Fire Resistance of Aluminum and Aluminum Alloys

& Measuring the Effects of Fire Exposure on the Properties of Aluminum Alloys

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Contents

Preface

Aluminum melts at approximately 660 °C (1220 °F), lower than most common structural metals such as iron and steel. Because of this, its behavior in fires can lead to confusion about its performance. Work was expended on this publication to document facts about the fire resistance of aluminum and aluminum alloys, and to enable engineers and designers to take account of aluminum's characteristic high resistance to burning while recognizing its relatively low melting point. The information includes facts with corresponding references; speculation and subjectivity are excluded.

Other publications have provided very useful technical data and guidance concerning some aspects of dealing with the characteristics of aluminum alloys with respect to fire exposure, but none has provided the full scope of coverage contained here.

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About the Author

John Gilbert (Gil) Kaufman has a background of over 50 years in the aluminum and materials information industries and remains an active consultant in both areas. In 1997, he retired as Vice President, Technology for the Aluminum Association, Inc., headqa rtered then in Washington, D.C. (now in Arlington, Va.), and is currently president of his own consultancy, Kaufman Associates.

Earlier in his career, Kaufman spent 26 years with the Aluminum Company of America, where he managed engineering properties and fabricating metallurgical research at Alcoa Laboratories. Many of the data presented in this volume were generated over the period when the author was active in and/or managing Alcoa Laboratories engineering properties research.

Kaufman subsequently spent five years with ARCO Metals, where he was Director of R&D and, later, Vice President, Research & Engineering. Kaufman also served for nine years as President and CEO of the National Materials Property Data Network where, working with STN International and Chemical Abstracts Service, he established a worldwide online network of more than 25 numeric materials properties databases.

Gil is a Fellow and Honorary Member of ASTM and a Fellow and Life Member of ASM International. He is a licensed professional engineer in Delaware. Gil has published more than 140 articles and six books on aluminum alloys and materials data systems.

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Introduction

The natural physical characteristics of aluminum and its alloys are such that they do not burn under normal atmospheric conditions nor do they contribute to flame spread or act as a fire accelerant. The data supporting these statements are provided in detail in the following chapters. Other organizations have addressed various aspects of this subject quite well (Ref 1–6), but none has addressed the whole scope of relevant material as attempted here.

The performance of aluminum alloys is excellent in many applications requiring exposure to relatively high temperatures, including (a) personal and commercial vehicles of many kinds, (b) marine applications such as fast ferry hulls and oil drilling rigs where superior corrosion resistance is critical, and (c) a variety of structural applications such as buildings, bridges, and pressure vessels. More details about the importance of aluminum's high resistance to burning in some of these applications is discussed.

Because aluminum melts at a temperature of approximately 655 °C, or 1200 °F (Ref 7, 8), lower than most common structural metals such as iron and steel, its behavior in some structural situations can lead to misunderstandings about its performance in fires. For example, when vehicles such as cars, trucks, or ships with aluminum components are caught in an engulfing fire, the aluminum components may be reported to have burned because they appear to combust and burn away. In fact, the aluminum components melt and run off, giving the appearance of being consumed in the fire. Aluminum or aluminum alloy components do not burn or contribute to the combustion.

Misunderstandings about aluminum behavior in fires has occurred in the past. For example, during the Falklands War in 1982, it was widely reported that the British warship HMS *Sheffield* was destroyed by Argentine rockets because the ship was made largely of aluminum and had combusted; in fact, the *Sheffield* was made entirely of steel and its destruction had nothing to do with aluminum (Ref 9).

It is the purpose of this book to describe the facts regarding the behavior of aluminum at very high temperatures, including those as high as or higher than necessary to cause it to melt, and to characterize its behavior in a wide range of applications where high-temperature performance is important. The behavior described is based entirely on documented test data, primarily the results of tests made in accordance with ASTM Standard Methods (Ref 10–12) and British Standards (Ref 13–17) .

Consideration is also given to situations where aluminum alloys have been exposed to fire but not melted and there is a subsequent need to estimate the residual strength of the exposed members. Although aluminum alloys lose strength when exposed to temperatures above approximately 100 °C, or 212 °F (Ref 18), they do not deform until temperatures near 500 to 600 °C (800 to 900 °F) are reached. Engineers must be able to determine whether aluminum alloy components that have had exposure to fire are able to continue to function satisfactorily or if performance has been compromised. By using nondestructive tests such as hardness and electrical conductivity measurements, it is possible to estimate with considerable accuracy the retained mechanical strength. Tools are included herein to guide estimates of this type.

There are, of course, applications where the high-temperature exposure is too great for aluminum to be used due to its low melting temperature. These are also documented, and guidance is provided for decisions on whether or not to use aluminum alloys in new applications.

The facts concerning the fire resistance of aluminum are:

- The physical properties of aluminum, notably high thermal conductivity, specific heat, and reflectance and its low emissivity, provide resistance to structures against temperature rise comparable or superior to that provided by steels in the early stages or in a non-engulfing fire.
- Even when temperatures do increase to intense incendiary levels, aluminum does not burn in air nor will it support combustion. When tested in accordance with ASTM or British standards, aluminum provides the highest ratings for resisting flame spread because it is not easily ignitable under atmospheric conditions and does not support flame spread.
- When necessary, the structural integrity of aluminum alloy structures can be protected against fire by practical and commercial fireproofing technology such as lightweight vermiculite concrete, similar to that used to fire protect steels, or Rockwool or gypsum sheeting.
- Aluminum is nonsparking in all environments and with all materials, with one known exception: when bare (unpainted or uncoated) aluminum is struck by or strikes rusty ferrous metals, sparks may result.
- Under conditions where it is likely or possible that aluminum may be struck by rusty ferrous metals, protective coatings such as paint are recommended to avoid any possibility of sparking.

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