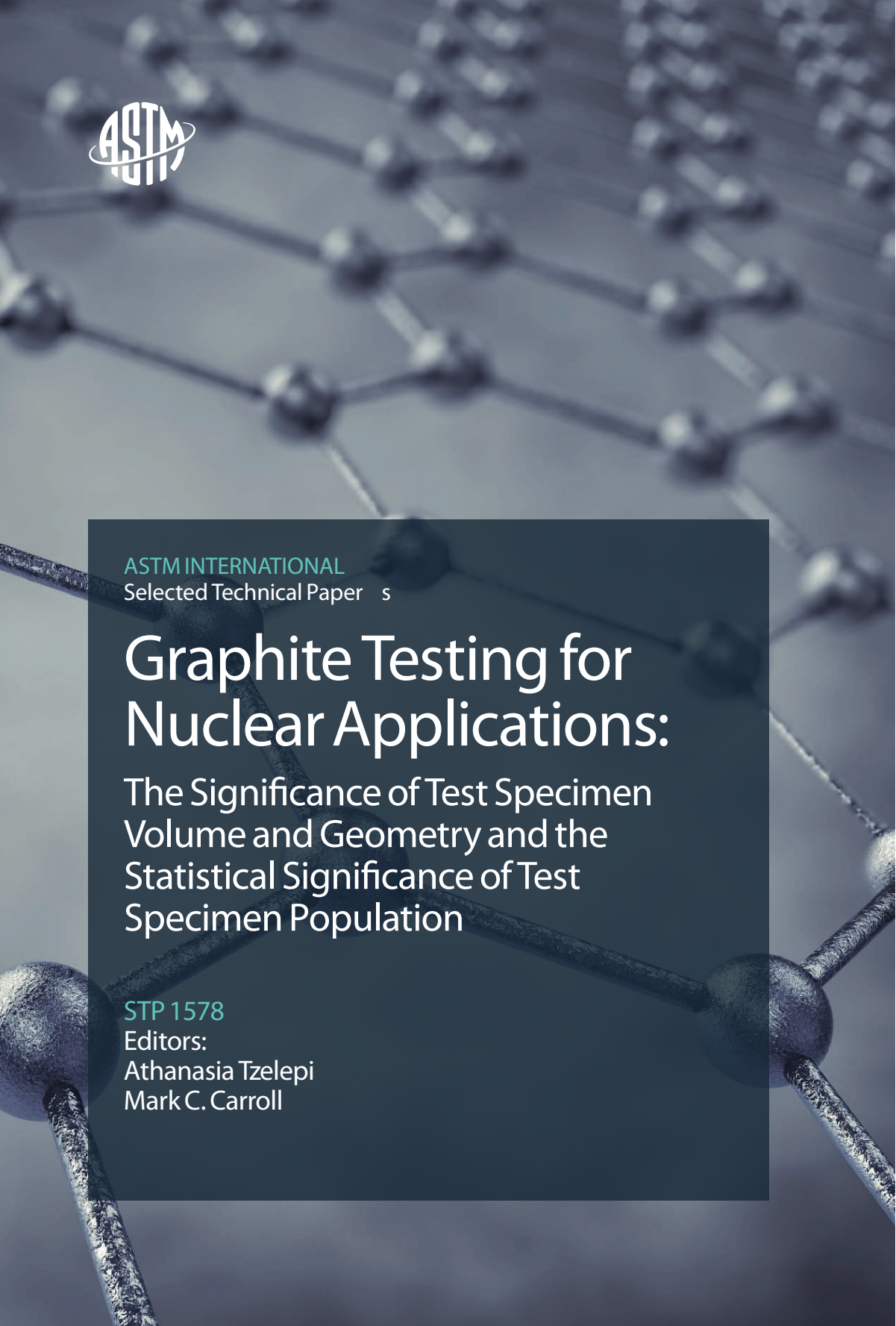

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Selected Technical Paper s

Graphite Testing for Nuclear Applications:

The Significance of Test Specimen Volume and Geometry and the Statistical Significance of Test Specimen Population

STP 1578
Editors:
Athanasia Tzelepi
Mark C. Carroll

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Foreword

This compilation of *Selected Technical Papers*, STP1578, *Graphite Testing for Nuclear Applications: The Significance of Test Specimen Volume and Geometry and the Statistical Significance of Test Specimen Population*, contains 10 peer-reviewed papers that were presented at a symposium held September 19-20, 2013 in Seattle, WA, USA. The symposium was sponsored by ASTM International Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and Subcommittee D02.F0 on Manufactured Carbon and Graphite Products.

The Symposium Chairpersons are Timothy Burchell, Oak Ridge National Laboratory, Oak Ridge, TN, USA, William Windes, Idaho National Laboratory, Idaho Falls, ID, USA, Stephen Duffy, Cleveland State University, Cleveland, OH, USA, and Athanasia Tzelepi, National Nuclear Laboratory, Sellafield, UK. The STP Editors are Athanasia Tzelepi, National Nuclear Laboratory, Sellafield, UK and Mark Carroll, Idaho National Laboratory, Idaho Falls, ID, USA.

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Overview

The inaugural symposium *Graphite Testing for Nuclear Applications: The Significance of Test Specimen Volume and Geometry and the Statistical Significance of Test Specimen Population* was held on September 19-20, 2013, in Seattle, WA. Held immediately following the *14th International Nuclear Graphite Specialists Meeting (INGSM-14)*, the symposium afforded the opportunity to draw from a number of international experts in the review of presentations on the symposium topic by invited speakers, each with unique perspectives on the issues facing test validation when evaluating graphite specimens with severe volume constraints. Under the direct coordination of ASTM members from subcommittee D02.F0 on Manufactured Carbon and Graphite Products, and the support of ASTM International, the symposium offered an overview of the various challenges faced by the subcommittee when reviewing and approving international standards that are becoming increasingly critical in the evaluation of graphitic carbon materials. With the expanding interest in graphite as both a moderator and structural material in advanced nuclear reactor designs, the reporting of mechanical and physical properties that provide the basis for use under strictly controlled conditions is crucial to the approval and use of graphite in highly regulated environments.

Currently, the most comprehensive set of test standards and specifications for graphite is published by ASTM International. At the outset, these standards and practices were largely devised to meet the general requirements of experienced graphite manufacturers who are unencumbered by constraints on test sample volume or geometry. Despite a long and successful history of graphite in the nuclear industry in the United Kingdom, along with successful smaller-scale programs in countries that included the United States, Germany, and Japan, the evolution of modern designs for next-generation nuclear reactors has necessitated a more thorough review of the present testing protocols and the potential effects on measured test results when the guidance of the standards with regard to specimen geometries cannot be met. The subcommittee seeks to draw from past experience, as well as modern testing developments, in order to ensure that the set of standards being approved through ASTM International continue to be not only relevant but highly valued in the international community. Research and development programs, ranging in origin from national laboratories to academia to industry, all require a carefully crafted set of guidelines for performing tests and reporting results when the data generated is to be utilized as the foundation for acceptance of graphite as a critical material in severe and/or long-term applications.

As a general rule, materials testing for nuclear reactor applications tends to have rather severe constraints. The cost of performing irradiated material evaluations limits specimen populations, and the internal structure of experimental reactors naturally constrains the volume and/or geometry of individual specimens. These constraints on test specimen size often result in a non-compliant application of published standards. Furthermore, constraints imposed by current standards, such as sample volume to grain size limitations, are rarely based on conclusions drawn directly from rigorous experimental evidence. Due to the importance of materials testing in designing and monitoring the safe operation of nuclear reactors, it is imperative to understand the conditions for accurate and reproducible testing of samples that are fully representative of the bulk material. Therefore, new data sets and a deeper level of scientific understanding are needed to critically evaluate new and updated standards with applications specific to nuclear industry use.

The symposium and corresponding *Selected Technical Papers* focused specifically on the testing of as-manufactured graphite with four underlying principal objectives:

1. To collect evidence on test specimen size effects for a range of properties, test specimen geometries and test specimen volumes, with a view toward the collation of data in a single reference,
2. to provide a technical (theoretical and/or experimental) basis for restrictions on test specimen sizes specified or suggested by applicable ASTM standards,
3. to provide guidance on the number of tests necessary for a valid measure of a given property, and
4. to facilitate the development of new standards that will address emerging issues in graphite evaluations for specific applications.

The organizing committee extended a limited number of invitations to international experts in the area of nuclear graphite testing. The content of this publication comprises the ten presentations at the symposium, arranged in the same order as presented in Seattle. While the specific focus of each individual paper results in a compilation that covers a wide range of perspectives, each is intended to address at least one of the above objectives. The valuable experience gained in the extensive use of nuclear graphite in the United Kingdom is capitalized upon in several talks from UK-based researchers, focusing not only on a comprehensive review of past experimental and theoretical work carried out by the UK nuclear industry, but also ongoing programs that are thoroughly evaluating specific test techniques. Size effect issues are analysed in several other papers that cover mechanical, thermal, and physical property measurements along with the considerations for using undersized specimens in these investigations. Laboratory-based work is not the only area being emphasized; two papers focus on modelling and simulation considerations as well as the evaluation of existing data sets with limited overall populations. Finally, a unique concluding paper presents a national regulator's view on the above challenges by drawing from experience of similar challenges faced with other materials.

Despite the high regard held for the present set of standards approved by ASTM International regarding the testing of graphite and carbon products, the D02.F0 subcommittee recognizes the need to stay aggressive in ensuring that the international standards remain up-to-date with regard to emerging materials challenges and applications. STP1578 is an example of one of the integral components needed to provide additional expertise from diverse backgrounds. The symposium provided an open forum to critically evaluate several of the many issues that confront ultimate materials validation and deployment when the specimens critical to materials acceptance face size and geometric limitations not currently addressed by existing test protocols.

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