

## CONTENTS

|                                                                                                 | Page      |
|-------------------------------------------------------------------------------------------------|-----------|
| <b>1 Introduction</b>                                                                           | <b>1</b>  |
| The Moisture Problem                                                                            | 1         |
| Changes in Performance                                                                          | 4         |
| Fire Exposure                                                                                   | 5         |
| Concluding Remarks                                                                              | 6         |
| <b>2 Thermal Conductivities of Unidirectional Materials</b>                                     | <b>7</b>  |
| Abstract                                                                                        | 7         |
| Introduction                                                                                    | 7         |
| Formulation of the Problem                                                                      | 8         |
| Shear Loading Analogy                                                                           | 9         |
| Thermal Model                                                                                   | 11        |
| Discussions                                                                                     | 12        |
| Nomenclature                                                                                    | 14        |
| References                                                                                      | 14        |
| <b>3 Moisture Absorption and Desorption of Composite Materials</b>                              | <b>15</b> |
| Abstract                                                                                        | 15        |
| Scope                                                                                           | 15        |
| Conclusions and Significance                                                                    | 16        |
| Analysis                                                                                        | 18        |
| Diffusivity                                                                                     | 22        |
| Test Procedures                                                                                 | 24        |
| Results for Graphite T300 Fiberite 1034 Composites                                              | 26        |
| Time Varying Boundary Conditions                                                                | 28        |
| Acknowledgments                                                                                 | 28        |
| Nomenclature                                                                                    | 29        |
| Appendix-Correction for Edge Effects                                                            | 30        |
| References                                                                                      | 33        |
| <b>4 Moisture Absorption of Graphite-Epoxy Composition Immersed in Liquids and in Humid Air</b> | <b>34</b> |
| Abstract                                                                                        | 34        |
| Introduction                                                                                    | 34        |
| Experimental                                                                                    | 35        |
| Materials Immersed in Liquids                                                                   | 36        |
| Material Exposed to Humid Air                                                                   | 40        |
| Summary                                                                                         | 46        |
| Appendix-Autoclave Cure Cycles                                                                  | 48        |
| Acknowledgments                                                                                 | 49        |
| References                                                                                      | 49        |
| <b>5 Moisture Absorption of Polyester-E Glass Composites</b>                                    | <b>51</b> |
| Abstract                                                                                        | 51        |
| Introduction                                                                                    | 51        |
| Experimental                                                                                    | 52        |
| Results                                                                                         | 53        |
| Summary                                                                                         | 62        |
| References                                                                                      | 62        |
| <b>6 Moisture Content of Composites Under Transient Conditions</b>                              |           |

|           |                                                                                                      |            |
|-----------|------------------------------------------------------------------------------------------------------|------------|
|           | <b>Abstract</b>                                                                                      | <b>63</b>  |
|           | Scope                                                                                                | 63         |
|           | Conclusions                                                                                          | 63         |
|           | Parameters Used in the Calculations                                                                  | 65         |
|           | Results                                                                                              | 67         |
|           | Appendix-Analysis                                                                                    | 75         |
|           | Acknowledgements                                                                                     | 77         |
|           | Nomenclature                                                                                         | 78         |
|           | Reference                                                                                            | 78         |
| <b>7</b>  | <b>Effects of Moisture and Temperature on the Tensile Strength of Composite Materials</b>            | <b>79</b>  |
|           | Abstract                                                                                             | 79         |
|           | Scope                                                                                                | 79         |
|           | Conclusions                                                                                          | 79         |
|           | Experimental                                                                                         | 81         |
|           | Results                                                                                              | 83         |
|           | Acknowledgments                                                                                      | 92         |
|           | Appendix-Autoclave Cure Cycle for T300-1034                                                          | 92         |
|           | References                                                                                           | 92         |
| <b>8</b>  | <b>Environmental Effects on the Elastic Moduli of Composite Materials</b>                            | <b>94</b>  |
|           | Abstract                                                                                             | 94         |
|           | Scope                                                                                                | 94         |
|           | Conclusions                                                                                          | 95         |
|           | Experimental                                                                                         | 96         |
|           | Results                                                                                              | 99         |
|           | Acknowledgments                                                                                      | 106        |
|           | Nomenclature                                                                                         | 106        |
|           | References                                                                                           | 107        |
| <b>9</b>  | <b>Effects of Thermal Spiking on Graphite-Epoxy Composites</b>                                       | <b>108</b> |
|           | Abstract                                                                                             | 108        |
|           | Introduction                                                                                         | 108        |
|           | Thermal Spikes                                                                                       | 109        |
|           | Specimens Immersed in Saturated Steam                                                                | 112        |
|           | Experimental                                                                                         | 112        |
|           | Results                                                                                              | 113        |
|           | Conclusions                                                                                          | 122        |
|           | Appendix-Autoclave Cure Cycle for T300/1034                                                          | 123        |
|           | Acknowledgments                                                                                      | 124        |
|           | References                                                                                           | 124        |
| <b>10</b> | <b>Environmental Effects on Glass Fiber Reinforced Polyester and Vinylester Composites</b>           | <b>126</b> |
|           | Abstract                                                                                             | 126        |
|           | Introduction                                                                                         | 126        |
|           | Experimental                                                                                         | 128        |
|           | Results                                                                                              | 129        |
|           | References                                                                                           | 144        |
| <b>11</b> | <b>Degradation of Tensile and Shear Properties of Composites Exposed to Fire or High Temperature</b> | <b>145</b> |
|           | Abstract                                                                                             | 145        |
|           | Introduction                                                                                         | 145        |
|           | The Problem                                                                                          | 146        |
|           | Mass Loss and Char Formation                                                                         | 146        |
|           | Loss of Strength and Modulus                                                                         | 152        |
|           | Appendix-Autoclave Cure Cycles                                                                       | 157        |
|           | References                                                                                           | 158        |

|                                                                                                   |                |
|---------------------------------------------------------------------------------------------------|----------------|
| <b>12 Electrical Hazards Posed by Graphite Fibers</b>                                             | <b>159</b>     |
| Abstract                                                                                          | 159            |
| Introduction                                                                                      | 159            |
| Experimental                                                                                      | 160            |
| Results                                                                                           | 162            |
| Summary                                                                                           | 164            |
| Acknowledgment                                                                                    | 164            |
| References                                                                                        | 165            |
| <br><b>13 Numerical Procedures for the Solution of One Dimensional Fickian Diffusion Problems</b> | <br><b>166</b> |
| Abstract                                                                                          | 166            |
| The Problem                                                                                       | 166            |
| Single Layer Composites-Constant Boundary Conditions                                              | 168            |
| Multilayered Composites-Transient Boundary Conditions                                             | 170            |
| TI 59 Program Listing                                                                             | 171            |
| Data Input – W8GAIN Program                                                                       | 172            |
| W8GAIN Program Listing                                                                            | 176            |
| <br>Index                                                                                         | <br>200        |