

A Gallery of Combustion and Fire

A Gallery of Combustion and Fire is the first book to provide a graphical perspective of the extremely visual phenomenon of combustion in full color. It is designed primarily to be used in parallel with, and supplement existing combustion textbooks that are usually in black and white, making it a challenge to visualize such a graphic phenomenon. Each image includes a description of how it was generated, which is detailed enough for the expert but simple enough for the novice. Processes range from small-scale academic flames up to full-scale industrial flames under a wide range of conditions such as low and normal gravity, atmospheric to high pressures, actual and simulated flames, and controlled and uncontrolled flames. Containing over 500 color images, with over 230 contributors from over 75 organizations, this volume is a valuable asset for experts and novices alike.

DR. CHARLES E. BAUKAL, JR. is Director of the John Zink Institute, a training and educational organization for combustion engineers and researchers using John Zink Co. LLC equipment, former Chair of the Central States Section of the Combustion Institute, and Program Chair for the American Society for Engineering Education.

DR. AJAY K. AGRAWAL is the Robert F. Barfield Endowed Chair in Mechanical Engineering at the University of Alabama.

DR. SANDRA OLSON is from the NASA Glenn Research Center and has served as Primary Investigator, Co-Investigator, and Project Scientist on numerous flight experiments and ground-based studies.

DR. MICHAEL J. GOLLNER is an assistant professor and Deb Faculty Fellow in the Department of Mechanical Engineering at the University of California, Berkeley.

DR. TIMOTHY J. JACOBS is a professor and the Steve Brauer Jr. '02 Faculty Fellow in the Department of Mechanical Engineering at Texas A&M University.

DR. MARK VACCARI is a development engineer at John Zink Hamworthy Combustion and an adjunct professor at the University of Tulsa.

Cambridge University Press
978-1-107-15497-1 — A Gallery of Combustion and Fire
Charles Baukal, Jr.
Frontmatter
[More Information](#)

A Gallery of Combustion and Fire

Edited by

Charles E. Baukal, Jr.

John Zink Co. LLC

Ajay K. Agrawal

University of Alabama

Sandra Olson

NASA Glenn

Michael J. Gollner

University of California, Berkeley

Timothy J. Jacobs

Texas A&M University

Mark Vaccari

John Zink Hamworthy Combustion



CAMBRIDGE
UNIVERSITY PRESS

Cambridge University Press
978-1-107-15497-1 — A Gallery of Combustion and Fire
Charles Baukal, Jr.
Frontmatter
[More Information](#)

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom
One Liberty Plaza, 20th Floor, New York, NY 10006, USA
477 Williamstown Road, Port Melbourne, VIC 3207, Australia
314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre,
New Delhi – 110025, India
79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.
It furthers the University’s mission by disseminating knowledge in the
pursuit of education, learning, and research at the highest international
levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781107154971
DOI: 10.1017/9781316651209

© Cambridge University Press 2020

This publication is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without the written
permission of Cambridge University Press.

First published 2020

Printed in Singapore by Markono Print Media, Private Limited

A catalogue record for this publication is available from the British Library.

Library of Congress Cataloging-in-Publication Data

Names: Baukal, Charles E., Jr., 1959– editor.

Title: A gallery of combustion and fire / Charles E. Baukal, Jr. (John Zink
Co., LLC) [and five others].

Description: Cambridge ; New York, NY : Cambridge University Press,
2019. | Includes bibliographical references and index.

Identifiers: LCCN 2019019428 | ISBN 9781107154971 (hardback :
alk. paper)

Subjects: LCSH: Flame–Pictorial works. | Combustion–Pictorial works. |
Fire–Pictorial works.

Classification: LCC QD516 .G245 2019 | DDC 341/.361–dc23

LC record available at <https://lcn.loc.gov/2019019428>

ISBN 978-1-107-15497-1 Hardback

Cambridge University Press has no responsibility for the persistence or
accuracy of URLs for external or third-party internet websites referred to
in this publication and does not guarantee that any content on such
websites is, or will remain, accurate or appropriate.

Contents

<i>Preface</i>	<i>page</i> vii	2.12 Control of Nitric Oxides Emissions	52
Introduction	1	2.13 Gas Explosion in a Medium-Scale Vented Chamber	53
EDITED BY CHARLES E. BAUKAL, JR.		2.14 Large-Scale Structure–Fire Interaction: National Fire Research Laboratory Commissioning Test, Experiment, and Modeling	54
1 Fundamental Flames	4	3 Internal Combustion Engines and Gas Turbines	55
EDITED BY AJAY AGRAWAL		EDITED BY TIMOTHY J. JACOBS	
Introduction	5	Introduction	56
1.1 Different Types of Simple Flames	6	3.1 Single-Cylinder Version of a Cummins Six-Cylinder N-14 Highway Truck Engine	57
1.2 Laboratory and/or Idealized Flames	11	3.2 Mixing-Controlled Combustion in a Heavy-Duty Compression-Ignition Engine	58
1.3 Practical Flames	20	3.3 Visible Combustion Emissions in a Swirl-Supported, Light-Duty Diesel Engine	59
1.4 Spherical Flames	23	3.4 Sequential Images of Gasoline Compression Ignition Inside an Engine	61
1.5 Gas Jet and Liquid Flames	25	3.5 Spray–Swirl Interactions Stabilize Stratified-Charge SI Operation by Reducing Flow Variability near the Spark	62
1.6 Flames at High Speed	28	3.6 Quantitative Narrowband Infrared Imaging of a Turbulent Premixed Flame	64
1.7 Coal and Solid Particle Flames	29	3.7 Thermoacoustic Oscillation of a Confined Turbulent Swirl Flame	66
1.8 Metal Power Flames	36	3.8 Effects of H ₂ Enrichment on Flame Stability and Pollutant Emissions for a Kerosene/Air Swirled Flame with an Aeronautical Injector	68
2 Computational Fluid Dynamics	39	3.9 Effects of Carbon Dioxide Addition on Turbulent Premixed Flames	70
EDITED BY MARK VACCARI		3.10 Application of a Dielectric Barrier Discharge (DBD) to Retard Flashback in Lean Premixed Dump Combustors	72
Introduction	40		
2.1 LES Simulation of a Gas Turbine Combustor	41		
2.2 Annular Burner Ignition	42		
2.3 Numerical Simulation of a Spray	43		
2.4 Flame Ignition and Propagation in Aeronautical Swirled Multi-burners	44		
2.5 Direct Numerical Simulation of a Transcritical Flame	45		
2.6 Large Eddy Simulation of a 42-Injector Liquid Rocket Engine	46		
2.7 Numerical Simulation of a Rotative Detonation Engine	47		
2.8 RANS Simulation of an IFRF Coal Furnace	48		
2.9 RANS Simulation of a Glass Furnace	49		
2.10 LES Simulation of a Flameless Combustor	50		
2.11 Enclosed Ground Flare	51		

4 Low-Gravity Flames	74	5.5 Flares	134
EDITED BY SANDRA OLSON		5.6 Oxygen-Enhanced Flames	139
Introduction	75	6 Fires	140
4.1 Gaseous Fuels	76	EDITED BY MICHAEL J. GOLLNER	
4.2 Liquid Fuels	81	Introduction	141
4.3 Thick Solid Fuels	88	6.1 Pool Fires	142
4.4 Thin Solid Fuels	95	6.2 Flame Spread and Fire Growth	148
5 Industrial Flames	107	6.3 Fire Suppression	156
EDITED BY CHARLES E. BAUKAL, JR.		6.4 Fire Whirls	160
Introduction	108	6.5 Wildland Fires	166
5.1 Metals Industry	109	6.6 Smoldering Combustion	171
5.2 Process Heating	118	Author Index	176
5.3 Power Generation	131	Subject Index	179
5.4 Infrared Heating and Drying	132		

Preface

This book is the result of two primary factors. The first is the success of a previous Cambridge University Press book published in 2003 entitled *A Gallery of Fluid Motion* edited by M. Samimy, K. S. Breuer, L. G. Leal, and P. H. Steen. That book was patterned after two earlier graphical books on the subject of fluid flow. The first is *Illustrated Experiments in Fluid Mechanics: The NCFMF Book of Film Notes* by Asher H. Shapiro, published by MIT Press in 1972. The second was a very successful book by Milton Van Dyke, entitled *An Album of Fluid Motion*, published by Parabolic Press in 1982. All of the images that appear in *A Gallery of Fluid Motion* were winning images as selected by the American Physical Society in an annual contest held since 1983. The mostly color images were selected for artistic and technical merit. All of the images were previously published in the journal *Physics of Fluids*.

The second factor leading to this book is the Combustion Art contest sponsored by the Central States Section of the Combustion Institute (CSSCI). Sandra Olson, one of the editors of the present book, has led this competition for many years where the winning art since 2004 is posted online (www.cssci.org/). Cambridge University Press heard about this competition and contacted the CSSCI about authoring a book similar to *A Gallery of Fluid Motion* but on the subject of combustion. Four of the editors of the current book (Agrawal, Baukal, Jacobs, and Olson) are or were members of the CSSCI board. The initial book title was extended from *A Gallery of Combustion* to *A Gallery of Combustion and Fire* when an extensive section on fire was added. The International Association for Fire Safety Science sponsors a fire science image contest that was of interest to this project.

This is the first known book of its type, as no other books were found that take a primarily graphical

approach to combustion. There are a number of unique aspects of the book. There are numerous full-color images of all aspects of combustion including actual and simulated flames and fires. Each image includes a brief description with details of how it was generated. The book includes small-scale academic flames, large industrial flames, and fires. A wide range of pressures is considered, including low gravity, atmospheric, and pressurized flames relevant in space, industrial, and propulsion applications, respectively. The book combines the science and art of combustion.

There are many potential benefits of this book. The full-color images are essential to understand combustion, and represent a significant improvement compared to most earlier books on the subject, which are in black and white. There is a full range of flame types from academic to industrial, whereas most combustion books deal with one or the other. The book includes both traditional controlled flames as well as uncontrolled fires. It is detailed enough for the expert yet simple enough for the novice.

The book is designed primarily to supplement existing combustion textbooks used in both undergraduate and graduate courses as well as in short courses on combustion. It should be of interest to anyone working in the field of combustion, including professors, researchers (academic, industrial, and government), designers, students, industrial users, and even to nontechnical readers interested in this subject. While most of the images are included for pedagogical purposes, there are some of artistic merit as well. Due to space limitations, no attempt has been made to be comprehensive, but an objective of the book is to be representative of the numerous types and aspects of combustion. No prerequisite knowledge is required to use the book.

Cambridge University Press
978-1-107-15497-1 — A Gallery of Combustion and Fire
Charles Baukal, Jr.
Frontmatter
[More Information](#)