall be transferred to the appropriate climatic chamber, and conditioned accord-
antly, after completion of the preconditioning (including in Procedure 6 or 4). The specimens shall be held at the test temperature for at least 3 hr. prior to testing, and in no case for less than the time required to assure thermal equilibrium.

10.056 Selection of Conditioning Procedure.

10.056.1 In the case of materials covered by ASTM specifications, reference should be made directly to determine the conditioning procedures to be used.

10.056.2 In the case of all other materials, the choice between procedures should preferably be based on the experience and results obtained during the test.

10.057 Report. The report shall state the conditioning procedure used and also the relative humidity and temperature of the atmosphere in which the tests were made.
10.0 SUMMARY OF STANDARDS TEST PROCEDURES

10.0.10 Standard Test Methods O1121


10.0.12 Standard Conditions

10.0.12.1 Quoted laboratory atmosphere shall be 25 ± 0.5°C (77 ± 9°F) and 50 ± 5% relative humidity.

10.0.12.2 Quoted Test Temperature Other Than Standard Laboratory Temperature, data shall be to be obtained for comparative purposes at a specific temperature which either cause to be the standard laboratory temperature, the temperature shall be selected from Table 10.022.1.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Test Temperature</th>
<th>C</th>
<th>F</th>
</tr>
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<td></td>
</tr>
<tr>
<td>80</td>
<td>160</td>
<td>182</td>
<td></td>
</tr>
</tbody>
</table>

10.0.12.3 Conditioning Prior to Test

10.0.12.4 For Standard Laboratory Atmosphere, (Section 10.02.1.1), the conditioning period prior to test shall be 16 hours per specimen for the specimen in less than 100 square inches for each inch thick.

10.0.12.5 For Standard Test Atmospheres Other Than Standard Laboratory Temperature (Section 10.02.2.1), the conditioning period at the Testing Temperature and Humidity shall be at least 24 hours immediately prior to tests unless otherwise specified.

10.0.12.6 Specimen Selection and Number

10.0.12.7 Specimens shall be obtained if possible from the product to be tested, from at random, and in such cases shall be taken at random in accordance with the requirements of the specification covering the particular material. In cases where such selection is not possible, they shall be selected from the shipment or group of shipments from the finished article, the manufacturer shall furnish the detailed test operation, or the relevant events as required by the specifications or the procuring agency. The number of samples to be rejected from each lot shall be specified in the material specification.

10.0.12.8 The number of specimens to be tested in each type of test shall be as specified in the material specification, but not as specified, at least five specimens shall be tested.

10.0.12.9 In testing requirements under a material specification, and in preparing specimens, consideration should be given to the size and shape of the material, and to the nature of the test, so as to make the test as representative as possible of the material.

10.0.12.10 Test Results

10.0.12.11 The results of the tests for the specimens tested shall be in accordance with the requirements of the material tested under this specification.