Selected Works of Jim Quintiere

Compiled Commentaries and Reflections

Contents

Preface

The fire science and engineering community has been shaped in profound and enduring ways by the life and work of Professor James (Jim) Gennaro Quintiere (5/5/1940 – 23/12/2024). His unique ability to bridge rigorous scientific theory with practical applications revolutionized our understanding of fire behavior, and his influence resonates through generations of students, researchers, and professionals across the globe.

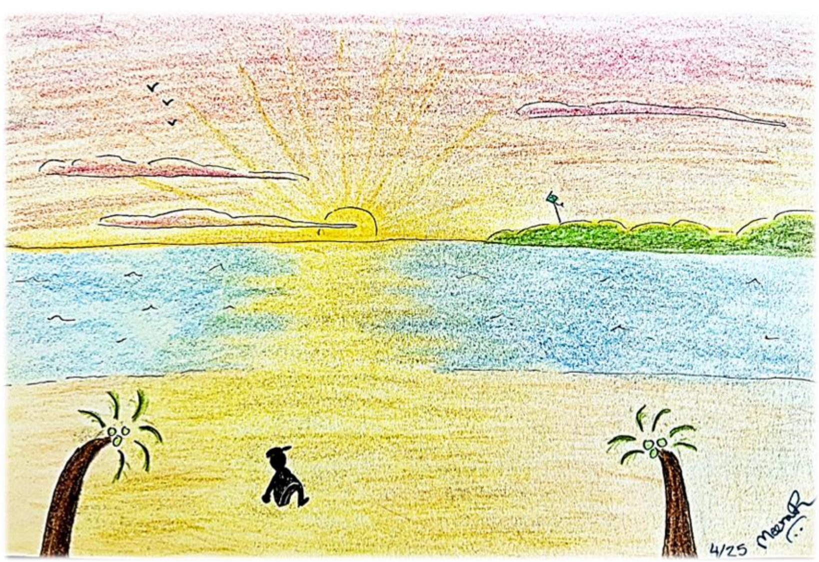
This volume, *Selected Works of Jim Quintiere*, is a curated compilation of landmark contributions that not only showcase the breadth and depth of his scholarship, but also reflect the character and conviction with which he pursued truth—whether in the laboratory, the classroom, or in service to public safety. Spanning foundational textbooks, pioneering fire investigations, and insightful theoretical advancements, this collection offers a window into Jim's enduring legacy. Each chapter is enriched by personal commentaries from his colleagues, students, and collaborators, illuminating the intellectual and human dimensions of his work.

We begin this collection with tributes from Jim's family, whose stories remind us that behind every equation and lecture was a man of deep personal character. To his brother Gary, Jim was a steady, brilliant presence—always there to guide, teach, and lift others up. To his cousin John, Jim was an unforgettable blend of creativity, humor, and fierce compassion, whether building model airplanes, dancing in the Mummers parade, or fighting for the truth behind the collapse of the World Trade Center. These early chapters ground the technical legacy that follows in something even more enduring: a legacy of love, care, and principle.

More than a record of scientific achievement, this collection is a tribute to Jim as a teacher, mentor, and friend. He was "Professor Heat Flux" to some, a tireless advocate for justice to others, and always a man who cared deeply about the people and the principles behind the science. His signature blend of curiosity, clarity, and courage continues to inspire all of us who seek to understand and tame the power of fire. We present this volume with gratitude—for the lessons learned, the paths illuminated, and the legacy that lives on.

To those who brought the logic of science to fire—this book strives to carry forward their spirit and Jim's.

May 3, 2025



My Father - My Hero

Christopher R. Quintiere

From the very beginning, my father was a source of encouragement and positivity in my life. I felt safe and secure in his presence and the positive impact he had on me will continue throughout my entire life.

My father was a hard worker, but always managed to ensure his family felt cared for and loved. He made a real effort to be present and spend meaningful time with his family; I especially cherished our weekend time together. There would be household responsibilities that required the attention of any working parent, but my father found a way to make these chores entertaining for my brother Scott and me. After the chores were taken care of in the morning, I could count on us doing something fun together afterwards. I remember climbing in his little red Dodge Colt and embarking on these adventures. I never knew what my father had planned, but it was always something new and exciting like a park, ballgame, or museum visit. It was during these car rides where my father would teach me things about life and our existence. I remember being able to ask him almost anything and he would always have an answer. There was only one question that perplexed him, one question he could not answer and would spend his life trying to understand. He wanted to know why my brother Scott was autistic. This question plagued my father, but I would always reassure him that some questions in life are not meant to be answered. My father loved Scott fiercely and was an incredible advocate for him.

During my time as a student at UMD, I had the chance to experience how committed my father was to his students. My father and I would sometimes have lunch on campus together. On one occasion, I happened to arrive early to his classroom and quietly snuck in while he was finishing his lecture.

After the class ended, one of his students recognized me and stopped by for a quick chat. When I asked him how class was, he responded by saying that he did not understand everything my father was teaching that day, but was reassured in knowing that my father would take the extra time needed to explain it to him personally. This encounter showed me that my father would do whatever was necessary to ensure his students had the confidence to succeed. This was clearly his mission in life with everyone he encountered.

As I grew older, I began to realize that my father was someone very rare and rather unique. He had a tremendous effect on so many people. He was a family man, a best friend, an advocate for happiness, an engineer, a professor, a mentor, a published author, an artist, a musician, and a comedian. My father's ability to completely transition into these different roles always amazed me. His relentless pursuit for success in all these roles was just a part of who he was. Regardless of his many talents and abilities, my father was hard on himself and would often dwell on what he considered to be failures in his life. However, he refused to let these failures consume him and define who he was. His will and determination for success and happiness in life outweighed the depression that he fought throughout his life. My father was a man with a strong moral compass, a man of integrity, and a constant seeker for the truth. With his credentials and experience, he could have chosen a different career path altogether. Instead, he chose the road of knowledge, understanding, and teaching that knowledge to all those around him.

I was once asked who inspired and motivated me in life. The answer is my father. He taught me the lessons in life needed to be a successful individual. He is the person who loved me and everyone he knew unconditionally. He was the person who threw me a lifeline, even while he was grappling with life's challenges at the same time. I could not be prouder of who my father was. My father, "Dr. Q," was my hero, my rock, and my best friend.

My Brother Jim— Always There

Gary Quintiere

We grew up in an "un-privileged" home. Our parents were working-class people — mom, an immigrant from Sicily; dad, a first-generation American. Neither had gone to high school. Both were compelled to work in order to help their families.

Jim was born in 1940; I came along 4 years later. As youngsters, we slept on a pull-out sofa in the parlor of our 3-room "cold-water" apartment — no hot water on-call at the tap. After a few years, we moved up to a 4-room "cold-water" apartment and, just after my first year of high school, a real house. Progress, yes. But in each new place, we shared a room.

Out of these cramped conditions, our bond as brothers was forged. We were alike in many ways, but quite different in others. We shared an interest in music: Jim played the accordion while I strummed away on my guitar. Sometimes we would play for family get-togethers, along with our cousins — Joe on clarinet and John on piano.

Jim was stand-out smart from the get-go. Good in all subjects, but excelling in math and science. In his senior year in high school, he won a science contest that afforded him a free trip to California — an amazing feat at that time.

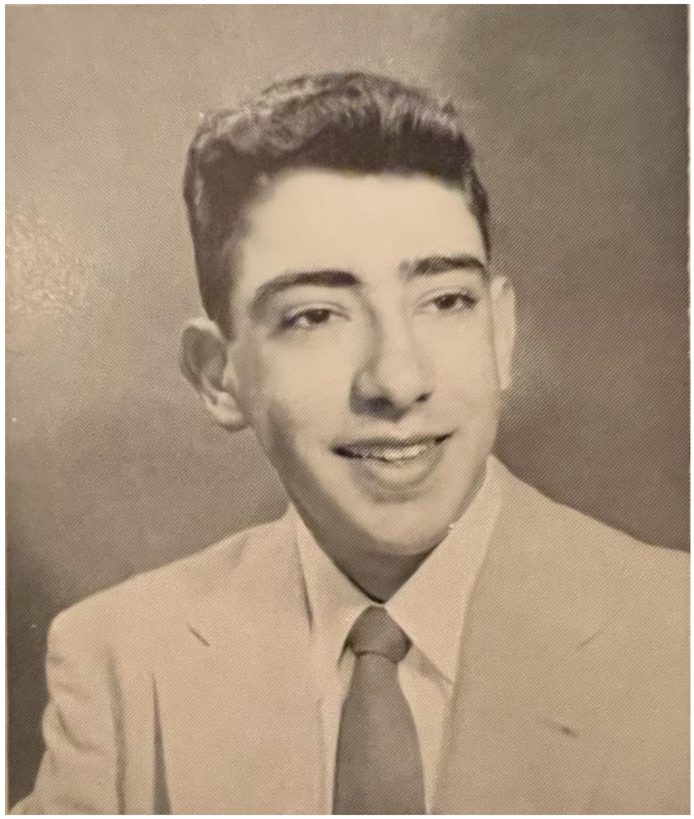
Like most brothers, we harassed each other mercilessly, but rarely with ill intent. I always looked up to Jim and, in a pinch, I knew he would always be there — to provide guidance and lend support.

When Jim became an altar-boy at our parish church. I wanted to follow suit but there was an obstacle — I needed to learn the Latin responses that were part of the Catholic mass at that time. This was a big deal for a 10-year kid old with a limited attention span. But Jim came through.

Like Jim, I played football in high school. However, unlike Jim, I was a lazy student. One semester, I came home with an F in chemistry. Jim was disappointed, but determined to set things straight. Despite his heavy workload at Newark College of Engineering, he took the time to teach me ways to short-cut and better understand many of the processes that were being taught in class. Next semester, I should have gotten an A, but the teacher was too embarrassed to give it to me. He couldn't understand how a "dumb jock" like me knew how to do things in a way that he hadn't taught. Thanks to Jim, I got my "Sicilian Revenge".

Football and moderately good test scores provided me with scholarship opportunities. I wanted to stay close to home, but Jim wouldn't hear of it. He had to commute to NCE because my parents couldn't afford the tuition at Rensselaer Polytechnic Institute. Lafayette College in Easton PA wanted me to visit — tour the campus; meet the coach. Jim drove me in his used VW. This changed my life — big time. Lafayette led to GW Law School and a productive career as a DC lawyer, with stints at two major firms. Thanks again, Jim.

Jim and I were not as close in our later years. Family and career obligations often had us going in different directions. But we never lost touch. And we never lost our brotherly connection, nor our affection for one another. If any good can be said to have come from his untimely death, it's that I've become closer to his son, my nephew Chris — a terrific young man who brings echoes of Jim each time we talk.



James Quintiere "Jim" 1955 Yearbook

Ben and Sadie Quintiere (top). James and Gary Quintiere (bottom)

My Dear Cousin Jim

John Livelli

Jimmy was the oldest of us male cousins, eight years older than me, the youngest. My earliest memory of Jimmy was of him and about 35 other junior accordionists at their music school concert. What a "wall of sound"! I remember Jim somehow knowing that I had wished for a Mr. Machine for that Christmas. Jim showed up with the robot, turning it on when I opened the door so it could walk in. Cool!

I remember the Quintieres' apartment in Passaic, New Jersey. I remember Jim showing me his collection of model bi-planes, which he had carefully crafted and hand-painted. *Blue Moon* and other doo-wop songs were playing on the radio. Jim was already at Passaic High, where the Shirelles, the first great "girl group," were among Jim's classmates, about to be famous. Just down the street was the deli owned by the parents of Joey Dee, whose band, the Starlighters, were about to hit it big with *The Peppermint Twist.*

Besides playing an instrument, Jim loved to dance. He was an avid swing dancer late into his adult life. His creativity also included painting his "Picassos," which he carefully copied and hung in his apartments. And every year, later in his life, Jim would create and send to all of his friends and relatives, a composite of photos, cartoons, and jokes, usually featuring his numerous foreign trips. Oh, and he loved animals, or at least those of the thoroughbred horse variety. He was a talented handicapper, and two-dollar bettor, regularly joined at the track by my brother Joe.

Perhaps Jim's greatest challenge, and heartbreak, was the plight of his first son, Scott, who has suffered, until today, from severe autism. Jim's steadfast dedication to Scott's care and treatment, over decades, was a major part of Jim's life. It often meant Jim having to fight actively to insure Scott was being properly treated and attended to.

Jim's concern for those who were suffering, particularly due to the neglect or incompetence of responsible officials, likely prompted his decision to forcefully advocate for the 9/11 families. He was determined to get to the truth behind the collapse of the twin towers. As usual, Jim was fearless, outspoken, and indefatigable. Jim's entire career was marked by a courageous determination to discover the truth.

The last time I saw cousin Jim was in March 2024. Jim had driven up to attend our Aunt's 105th birthday celebration. He had been struggling with medical conditions that often left him too weak to drive or concentrate on his work. He had cut back on his jamming with the music combo he marched with in the Mummers' parades. But Jim arrived at Marian's party with his accordion and Mummers costume. At the appropriate moment, he put on his costume, strapped on his instrument, and serenaded his beloved Aunt. That was Jim, a man who cared, served others, achieved much… while having fun! I will miss him deeply.

A Tribute to Professor Heat Flux

Professor Tingguang Ma

Starry Night, JQ's favorite for its turbulence.

Professor JQ, affectionately known as Professor Heat Flux by some of his students, was a figure whose passion for fire dynamics and dedication to education shaped the careers of countless students, myself included. He had a unique approach to teaching, combining rigorous theory with real-world applications, and his influence continues to guide us today.

The Meaning Behind the Name "Professor Heat Flux"

During one of our graduate classes on fire experiments, Professor JQ introduced the concepts of heat flux and heat transfer. To simplify, he used "J" for flux and "Q" for heat, and from that moment on, we all knew he wanted to be called Professor Heat Flux. While many of my peers still referred to him as Professor JQ, it was clear to me that what he truly valued was the elegance and simplicity of fire dynamics theory.

His commitment to making fire science accessible didn't stop with theoretical work. Although his fire dynamics textbook was groundbreaking and comprehensive, it was sometimes more advanced than a typical entry-level engineer could handle. To remedy this, he authored a second book on fire behavior, designed to appeal to firefighters and fire investigators. This effort highlighted his dedication to bringing the beauty of fire dynamics to all corners of the fire safety profession. It was an example I carried with me when preparing my own introductory textbook for firefighters, especially those in China.

The Art of Derivation

Professor Heat Flux had a distinctive teaching style, particularly in his passion for deriving equations. As a traditional professor, he believed that answers were embedded within the theory, waiting to be uncovered through the process of derivation. Whenever I approached him with a question, he would immediately grab a pen and begin working through the problem fluently, as though the solution was always just a few steps away.

He would often remind us that ABET accreditation required engineering students to solve problems by deriving equations, a perspective that greatly influenced my own work. I later published my first monograph on mixture flammability theory, not based on original data, but by using existing data to reconstruct the theory. Although I didn't employ his dimensionless groups, I relied on the concept of flammable flux—another form of heat flux —which was a direct influence of his work.

The Power of Problem-Solving

One of Professor Heat Flux's most notable contributions to fire dynamics education was his collection of problems and solutions. Every year, he crafted new problems for homework and exams, often embedding complex theoretical concepts into real-world scenarios. This process continued for a decade, resulting in a comprehensive solution manual that supported his textbook. Although he sometimes lamented the loss of creativity in devising these problems, he always emphasized that these problems were meant to be shared freely. "There are no copyrights," he would say, "you solve it, you have it."

Today, many of the problems in the solution manual for my own textbook are inherited from him—50% from his collection, 30% from Professor Drysdale, and 20% from my own flammability theory. Like Professor Heat Flux, I provide these problems and solutions to my students at no charge. It's a simple reminder that engineering education is not about protecting intellectual property, but about passing on knowledge for the greater good.

The Waco Investigation: A Key Moment

Professor Heat Flux's work was not confined to the classroom. He made significant contributions to fire investigations, most notably in the aftermath of the Waco disaster. He authored an entire chapter on his experience with fire investigations, offering a detailed analysis of heat transfer in the structure. Although his approach—focusing on individual components like the trusses in the WTC building—sparked debates on the utility of such analyses in system safety, it gave us valuable insights into structural integrity and fire dynamics. His perspective on understanding fire behavior through detailed component analysis shaped how I think about fire investigation today.

Art and Fire Dynamics: A Unique Perspective

A fascinating aspect of Professor Heat Flux's teaching was his ability to connect fire dynamics with art. He frequently referenced art pieces to illustrate complex fire-induced flows. I will always remember his references to Van Gogh's Starry Night (see figure 1), which was greatly influenced by the Japanese art piece, Tsunami by Hokusai (see figure 2). These were not just artistic choices; they reflected his ability to interpret fire dynamics in ways that went beyond the engineering lens.

Tsunami by Hokusai, a masterpiece on gravity currents.

His love for art was intertwined with his passion for research. He believed that the beauty of a theory could be seen in the same way as one appreciates a great work of art—through interpretation and understanding. Just as artists interpret their subjects in unique ways, researchers like us interpret the world through our theories. Inspired by his approach, I've often cited ancient drawings in my history books, supporting my theories while showcasing the intersection of art and science.

Farewell, Professor Heat Flux

As I reflect on the legacy of Professor Heat Flux, I am reminded of the profound impact he had on my academic journey. His teachings, his dedication to problem-solving, and his ability to draw connections between disciplines continue to influence my work. I only wish I could share my latest discoveries with him, especially the way in which art and fire dynamics can be intertwined. Unfortunately, with his passing, it feels as though a unique perspective on my work has been lost.

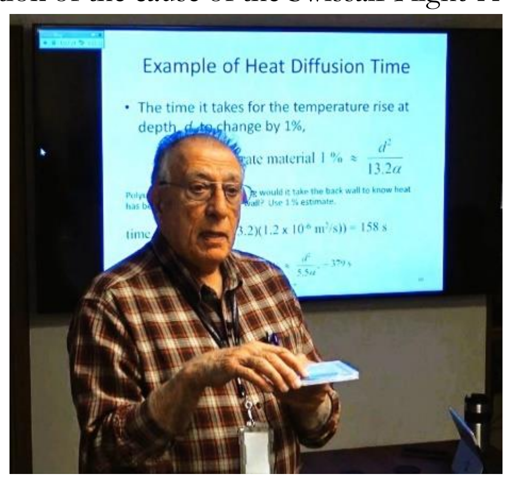
Nonetheless, his influence lives on through me and countless others. His teaching style has now passed to China, where it will continue to shape the minds of future fire engineers. In the field of fire dynamics, he will be remembered as a true pioneer—someone who not only taught us how to solve problems but also how to see the world through the lens of fire and science.

Thank you, Professor Heat Flux. You will always be remembered, and your contributions will never be forgotten.

Professor James G. Quintiere: Friend of Aviation Safety

Rich Lyon, Federal Aviation Authority

Throughout his 40-year association with the Federal Aviation Administration (FAA), Dr. James G. Quintiere has been a friend to aviation safety and mentor to the Fire Safety Branch. Jim had an intuitive grasp of the essential physics of complex fire phenomena and would find engineering solutions based on fundamental principles. A good example is Jim's elucidation of the cause of the Swissair Flight 111 accident over Nova Scotia on September 2, 1998, that killed all 229 passengers and crew. The origin of the in-flight fire was the attic space above and behind the cockpit ignited by arcing of compromised electrical wiring. But the only fuel source was the thin metalized polyester (MPET) films encapsulating the fiberglass blankets of the thermal acoustic insulation on the attic floor and between the ribs of the fuselage. Freestanding MPET films melted and shrunk away from the flame to pass the FAA Bunsen burner test for flammability or burned with a small flame that propagated slowly, which was inconsistent with the intense fire that had burned through the aluminum fuselage above the attic space in a matter of minutes. Desperate to resolve this inconsistency the Transportation Safety Board of Canada, visited the FAA Technical Center in Atlantic City, New Jersey to conduct full-scale aircraft fire tests. After weeks of failed attempts to reproduce the intense fire, Jim suggested pulling insulation blankets from the ribs and piling some of these on the attic floor to simulate a maintenance mishap that would increase the fuel density and radiant feedback of burning MPET. Igniting these blankets with a spark produced a fire so intense it melted the aluminum fuselage above the fire, as observed in the fuselage wreckage recovered from the accident site. TSB Canada transported the aircraft test section back to Canada to document these findings in a final report and the FAA issued an order to remove all MPET insulation blankets from transport aircraft. Jim's effort resulted in a new FAA rule that thermal/acoustic insulation blankets resist flame spread under radiant heat (radiant panel test).



Sincere thanks to Professor Quintiere for his great contributions to the development of fire research in Japan

Professor Takeyoshi Tanaka, Kyoto University, Japan

1. Early Encounters with Dr. Quintiere

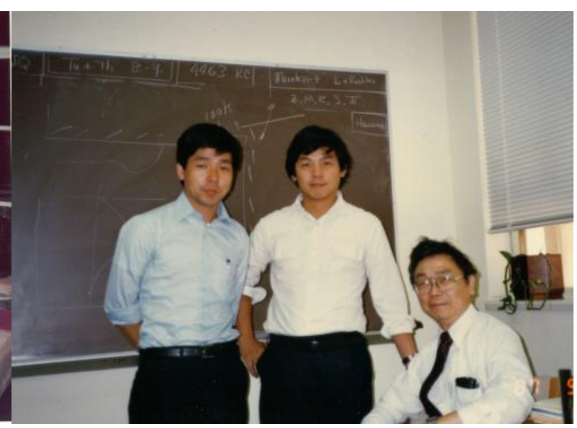
In 1973, I was employed by the Building Research Institute (BRI) as a researcher in the fire research group. At that time, Dr. Wakamatsu, Prof. Kawagoe, and others frequently mentioned several famous foreign researchers, such as Dr. P.H. Thomas (UK), D.J. Rasbash (UK), Dr. Harmathy (Canada), and Prof. Pettersson (Sweden). As a result, I vaguely assumed that there were no urgent fire problems in the U.S., unlike other countries, including Japan, which urgently needed post-war reconstruction of cities devastated by World War II.

It took me some years to understand why there were many small concrete houses around the BRI campus for BRI workers and why studying fire-resistant test methods was important. This was simply due to the severe shortage of houses after the war, as the reconstruction of cities with noncombustible houses was a national aspiration.

Probably, it was only two years after I started working at BRI when Dr. Quintiere visited us. He looked no older than 40 and had sleek, black hair.

At the meeting, most members of the fire research group could not speak English fluently. Although a few people had studied in the UK, I am sure Dr. Quintiere could not understand our English very well. My own English was terrible, so I could not understand the discussion at all. At the very least, this meeting made us recognize the necessity of studying English more seriously. Nevertheless, my English is still poor.

Incidentally, I later learned that the BRI visit was Dr. Quintiere's first trip abroad, making it a big event for him.



2. UJNR Panel on Fire

Regardless of the purpose of Dr. Quintiere's BRI visit, a proposal to establish the UJNR (U.S.-Japan Conference on the Development and Utilization of Natural Resources) Panel on Fire arrived the following year. After domestic discussions in Japan, it was launched in 1976.

As I later learned, Prof. Howard Emmons of Harvard University played a key leadership role. At that time, about 20,000 people were dying from fires annually in the U.S. To address this issue, he sought to launch a project called the Home Fire Project involving CFR (NBS, U.S. Department of Commerce) and U.S. universities. He also went on a global tour in search of potential partners, including Dr. P.H. Thomas (UK) and Prof. Akita (University of Tokyo).

After returning home, Prof. Emmons secured funding from the National Science Foundation (NSF) and launched the Home Fire Project. It was precisely at this time that the inquiry for the UJNR Panel on Fire came to Japan.

When the UJNR Panel on Fire began, my first impression was that the U.S. research topics and methodologies were generally oriented toward strict scientific principles, while Japanese research was more focused on applied engineering, although some topics were common to both sides. I believed it was highly beneficial for different research groups to gather at the same table to exchange ideas and advise one another.

U.S. researchers devote significant effort to setting up experimental apparatus and environments to obtain highly precise data on various fire phenomena, such as combustion reactions, heat transfer, and gas flow. On the other hand, as someone with a background in architectural engineering and a focus on applied research, my primary interest lay in how to effectively utilize these meticulously measured data to create fire-safe building environments.

While participating in the UJNR Panel on Fire, I received an offer from Dr. Quintiere to become a visiting researcher, and I had no reason to hesitate. It was my first opportunity to study abroad, and an exciting experience for my family as well.

Dr. Quintiere was a highly versatile researcher, deeply interested in various aspects of fire, including compartment fires. Prof. Emmons was developing a single-room fire model called the Harvard Fire Model and repeatedly stated at UJNR Panel meetings that the ultimate goal was to create a model that could predict the fire environment in any given location. At that time, I had already developed a multi-room smoke spread model and presented it at a UJNR Panel on Fire meeting held at NBS.

As my academic background was in architecture and building engineering, my understanding of physical and chemical aspects was poor at that time. Therefore, my stay at NBS provided a valuable opportunity to improve the smoke model.

The initially planned length of my stay was one year, but Dr. Quintiere kindly offered to extend it for another year. I would have liked to stay longer, but BRI denied my extension because a five-year research project by the Ministry of Construction was about to begin. The project aimed to develop a performance-based fire safety design method for buildings, a topic I had previously discussed with Dr. Wakamatsu before going to NBS. Thus, I had no choice but to return to Japan. Nevertheless, I continued attending the UJNR Panel on Fire and presented intermediate results from the project.

After my visit, NBS continued to invite many researchers from BRI, CFR, and Tokyo Science University, while Japan also hosted several researchers, **though their stays tended to be short—**about one month due to budget limitations on the Japanese side.

3. IAFSS

The research results of the UJNR Panel on Fire gradually spread beyond the U.S. and Japan.

When I visited CSTB (France) to study European building regulations, I discovered that CSTB researchers who had previously visited Dr. Quintiere to study fire models were developing their models based on the Harvard and NBS models for EDF (Électricité de France). Similarly, Dr. Sjölin of the Swedish Fire Research Board praised the UJNR Panel on Fire for its global impact on fire research.

The creation of the IAFSS (International Association for Fire Safety Science) was discussed and agreed upon when leading fire researchers met in 1984 at FRE (UK), including Dr. Quintiere (U.S.), Dr. Thomas (UK), Prof. Kawagoe (Japan), Prof. Akita (Japan), and Dr. R. Friedmann (U.S.). The first symposium was held in 1985. Since then, symposia have been held approximately every three years, rotating among Asia-Oceania, Europe, and North America.

As I learned from Dr. Quintiere, the creation of the IAFSS was driven by fire researchers who sought a forum where researchers from various fields could gather, present their work, and engage in discussions.

4 . The International Expansion of Collaborative Research in Fire Science

Below is a timeline showing the establishment periods and subsequent developments of major international conferences related to fire research.

As observed here, the world's first collaborative research in this field was the Japan-U.S. joint research conducted by the UJNR Panel on Fire. Following this, the International Association for Fire Safety Science (IAFSS) was established, bringing together fire researchers from countries worldwide.

Additionally, the Asia-Oceania Symposium on Fire Science and Technology (AOSFST) can be considered the Asia-Oceania counterpart of the IAFSS. It provides a more accessible platform for fire researchers from this region to present their research.

The SFPA Symposium is a fire research conference hosted by the SFPA. Although its headquarters is located in Maryland, USA, the organization has numerous chapters worldwide, allowing for biennial conferences held in various locations. A unique feature of these symposia is their strong emphasis on presentations related to performance-based fire safety design, including a themed design competition held at each event.

The international expansion of fire research activities has been made possible through the extraordinary efforts of many pioneers, including Professor Quintiere.

However, that alone does not explain the full extent of its development. Throughout his tenure at the National Bureau of Standards (NBS) and later as a professor at the University of Maryland, Dr. Quintiere continuously attracted young researchers from around the world. Under his guidance, they grew into fire researchers, and today, they support the field of fire science.

From personal experience, I know that he was a kind and caring mentor. However, I cannot help but feel that there was something beyond just that.

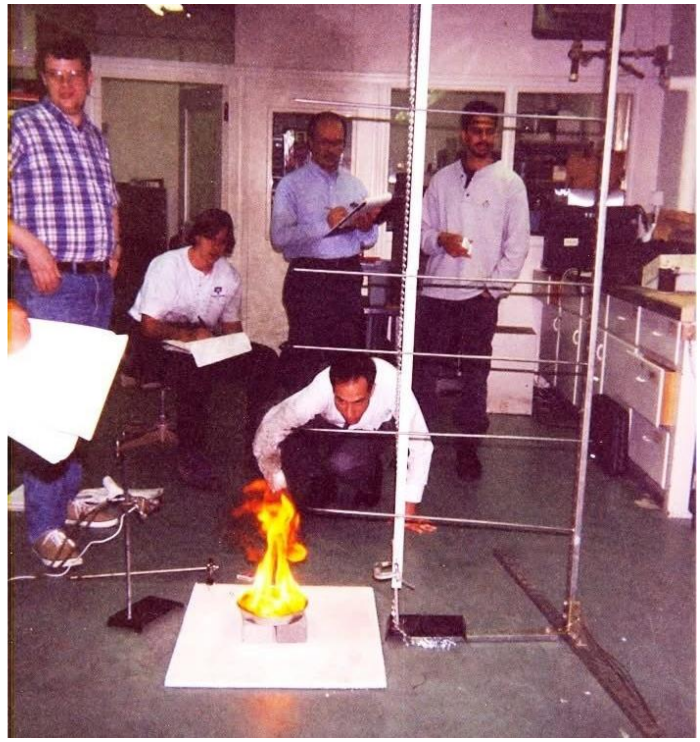
Table Major International Conferences on Fire Research

	UJNR Joint Fire Panel Meeting(*1)			IAFSS(*2)			AOSFST(*3)			SFPE Int'l Conference(*4)		
Year	No.(Month)	Venue	Country	No.(Month)	Venue	Country	No.(Month)	Venue	Country	No.(Month)	Venue	Country
1976	1st (04)	Washington D.C.	USA									
	2nd (10)	Tokyo	日本									
1977												
1978	3rd (03)	NBS	USA									
1979	4th (02)	Tokyo	日本									
1980	5th (10)	NBS	USA									
1981	6th (05)	Tokyo/Tsukuba	日本									
1982												
1983	7th (10)	NBS	USA									
1984												
1985	8th (05)	Tsukuba	日本	1st (10)	NBS	USA						
1986												
1987	9th (05)	Boston	USA									
1988	10th (10)	Tsukuba	日本									
1989	11th (10)	Berkeley	USA	2nd (06)	Tokyo	日本						
1990												
1991				3rd (07)	Edinburgh	UK						
1992	12th (10)	BRI/FRI	日本				1st (10)	USTC, Hefei	China			
1993												
1994				4th (07)	Ottawa	Canada						
1995							2nd (09)	Khabarovsk	Russia			
1996	13th (02)	NIST	USA							1st (09)	Ottawa	Canada
1997				5th (03)	Melbourne	Australia						
1998	14th (05)	BRI/FRI	日本				3rd (06)	Singapore	Singapore	2nd (05)	Hawaii	USA
1999				6th (07)	Poitiers	France						
2000	15th (03)	San Antonio	USA				4th (05)	Waseda U.	日本	3rd (06)	Lund	Sweden
2001							5th (12)	Newcastle	Australia			
2002				7th (06)	Worcester	USA				4th (03)	Melbourne	Australia
2003												
2004							6th (03)	Daegue	Korea	5th (10)	Luxemburg	Luxemburg
2005				8th (07)	Beijing	China						
2006										6th (06)	Waseda U.	日本
2007							7th (09)	Hong Kong	Hong Kong			
2008				9th (09)	Karlsruhe	Germany				7th (04)	Auckland	NZ
2009												
2010							8th (12)	Melbourne	Australia	8th (06)	Lund	Sweden
2011				10th (06)	U. Maryland	USA						
2012							9th (10)	Hefei	China	9th (06)	Hong Kong	Hong Kong
2013												
2014				11th (02)	Caterbury	NZ				10th (11)	Gold Coast	Australia
2015							10th (10)	Tsukuba	日本			
2016										11th(?)	Warsaw	Poland
2017				12th (06)	Lund	Sweden						

(*1) The US-Japan Cooperative Program in Natural Resources, Panel on Fire, US-Japan Joint Panel Meeting
(*2) International Association for Fire Safety Science, International Symposium
(*3) Asia-Oceania Symposium on Fire Science and Technology
(*4) SFPE International Conference on Performance-Based Codes and Fire Safety Design Methods

Jim Quintiere's Involvement with SFPE

Morgan Hurley



I was privileged to have Jim Quintiere as a professor at the University of Maryland both during my undergraduate studies (when he was an adjunct professor) and later when I was a graduate student (when he was a full-time professor). The photograph is one that he took in his graduate "Fire Dynamics Laboratory" course in the late 1990s. We measured flame heights and fire plume temperatures, and we compared our measurements to predictions that we developed using correlations from the literature.

Later, Jim led a task group at the Society of Fire Protection Engineers that was responsible for developing a guide on determining the fire boundary conditions for purposes of conducting a performance-based design of a building's structure. The goal was to determine a fire exposure that was tailored to the building as an alternative to the "standard" fire exposure that is found in ASTM E119 or ISO 834.

Under Jim's leadership, the task group decided to focus on fully developed fires since (1) there could be a lot of variability during fire growth (depending on where the fire started) and (2) the impact of a fire on the structure would generally be dominated by the fully developed stage of a fire.

Jim advocated for simple predictive methods like algebraic correlations as opposed to more complicated methods like computer fire models. The task group identified eight predictive methods from the literature for inclusion in the guide. However, the task group wanted to do more than just identify the methods; they also wanted to provide guidance on which methods should be used under which conditions.

Developing recommendations for which methods should be used under which conditions required comparing predictions to fire test data. We selected a database of experiments that were performed under the auspices of the CIB to use for the comparison. This database was supplemented by fire experiments in long and narrow compartments.

As the SFPE staff member who was assigned to the project, comparing model predictions with the test data fell to me. Although Jim was not my advisor while I was in graduate school, this effort felt like a thesis project. I regularly met with Jim to present my work, and he gave me suggestions on how I should proceed. When the project was finished, I felt like I should have received a PhD!

All kidding aside, Jim was a key contributor to the fire protection engineering profession – through the research that he performed, through the students that he taught, and through his leadership in professional societies like SFPE.

Memories of Prof. Quintiere

Professor Weicheng Fan Institute of Public Security, Tsinghua University

Dr. James Quintiere is an old friend of the State Key Laboratory of Fire Science (SKLFS). The SKLFS has its origins in the 1987 Great Xing'an Mountains Forest Fire. The fire covered an area of 13,700 square kilometers, making it the most severe wildland fire in China over hundreds of years. After this fire, I put forward a proposal to the Central Government of China to establish a national-level basic research center for fire safety. Subsequently, in 1990, the SKLFS was laid the foundation stone. Up to now, the SKLFS, currently led by Prof. Naian Liu as the lab director, has developed into an internationally renowned research center for fire safety. During the more than 30-year history of the laboratory's development, Professor Quintiere has always strongly supported the construction of the laboratory and provided a great many valuable suggestions for the laboratory's construction work. He has met with me on several occasions during international academic conferences, discussed the construction plan of the SKLFS, and imparted a great deal of valuable experience in laboratory construction. He has also visited the SKLFS in person on multiple occasions, listened to the development reports of the laboratory, and provided specific guidance on the laboratory's construction work in a targeted manner.

The construction of the SKLFS has promoted the establishment of the discipline of fire science in China. During the construction process, it faced great difficulties such as an almost blank situation in aspects like the research team, experimental facilities, and talent cultivation system. Therefore, there was an urgent need to fully absorb the valuable experience of international fire research institutions. When Professor Quintiere served as the President of the International Association for Fire Safety Science, from a strategic height of promoting fire safety research in China and even the entire Asia-Pacific region, he was generous in sharing his knowledge and expertise for all aspects of the construction work of the SKLFS. His guidance played an important role in enabling the development of the SKLFS to stay on the right track.

From the very onset of the SKLFS's construction, I engaged in extensive and profound exchanges with Professor Quintiere, securing his unwavering support for the laboratory's development. These experiences have since crystallized into cherished memories in my heart.

When the SKLFS was first established, we placed extraordinary emphasis on the advancement and innovation of experimental equipment. During the International Symposium on Fire Safety Science held in Edinburgh in 1991, Prof. Quintiere and I exchanged ideas, where I expressed my vision to explore the universal drivers and principles underlying various types of fires through cutting-edge experimental devices. On this foundation, I hoped to further develop advanced fire prevention and control technologies. I vividly recall Prof. Quintiere’s enthusiastic praise and encouragement for my concept, affirming his belief in the success of our fire laboratory. Subsequently, we had the privilege of inviting distinguished scholars from the international fire community to visit our laboratory. When Prof. Quintiere visited us, he thoroughly inspected the entire facility and graciously penned a commendatory paragraph for our laboratory, expressing his deep appreciation and encouragement. He confidently declared that our laboratory would soon rank among the world's premier fire science research institutions.

In 1994, I embarked on a three-month collaborative research project at the University of Maryland, during which I proposed the ambitious plan to establish a Thermal Safety Engineering Research Center within the SKLFS. I sought Prof. Quintiere’s guidance and invited him to serve as a consultant for the center. After attentively listening to my proposal, Prof. Quintiere responded with great seriousness, "Please elaborate on the precise vision of this engineering center—what specific objectives it aims to achieve and how these goals will be realized. Only then can we determine whether I might contribute some constructive ideas." Subsequently, he shared his profound insights regarding the emphasis I placed on studying the universal mechanisms and principles of fire phenomena. While acknowledging the importance of focusing on common laws, Prof. Quintiere also underscored the necessity of personalized research tailored to the unique needs of individual nations. He argued that by addressing such specific requirements, we could refine and deepen our understanding of the overarching principles.

Left: Prof. James Quintiere and Prof. Weicheng Fan; Right: Prof. Shufen Li, Prof. James Quintiere and Prof. Weicheng Fan

For many years, we have aspired to organize an international scientific conference on fire safety. When I shared this vision with Prof. Quintiere, he proposed that we should also gradually introduce SKLFS to globally renowned experts. Following his suggestion, we leveraged the International Visiting Scholars Program of the Chinese Academy of Sciences to invite a multitude of world-class scholars to visit and engage in exchanges with our laboratory, thereby deepening their understanding of our research endeavors. Ultimately, the 8th International Symposium on Fire Safety Science was triumphantly convened in China in 2005.

Throughout his illustrious career, Prof. Quintiere devoted unwavering attention to the construction of the foundational theories of fire science. His numerous works have become timeless classics in this domain, leaving an indelible mark on the advancement of fire science through their groundbreaking contributions. His legacy will forever be cherished as we continue to uphold and perpetuate his profound academic spirit.

Jim Quintiere and Fire Research at NIST

Anthony Hamins and Thomas Cleary, National Institute of Standards and Technology

We joined the Center for Fire Research (CFR) of the National Bureau of Standards (now NIST) in 1986 and 1987, when Jim was Chief of the Fire Safety Technology Division. CFR was composed of an extraordinary group of scientists and engineers. The last decade had been an exciting time in fire safety science research, and CFR and Jim were at the center of the action with a dynamic fire grants program and lots of visitors who were pioneers in their areas of expertise. He oversaw work on compartment fire modeling, hazard analysis, and fire growth and extinction. Jim thrived among this high-level group, helping to guide their research and at the same time, benefitting from their and insight and perspectives. The group made each other better and their combined output was a significant contribution to the current understanding of fire safety science.

In 2017, Jim wrote a memoriam for Robert Levine, one of Jim's NIST colleagues. Jim wrote that Robert's legacy in fire research "will live on". And so it is with Jim. Jim's legacy in fire research will live on through his technical work, his leadership in the field, and through his students.

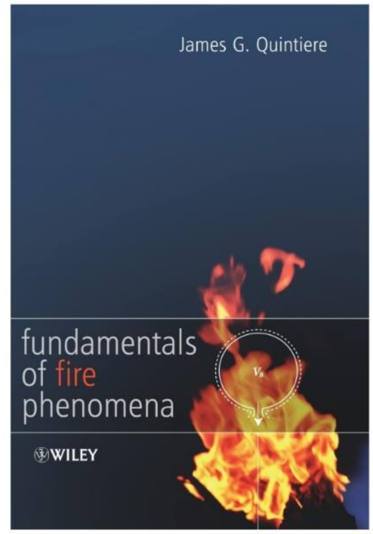
Center for Fire Research, National Bureau of Standards (now NIST); Summer 1986.

	A	B	C	D
1	John Lyons, NIST Director, former Director of the Center for Fire Research; later Director of the U.S. Army Research Laboratory	Alex Robertson, Radiant Panel Flame Test Method, ASTM Templin Award 1957; Ingberg Award 1973; Award of Merit 1981; Dudley Award 1986 NBS Rosa Award 1978	Walter Jones, FAST and CFAST fire models	Vahid Motevalli
2	John Rockett, First Director of Basic Research at FM	Jeff Shibe	Guest researcher	Bill Rinkinen, engineering technician
3	Jim Quintiere, Chief, Fire Safety Technology Division	Barbara Levin, Leader toxicology studies	Billy Lee	Wayne Steiffle
4	Darlene Dorsey, administrative assistant	Bob Levine, PhD under Hottel, Associate Director of Research at Rocketdyne 1959-66, President of the Combustion Institute 1974-78, founding Chief of Fire Science Division, NBS	Bud Levin, psychologist	Josh German
5	Debbie Cramer, administrative assistant	Andy Fowell, Deputy Director, Center for Fire Research	Rick Peacock	Doug Walton, developer of ASET-B fire model, large fire experimentalist
6	Jack Snell, Director, Center for Fire Research	Kate Stewart, administration	Betty Thames, administrative assistant	Dave Stroup, experimentalist and software developer
7	Bernie McCaffrey, co-developer of MQH model	Henry Mitler, developer Harvard First fire model	Bill Parker, 2016 DiNenno Prize	Lynn Forney, evacuation and tenability modeler
8	Harold "Bud" Nelson, SFPE Harold E. Nelson Professional Service Award (Inaugural Awardee), NFPA Standards Medal, 1990	Ed Budnick	Dan Gross	Glenn Forney, developer of CFAST and Smokeview, 2012 Sjölin Award winner
9	Kenneth Steckler	Vytenis Babrauskas, 2024 DiNenno Prize	Bill Pitts, fire dynamics and chemistry	Sandy Davis
10	----	Takashi Kashiwagi, U.S. Department of Commerce, Bronze Medal, 1982; Silver Medal, 1991; Gold Medal, 2000	Jim Raines, computer technician	Len Cooper, developer of (CCFM) Consolidated Compartment Fire Model
11	----	----	Tom Ohlemiller, ASTM Ingberg Award (2002)	----

Fundamentals of Fire Phenomena

J. G. Quintiere, John Wiley & Sons, 2006

Commentary by Professor Ya-Ting Liao, Case Western Reserve University



Prof. Quintiere's Fundamentals of Fire Phenomena provides a comprehensive and structured approach to understanding the science of fire. It is particularly helpful for those who have a background in thermal fluids but are new to fire sciences. The first few chapters comprehensively review the key concepts of heat transfer, fluid dynamics, and gas kinetics. Readers with an engineering degree have been exposed to some of these concepts but these initial chapters help refresh their memory and connect these concepts to fire systems. The book then dives into various fire phenomena, such as premixed flames, diffusion flames, ignition, flame spread, fire plume dynamics, compartment fires, and scale modeling of fires. Quintiere's approach focuses on theoretical derivations. I especially appreciate the explanations of the underlying physics of each fire phenomenon, and the associated mathematical formulations and correlations. These not only help the readers better comprehend the materials but also equip them with the skills to develop new theories or correlations for their own research. Meanwhile, Prof. Quintiere made sure to supplement these detailed mathematical derivations by practical examples. These help the readers appreciate the relevance of the textbook content to real-world fire scenarios. The book also includes well-designed problem sets at the end of each chapter for readers to practice and test their learning, which I found extremely helpful. All of these components make this book a valuable resource for students, researchers, and practitioners in fire science research and fire protection engineering.

I have been using this book as a textbook in my graduate-level course, Fire Dynamics. This course was the very first course I taught when I became a faculty member in the department of Mechanical and Aerospace Engineering at Case Western Reserve University in 2015. As nervous as I was as a first-time course instructor, the structure of the book content made the teaching natural and easy to prepare. Also, with the privilege to have known and interacted with Prof. Quintiere in various conferences, I felt like he was in the classroom with me sharing his passion and expertise with the class. I especially enjoyed impressing students with my encounters with him.

Prof. Quintiere has made a tremendous impact on fire science and engineering, in many ways. I believe this textbook is one of those ways, which has impacted my own career and the careers of countless students at institutions around the world. Through this textbook, he will continue inspire students for years, continuing his legacy into the future.

Dr. Quintiere at the 2018 International Symposium on Combustion at Dublin, Ireland. From left to right, Prof. Naian Liu from State Key Laboratory of Fire Science, Prof. James Quintiere, and Prof. Ya-Ting Liao from Case Western Reserve University.

Commentary by Professor Michael Gollner, University of California, Berkeley (Formerly University of Maryland)

Jim Quintiere or "JQ", as he was affectionally known by students had a profound impact on my career. It was his former MS student, Jonathan Perricone (then at Schirmer Engineering) who convinced an aerospace-focused mechanical engineer to try an internship in Fire Protection Engineering. Later, I connected with Ali Rangwala, another of his former MS students and professor at WPI, who became a long time mentor from my MS, PhD, and beyond. While my advisor, Forman Williams had the greatest depth of knowledge in combustion, I was somewhat lost when I began an MS and later PhD in fire. I did have some good books and papers, but it wasn't until my advisor handed me Quintiere's manuscript for his book Fundamentals of Fire Phenomena, that I could finally start to synthesize and understand the intricacies of fire *science.*

Fundamentals of Fire Phenomena is, in my opinion, the definitive reference guide for anyone hoping to further understand the science of fire. It is constantly on my desk, chapters used in my classes, and guiding my research and teaching of many subjects. What I love about this book is how it seeks to explain fire both phenomenologically and mathematically. Jim's rigor in mathematics comes out in the elegant way equations are derived using the simplest and most straightforward means possible. Combined with his thorough explanations and examples it becomes clear to readers not only where the relationships that underly fire science originate, but how they physically govern the phenomenon of fire.

While I had read many other books and manuscripts before *Fundamentals of Fire Phenomena*, this book has shaped my thinking, teaching, and research about fire. When I teach ignition, I instinctively start with his explanations of chemical, mixing and pyrolysis times, and proceed to delve into the depths of thermally thin and thick theory. He had a way to synthesize a vastness of knowledge in the field into something an undergraduate could understand and follow while at the same time an experienced researcher could continue to reference for decades. I am well aware he could have made this text exceedingly more complex. I taught the graduate course he created, Diffusion Flame Analyses at the University of Maryland for several years, which was largely based on his original notes he shared with me. He could go into incredible depth, deriving each paper in explicit detail that was fun to shepherd graduate students through, but doing so helped highlight just how clearly he could synthesize these complex derivations into simpler explanations in his textbook.

I first met Jim at the 2011 IAFSS conference in Maryland, an organization he helped found and that I later served on the board of for many years. He was wearing a Hawaiian shirt sitting next to an accordion and as a young graduate student it took me quite a while to figure out who he was! I only really got to know him once I joined the faculty of the University of Maryland. We were blessed to have such a knowledgeable and fun colleague around. I could come with a question about any subject, and he always had some insight or additional direction as well as copious references. An afternoon meeting with a graduate student might be punctuated by an accordion performance, and we might find the printer paper was missing because someone was printing horse racing statistics… but we were truly privileged for the time we had with Jim's insights, knowledge, humor, and advice.

His passion for fire was unmatched. I always enjoyed his stories and excitement, especially about the next problem he was tackling or seeking to understand. He was relentless in his investigation on the World Trade Center for years afterwards, pushing for further understand and trying to understand each detail of the event. The same was for a plane disappearance and the potential role of lithium-ion batteries. He was constantly working on batteries since the incident with the FAA and was proud of the progress he made characterizing their hazards. He'd often dig up old reports and videos (some from WWII) he would share with me related to whatever I was working on. We had a wonderful experience once in Missoula, Montana staying in a cabin on a lake and talking nothing but fire science with many other "legendary" fire science figures. However, I most respected his integrity. He would relentlessly pursue the truth and would stand by what he thought was right regardless of the consequences.

Jim was passionate, inquisitive, and had the greatest depth of knowledge of fire I've ever come across. He could delve into fundamental equations, derive theories, then talk through experiments with fire investigators with no mathematical knowledge at all and yet still explain fire at depths others could not. It is no mystery that he was revered not only by the fire science community but also fire investigators and practitioners. He never let anyone less mathematically inclined feel inferior, but sought to explain and help them understand at their level. It didn't matter what fire phenomena was occurring, in a building, a wildfire, or in space, Jim could see through the problem and get at important insights at what seemed like the snap of a finger. He just understood how thermal fluid physics interacted so deeply alongside so many years of experience it seemed as if complicated problems became clear to him. He was also interested in many problems beyond fire, and we had many enjoyable and deep discussions together with my wife, Agnieszka and other colleagues on astrophysics, astronomy and beyond.

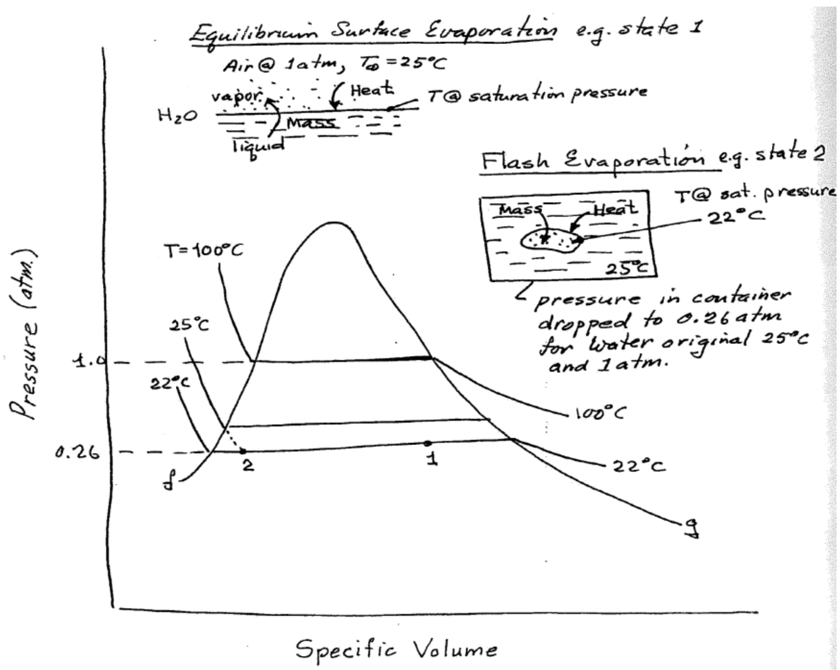
It was a privilege to know and work with Jim. Without his influence on the fire research community, I would not have been where I am today, and probably never found "fire" as a direction for my career. I regret not asking more questions and spending more time but am thankful for all I was able to learn and the many enjoyable times we were able to share. JQ has left a profound impact on so many, and he will be sorely missed.

Quintiere barging into Professor Gollner's office with an accordion during a meeting with Pietro Maisto (graduate student) and Professor Andre Marshal

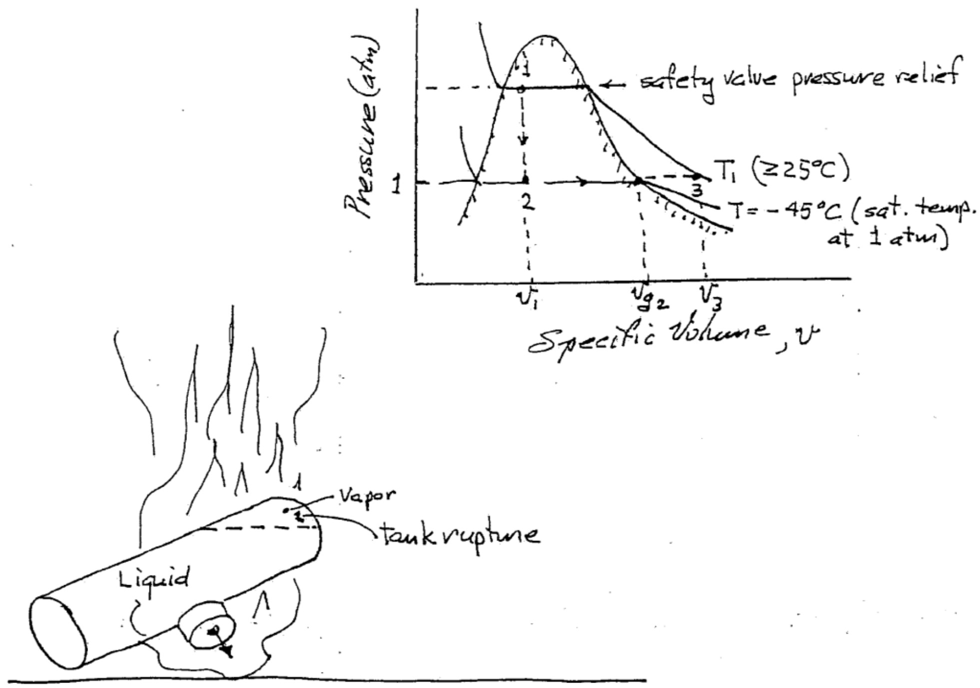
Commentary by Dr. Sara McAllister, Rocky Mountain Research Center

My first exposure to this book was in the fall of 2004. Yes, the book wasn't published until 2006. I was a graduate student in Prof. Carlos Fernandez-Pello's Combustion Processes class at U.C. Berkeley, and we were using part of the draft as course material. I was one of those "students who suffered through early incomplete versions," as noted by Jim in his preface to the book. But "suffer" wasn't the right word. It was already immensely helpful. Though it is a fire book, we were using it in a combustion class. The class was both an upper division undergraduate elective and graduate level course, and at the time, there really was no appropriate textbook that covered the material at the right level of detail. Jim brought his rigorous analytical background which aligned well with much of the combustion course material, but the book also provides approachable, somewhat simplified analyses that are well suited to coursework at that level, whether fire or combustion. We were given chapters 3-7 which cover basic, fundamental material for both fields. Much of the text was complete, but many of the figures were still hand drawn, works in progress, such as Figures 6.6 and 6.7 below.

Nowadays, the published version has a permanent place on my desk. In addition to many scrap pieces of paper stuffed in as bookmarks, there are permanent breaks in the binding at Chapter 7 – Ignition of Solids, Chapter 8 – Fire Spread on Surfaces and Through Solid Media, and Chapter 10 – Fire Plumes. I refer to those chapters constantly for information and reminders of explanations for many fire behavior phenomena. When writing papers on ignition, I always use "Section 7.2 – Estimate of ignition time components" in my list of references. The way he approaches ignition, breaking the process into three components (heating to the pyrolysis temperature, mixing of fuel vapors with air, chemical induction/combustion time) is a concept that I repeatedly refer to. I really appreciate that he presents rough estimates for the time of each process to drive home the point that ignition can be reasonably well predicted by the heating time alone. In fact, it's an explanation that I love so much that I may have stolen it when writing my own chapter on condensed phase ignition...



Equilibrium and flash evaporation processes illustrated for water



BLEVE Illustration

Commentary by Giayan Su and Ali Rangwala

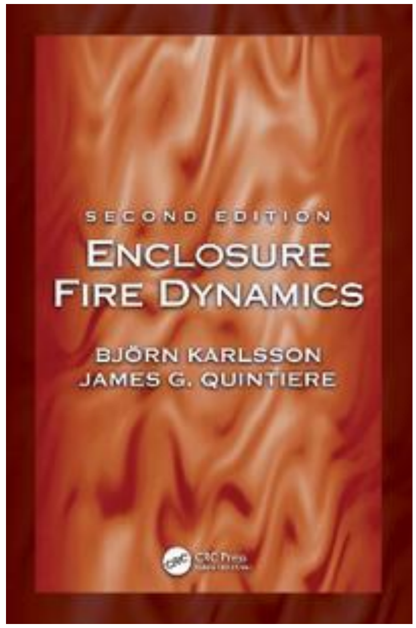
We graduated from UMD in '02 with Dr. Q as our thesis advisor. Su worked on the topic of scale modeling for water mist fire suppression and Rangwala worked on compartment fires. It was the time when Dr. Q was working on his seminal book, Fundamentals of Fire Phenomena. He had tasked the two of us to create the solutions for the book's exercise problems, a challenging but rewarding experience. We split the problems, with Su working on the solutions with even numbers and Rangwala working on solutions that were odd numbered.

Those were different times—a world without cell phones in class, YouTube, or Gmail. We still took notes by hand (this is why the solution manual is handwritten). The UMD Fire Protection Engineering program was alive with brilliant minds—Quintiere, Milke, Mowrer, Torero, Brannigan, and Spivak. Fire Dynamic Simulator (FDS) was being taught for the first time by Mowrer and McGrattan in the FPE computer labs.

Dr. Q's ability to systematize fire science, define its principles, and develop practical experimental solutions, has left an indelible mark, shaping generations of professionals and educators. Dr. Q was truly a legend, and his contributions will inspire us for years to come.

Enclosure Fire Dynamics

Björn Karlsson and James G. Quintiere



Cover of the 2nd edition of "Enclosure Fire Dynamics".

Commentary by Professor Nils Johansson, Lund University, Sweden and Professor Björn Karlsson, University of Iceland, Iceland

In 1986, Lund University in Sweden welcomed its first cohort of students into the newly established Fire Protection Engineering program. This initiative stemmed from a long-standing ambition to enhance the application of engineering principles within the Swedish Fire Service. Recognizing the need for a more scientific and systematic approach to fire safety, authorities and academic leaders sought to bridge the gap between traditional firefighting methods and modern engineering solutions. The introduction of this university-level education was designed not only to equip students with advanced theoretical and technical knowledge but also to complement their learning with hands-on fire service training at the Fire Service Academy.

In the late 1980s, efforts began to develop a model curriculum for fire safety engineering, laying the foundation for a more structured and internationally recognized discipline. Led by Professor Sven-Erik Magnusson of Lund University, the initiative brought together a team of esteemed academics, including Professor James Quintiere, along with several other distinguished professors. Their collaborative work culminated in the publication of the curriculum in Fire Safety Journal in 1995. This milestone not only helped define fire safety engineering as a distinct field but also clarified its role within the broader engineering landscape, distinguishing it from other engineering disciplines and establishing a framework for future education in the field.

It soon became clear that dedicated course material was needed for the study of enclosure fires. During the 1990s at Lund University, the material for the Fire Dynamics course was initially assembled from various sources, consisting of a collection of research papers and technical reports, like an early report by Prof. Magnusson on Smoke Movement in buildings from 1983. This reliance on diverse materials highlighted the need for a more structured and comprehensive educational resource to support the growing field of fire safety engineering.

A decision was made to invest greater effort into developing a dedicated course book on enclosure fire dynamics, aimed at students who had already acquired fundamental knowledge in heat transfer and fire chemistry. Leading this initiative was Dr. Björn Karlsson, a recently graduated PhD. The strong professional ties between Professor Sven-Erik Magnusson and Professor James Quintiere resulted in a productive collaboration. Dr. Karlsson was invited as a Visiting Professor to the University of Maryland in 1996, where he and Professor Quintiere produced a first manuscript of a textbook for students, ultimately shaping the development of what would become a key educational resource in the field, the book Enclosure Fire Dynamics, authored by Karlsson and Quintiere.

Throughout the 2000s and 2010s, the book served as a cornerstone of Fire Dynamics education, playing a vital role in both the Swedish fire protection engineering program, which welcomed cohorts of 50 students, and the International Master's Program in Fire Safety Engineering (IMFSE), with cohorts of 25 students.

The book Enclosure Fire Dynamics has been instrumental in advancing fire dynamics education, serving as a foundation for course development and making science-based fire safety engineering more accessible to students worldwide. Its well-structured layout, logical progression, and worked examples have made it an invaluable resource for both teaching and learning. Much of this achievement is due to the invaluable contributions and insights of Professor James Quintiere, whose expertise has played a crucial role in shaping the field.

In recent years, a second edition of the book has been published to reflect new advancements in the field. Professor James Quintiere provided valuable insights during the revision process, which was edited by Dr. Nils Johansson, ensuring the book remains relevant for the next generation of fire safety engineers.

Professor James G. Quintiere had an outstanding record as a scientist, a teacher and an engineer. With his great talent to develop practical engineering applications from fundamental concepts and creative experimental work, he has been instrumental in the development of educational material for students, producing the foundation for curricula and teaching material in the field of Fire Protection Engineering worldwide.

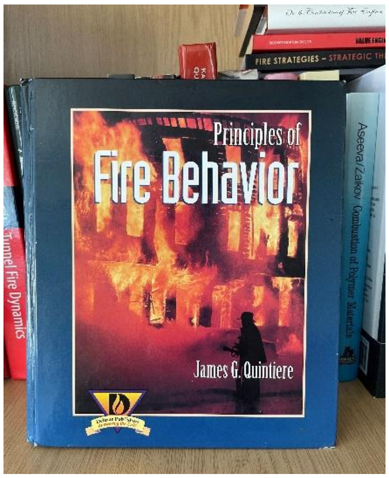
The staff at Lund University will remember the generosity, kindness, and the invaluable contribution of the legendary Professor James G. Quintiere when creating and developing our educational programs in Fire Engineering.

Principles of Fire Behavior

J. G. Quintiere

1st edition: Delmar Publishers, 1998

2nd edition: CRC Press, 2017



Commentary by Professor Guillermo Rein, Imperial College, UK

Among the few books that created fire science, *Principles of Fire Behavior* by Prof. James G. Quintiere (1940-2024) holds a special place. I have long admired this text, especially the first edition of 1997, which remains, in my view, the finest introduction to fire science for a general audience. It is the book I most often recommend and have frequently given as a gift to students and non-fire colleagues beginning their journey into the field. Fire science needs a big gate, one that invites, guides, and encourages others to enter. *Principles* is that gate.

Prof. Quintiere was a trailblazing figure in fire science and engineering, with a career spanning over five decades since his PhD in 1970. He authored hundreds of publications and several landmark textbooks. He is known for shaping the fire engineering community through both scholarship and teaching.

This textbook captures that spirit. It reflects not just his knowledge, but also his engagement with students over many years and diverse technical backgrounds. The clarity of explanations, the carefully crafted diagrams made by himself, and the deliberate choice of steps and topics reveal a teacher who had taught these concepts numerous times, listened to questions, and refined his answers. It is clear that he learned a great deal from his students, and this book is, in part, a product of those classroom discussions.

The book introduces key topics such as heat transfer, ignition, flames, fire spread, plumes, and forensics with a quantitative standpoint typical of engineering but without overwhelming the reader with details. It is rigorous, but accessible, brief yet complete. It bridges theory and real-world applications like few others, and this is what makes it so enduring and valid across disciplines.

Although a second and larger edition was published years later, the original has a special character for me. The clarity, tone, and balance of the first edition are exceptional. The essence was captured in that first version that remains unique.

Quintiere's *Principles of Fire Behavior* is not just a textbook, it is a reflection of a life devoted to understanding and teaching fire. Like Jim himself, it is both rigorous and welcoming. It continues to guide and inspire, and I believe it will for many years to come.

Commentary by Dr. Sara McAllister, Rocky Mountain Research Center

This book (in both editions) has probably got to be the only textbook(s) that I have read cover-to-cover since I was a student. Both editions are easy to read and make the material very approachable, as the intended audience includes firefighters, fire investigators, and other non-engineers looking to understand fire. The second edition fills in a fair amount of material and examples that was omitted in the first round. This book is really a testament to Jim's ability to communicate with people at all levels of technical background. It was truly an inspiration and a model for how we wanted to approach writing our Wildland Fire Behavior book. I especially love how the book discusses complex engineering problems without differential equations (if you want those, read his Fundamentals of Fire Behavior book!) but using simple approximations using basic algebraic equations to appreciate the scales of values one could expect. The examples are perfect for seeing how the science is applied to real scenarios.

Commentary by Professor Milosh Puchovsky, Worcester Polytechnic Institute

Principles of Fire Behavior serves as a foundational text for fire protection professionals striving to gain a better understanding of fire phenomena and its effects. The text is especially appropriate for students studying fire protection engineering at the collegiate level. The text facilitates the student's learning process offering a very useful balance between theoretical concepts and practical applications.

The book effectively covers fundamental principles such as heat transfer, combustion chemistry, flame propagation, and fire suppression mechanisms. It enables students to gain a solid scientific basis for understanding how fires develop, spread, and are controlled.

Quintiere presents complex topics in a clear and structured manner, making them accessible to students with varying levels of prior knowledge in math, physics, chemistry and engineering science. The logical progression of topics provides a strong conceptual framework to better understand fire ignition, growth and spread.

Principles of Fire Behavior is an engineering text incorporating mathematical models and equations to explain fire dynamics. This is particularly useful for students in fire protection engineering and other technical disciplines that require a quantitative understanding of fire behavior.

The text includes numerous real-world examples, case studies, and historical fire incidents, which help bridge the gap between theory and practice. These examples enhance students' ability to apply fire behavior principles to actual real-life building conditions and scenarios.

Overall, *Principles of Fire Behavior* is a highly effective college textbook for students studying fire science, fire engineering, and fire protection. Its rigorous approach makes it an excellent resource for understanding fire dynamics at a deep level, building upon a student's technical background. It is an essential resource for those seeking a scientific and analytical approach to applying fire behavior principles in the field.

Commentary by Brian S. Grove, ATF

As a fire protection engineer with the Bureau of Alcohol, Tobacco, Firearms and Explosives my job is to provide scientific support to ATF Certified Fire Investigators throughout the US and its territories. I have been doing so for the last 25 years. During this time, I have worked at numerous fire scenes and interacted with hundreds of state and local fire investigators as well. I also observed a change not only in investigator's attitudes towards their personal safety but also their willingness to adopt scientific principles to their investigations.

In 1997 I was a grad student at UMD working with Prof. Quinitiere. At that time, he was hosting a class on fire dynamics and science for ATF CFI's. (Several of Jim's students were asked to assist with the class.) Prior to the class he and Bud Nelson had ingratiated themselves with ATF through their work at the Dupont Plaza hotel fire investigation. ATF recognized the value that these two scientists brought to the investigation and was eager to have their fire investigators learn from them. My first interactions with ATF CFI's was eye-opening to say the least. I had spent four years on an engineering campus and the majority of these investigators had little or no post-secondary science education. When Dr. Quinitiere began presenting the class with some basic equations, one of the students blurted out, "How do you expect me to learn this stuff; the biggest word I know is mayonnaise!" This was a rowdy group and Jim fit right in. He was quickly able to pivot and make complex scientific principles accessible to the students in the class. The class handout included a three ring binder filled with his notes and writings. Students were asked to proofread and provide feedback on their understanding of the content. A year later these class notes were released as the first edition of the book "Principles of Fire Behavior".

The book(s) "Principles of Fire Behavior" by Dr. James Quintiere has had a profound and lasting impact on fire investigations by providing a clear, accessible, scientifically grounded understanding of fire dynamics. This foundational understanding has allowed investigators to approach fire scenes with comprehension of the processes that create the observational indicators they rely upon, thus enabling them to more accurately determine the origin, cause, and progression of fires and defend their hypotheses in court.

Photo credit: Kristopher Overholt

Jim Quintiere's scale modeling investigation of the collapse of World Trade Center

Professor Kozo Saito, University of Kentucky and Professor Forman Williams, University of California, San Diego.

Jim Quintiere was a strong supporter for and believer of scale modeling fire phenomena. He wrote a summary of the first international symposium on scale modeling, ISSM, which was held in Tokyo Japan 1988 and his summary was published in Progress in Scale Modeling [1]. He and his students at University of Maryland designed a reduced partial scale model of the WTC building floor into which a jetliner crashed. While attending the first ISSM, Jim learned of Dick Emori's work on the reconstruct of the accidental crash of an automobile into a road signpost, in which Emori used a dummy-weight technique to satisfy the surface/volume scaling requirement, which became a hallmark of scaling laws in impact-caused structural damages. Quintiere wisely applied this technique to reconstruct the collapse of the World Trade Center buildings resulting from the jet-liner crashes. Jim knew that the numerical simulation made by a different team of investigators [2] needed to be tested against experiments. Since full-scale experiments were out of the question because of both the expense and the risk, as well as the timeliness, Jim saw reduced-scale-model experiments as the only viable technique. The following is an excerpt from his symposium summary.

"The use and value of the wind tunnel in the design and development of aircraft is well known among the general public. Even the Wright brothers had to rely on a wind tunnel in their bicycle shop to adequately design the power needed for the lift and drag of their aircraft. Today it is still a hallmark of sound aircraft design, with computations augmenting it. In other fields it is much less recognized. What does it have to offer, even in an incomplete rendition? Firstly, a sound model can reveal the overall nature of a complex system phenomena and its interaction of effects. Secondly, the ability to measure and display the results are relatively easy. Thirdly, the cost of the approach in time and money can be less than computer simulations and field tests. Fourth, the phenomena, even if slightly off-scale, behave as the physical laws intended them, and no ad hoc or complex modeling algorithms are necessary. Finally, the results of a physical scaled system can provide a range of data that should be essential for serving as the means for validating any computer simulation.

An interesting aside from the substance of the meeting is the World Trade Center 9/11 event. It was suggested to the investigators that a scale modeling approach be taken for all the reasons just given. Scale modeling could have addressed the aircraft collision, the fire growth, and the effects of the fire on the structure and its subsequent collapse. Instead, the official government investigators took a nearly exclusive computational approach [3], with their costs at nearly $20 million. A scale model of the fire behavior on the 96th floor of WTC 1 was accomplished by a junior class project at the University of Maryland [4] for about $2000."

Jim Quintiere's team succeeded in obtaining temporal temperature profiles from the scale model experiments and carefully compared them to NIST's corresponding numerical simulation results, which were available at that time. Jim's team found the difference between the two approaches (numerical simulation and scale modeling) was primarily due to different fuel loadings assigned to the respective analyses by working from the same office furnishing data. He concluded that "this issue was still unresolved. Its lack of resolution displayed the need for deeper scrutiny of such investigations. Unfortunately, scale modeling did not play a role in the WTC investigation because of the lack of generally accepted scaling laws that applied to fire propagation, temperature evolution, and structural response." As Jim correctly pointed out in the above, the last statement shows the lack of a real understanding in the role of scale modeling, since scale modeling not only can validate numerical model predictions but also can enhance our understanding of the root cause mechanism that contributed to the collapse of TWC. Scale modeling played a significant role in the recent investigations of two large-scale disasters, a jet liner crash into Mt. Fuji and the Great-Kanto-Earthquake-caused-catastrophic fire whirl casualty [5].

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A suggested cause of the fire-induced collapse of the World Trade Towers

J. G. Quintiere, M. di Marzo, R. Becker, *Fire Safety Journal,* Vol. 37 707-716 (2002)

Abstract

An analysis is presented that calculates the temperature of the steel truss rods in the World Trade Center towers subject to a fire based on the building ventilation factor. The CIB correlation is used for the fire. Conduction analyses are made taking into account variable properties for the steel and the insulation. A structural failure model is described based on compression buckling of the truss rods due to a reduction in the Young's modulus. The computed times for the estimated failure or incipient collapse of the floors in both towers has been computed as 105±20 min for WTC 1 (north) and 51±9 min for WTC 2 (south), compared to the collapse times from the aircraft impact of 104 and 56 min, respectively. The insulation thickness and the difference of 19.1 mm (34") and 38.1 mm (112") between the two towers appear to have been the root cause of the collapses.

Commentary by Professor Marino di Marzo

JQ approached me for the numerical computational portion of this paper. His idea was to use the standard ventilation limited theory to formulate the fire input and the structural analysis of the pristine building structure to predict the failure time from a numerical computation of the transient heating of the metal structure. This paper provided a simple analysis and the associated time of failure that were surprisingly close to the actual collapse times for the two towers. The key element that controlled such results was the thickness of insulation applied to the metallic structures in the floor assembly.

The paper came under strong critique from the fire community for two reasons: 1) the building was clearly not pristine, and 2) the fire was not necessarily limited only by ventilation. Investigators argued that the level of insulation after the plane impact was not known and the actual fuel load in the floors of concern was also not know. Therefore, they argued, that the initial and boundary conditions of our simulation were not clearly established hoping to effectively decouple the thickness of the applied insulation from the time of collapse (which the paper had clearly demonstrated).

The terrorist plan with the planes severing both the fire protection systems as well as the evacuation paths resulted in the loss of thousands of lives. It became quite clear to everybody that one hour or one hour and forty minutes would have been, in those extreme circumstances, inadequate to clear the buildings. Nonetheless, in his classic style, JQ had found a fertile ground for discussions and heated arguments. He recounted many such discussions and arguments over the course of many years thereafter. It was an endless endeavor, due to the lack of conclusive data, which he pursued with unsurmountable dedication.

Predicting the burning of wood using an integral model

M.J. Spearpoint, J.G. Quintiere, *Combustion and Flame*, 123 (3): 308-325, 2000

Abstract

This paper experimentally and theoretically examines the horizontal burning of four species of wood exposed to incident heat fluxes of 25–75 kW/m^2 with their grain oriented either parallel or perpendicular to the incident heat flux. Mass loss, temperatures, and char fractions were measured. A one-dimensional integral model that describes the transient pyrolysis of a semi-infinite charring solid subject to a constant radiant heat flux was developed. The solutions to the integral model for the burning rate were compared with data using analytical short-time and long-time solutions. Reasonable comparative results are shown for mass loss rate, surface temperature, char depth, and effective thermal penetration.

Predicting the piloted ignition of wood in the cone calorimeter using an integral model — effect of species, grain orientation and heat flux

M.J. Spearpoint, J.G Quintiere, *Fire Safety Journal*, 36(4): 391-415, 2001

Abstract

This paper experimentally and theoretically examines the ignition of 50 mm thick samples of wood in the cone calorimeter. Four species of wood were exposed to a range of incident heat fluxes up to 75 kW/m^2 with their grain oriented either parallel or perpendicular to the incident heat flux. The time to ignition measurements obtained from the cone calorimeter were used to derive characteristic properties of the materials. These properties were used as input to a one-dimensional integral model that describes the transient pyrolysis of a semi-infinite charring solid subject to a constant radiant heat flux. The integral model predictions and experimental data compare well at incident heat fluxes above around 20 kW/m^2. At lower heat fluxes it was found that the ignition mechanism of wood is different from that at higher incident fluxes. This difference is believed to be due to char oxidation that precedes flaming ignition. The lowest radiant heat flux to cause ignition within 1½ h was found to be approximately 10 kW/m^2 depending on species, grain orientation or moisture content.

Commentary by Dr. Michael Spearpoint

While I was a Masters student UMD I had the job of looking after one of the laboratory areas in the Potomac Building in which the cone calorimeter was then located. It was in this laboratory that Dr Quintiere would run his ENFP620 class. It so happened that another student (Robert Schroeder) was doing a PhD through the University of California, Berkeley related to the post fire analysis of construction materials when exposed to long thermal exposures [1]. Robert wanted to use the cone calorimeter to carry out some controlled experiments, but as a remote student he was not able to do them himself. As I recall it, probably through a discussion with Dr Fred Mowrer, Robert agreed to hire a UMD graduate student to help do some of these experiments, and that graduate student was me. His samples included four different species of wood, different mixes of concrete, and pieces of gypsum wallboard.

Around about this time I was taking Dr Quintiere's Fire Dynamics course (ENFP 415) and during one of the lectures Dr Quintiere was discussing the development of his one-dimensional ignition and burning rate model. It was fascinating to see how Dr Quintiere was able to work through equations on the fly, although I suspect some students did not appreciate this while trying to take notes. Again, as I recall it, he mentioned the work that his previous student Don Hopkins had done using thermoplastics [2] and then Dr Quintiere probably said something about how it would be interesting to apply the model to a charring material. I realized there was a great opportunity here – I was already igniting and charring many samples of wood under the cone calorimeter. Robert was happy I use his samples for my thesis since our research goals were complementary but not overlapping, allowing us to share experimental data.

Doing the experiments took many, many hours. Robert wanted his samples exposed for up to something like 75 min at a time. The cone calorimeter was very temperamental, and it took me quite a while to realize that some of the electrical connections in the control panel had come loose and that is why I sometimes got really noisy output - a bit of re-soldering finally cured this. I recall that while I was doing the experiments Scott Dillon was preparing his thermocouples for his research [3] so I would lend a hand. It was also during the experiments I occasionally saw the wood samples re-ignite after long periods of glowing. Characterizing this ignition process was not part of my research, but I think it later inspired Dr Quintiere to have Nathasak Boonmee do his subsequent research [4].

For me it was fascinating to work with Dr Quintiere on the analysis. It was here I really began to appreciate the art of doing fire science. For example, Dr Quintiere explained to me where equations might be simplified because it was reasonable to assume what is likely to negligible. Part of the time I did my thesis Dr Quintiere happened to be on sabbatical at the FAA (but it also seems he was at Berkeley and spent a month in Denmark). I would send him pages of equations and notes via fax, as doing this by email could be a bit trickier back then, and he would scribble his thoughts and suggestions. I would get Dr Quintiere's response and see where I could make improvements. These exchanges were invaluable, and I still have all his annotated notes in a large ring binder.

I do not recall whether it was Dr Quintiere or I who suggested publishing the two resulting papers. I had already been involved in fire research topics over the previous 10 years or so due to my time at what was then known as Fire Research Station in the UK. I was already familiar with Fire Safety Journal, having published a paper or two previously. I was probably not as aware of Combustion and Flame at the time. Of the two, Combustion and Flame is generally more competitive for fire science papers due to its prominence within the broader combustion research community.

These two papers remain two of my most cited papers, and I do not think I will ever be able to write something again that will appear in Combustion and Flame. The presence of these papers in the literature is a testament to Dr Quintiere's mentorship—from his teaching in the Fire Dynamics course to his guidance during my thesis and his support in the publication process.

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Photograph of the Cone Calorimeter in the Fire Protection Engineering Laboratory, UMD (L) and ignited sample.

ENFP 620 – theory and practice

1989 Canadian mass fire experiment

J.G Quintiere, *Journal of Fire Protection Engineering* 5(2), pp. 67-78 (1993). Also in SFPE Engineering Seminars, 16-18 November 1992, Dallas, TX

Commentary by Professor Albert Simeoni, Worcester Polytechnic Institute

This paper presents an experimental burn of forest debris to simulate a mass fire, which was conducted in Ontario Canada in 1989. Jim and NIST were involved to help better understand mass urban fires. The experiment represents one of the seminal large-scale experiments for outdoor fires, along with the Sandia experiments for pool fires [1] and the International Crown Fire Modeling Experiments for wildland fires [2]. The research was at the confluence of several needs: the study of mass urban fires by NIST, the study of post-bombing firestorms by the US Defense Nuclear Agency (DNA), and the study of large wildfires by the Ontario Ministry of Natural Resources, Forestry Canada and the US Forest Service. A few US companies and universities also participated in the effort. The experiment focused on fire spread, energy released, and emissions.

The introduction starts with putting this work in its historical context and it, of course, mentions old major urban conflagrations and wildfires but it is worth noticing that it also mentions events contemporary to the work that have significantly influenced the development of modern fire science since the 1990's. Indeed, the great Yellowstone fire of 1988 brought new momentum to wildland fire research in the United States but also in Europe, while the Great Black Dragon Fire of 1987 in China led to the creation of the first National Laboratory dedicated to fire in China, the State Key Laboratory of Fire Science.

Approximately 480 hectares (1,200 acres) of forest debris were burned with several ignitions to create a mass fire, defined as a flame region of more than 100 meters (330 feet) in diameter. The experiment happened in the summer, in August. Ambient conditions were recorded, and the fire and its plume were captured with ground measurements (of fuel consumption, local wind, fire-induced wind and temperatures, as well as emitted gases and particles) and airborne measurements from a plane of the University of Washington (capturing a large panel of gaseous and particulate emissions at different plume heights).

The fire was lit expertly by helicopter to induce a mass fire, and it developed rapidly, creating a massive and fast-rising cumulus cloud that produced a thunderstorm with rain, hail and even snow. Measurements of fuel consumption and carbon production led to the estimation of a peak of energy of the fire around 40,000 MW (a burning couch peak release is around 2 MW). The induced ground winds peaked around 12 m/s (26 mph), the flame spread peaked around 1 m/s (2.2 mph) – a very high value for spreading fires – and flame heights peaked around 12 meters (40 feet). Interestingly, even for a fire as large as this one, oxygen measurements showed that oxygen availability was not a limiting factor. An analysis of the emissions showed a high level of smoldering combustion, which had to be expected for burning forest debris. Additionally, measurements in the plume showed a large amount of organic carbon, which is different from the soot produced by flames and is characteristic of burning biomass emissions. Higher in the plume, it was found that a large amount of smoke particles (between 30% and 90%) was removed by precipitations, which was important information for furthering the understanding of nuclear winter scenarios. Also, the smoke particles were found to raise lower than the condensation cloud, important information for smoke deposition in the atmosphere.

Several aspects make this pioneering work important for the science of outdoor fires. First, the magnitude of the effort allowed the team to capture effects that were observed and even sometimes measured through plumes but in a disparate way and never put together. Linking fire, plume, and emission dynamics together is still a major challenge faced by researchers today and this effort led the way. Then, this work innovated in providing an assessment of the fire dynamics by NIST, based on fire science, to support wildland fire behavior and fire emission research. This was a new approach at the time, which has become mainstream only recently. And finally, the ground measurements and the plume development analysis inspired a wealth of other studies for outdoor fires, and they clearly bear the mark of the rigorous scientific approach of fire problems that Jim has developed along is whole career.

Personally, I can add that the measurements of fire dynamics, fuel consumption, environmental conditions and plume development are very relevant to the wildland fire research that my group is conducting in the field. Indeed, the methods that we use and have developed are successors of what was done during the Canadian Mass Fire Experiment of 1989. This is true for us, but it is also true for the whole wildland fire behavior community, making this effort a seminal work in conducting large outdoor fire spread experiments.

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Commentary by Dr. Sara McAllister, Rocky Mountain Research Center

While mostly focused on fires inside the built environment, Prof. Quintiere's work spanned a large range (and scales) of topics, including the occasional foray into wildland fires. Because of his expertise in all things fire, our research group invited him out to Missoula for a retreat back in 2014, along with several others of the "greats" in fire and combustion engineering (Forman Williams, John de Ris, Kozo Saito – see Figure 1). Among other things discussed late into the night over beverages, we wanted to tap into his insight into how to approach a large-scale problem in more tractable ways.

This paper on mass fires presents an example of such a large-scale problem that incidentally effects both the built environment and the wildland. A mass fire is one in which large areas are on fire all at once and can typically be characterized as having flame heights much smaller than the diameter of the burning region. These fires are also sometimes called blowup fires, firestorms, conflagrations, etc. I first came across this paper when we were writing a literature review on mass fires. Mass fires were originally studied in the aftermath of WWII as they were purposefully generated to inflict large-scale destruction of cities and was also of upmost concern in the Cold War era due to the likelihood of such fires after nuclear detonation. This fire behavior is also possible in wildland fires in extreme conditions, on particularly hot, dry, and windy days after prolonged droughts. These conditions create massive spotting events that ignite large areas at once. Additionally, instead of large diameter woody debris, duff, and organic soil smoldering with little heat release rate like in normal fires, they burn in flaming mode for long periods of time, producing long-duration high heat release rates so that the fires begin interacting with the atmosphere, generating their own weather, as observed in the experiments reported here: "The fire caused a capping cloud to form and reach 6.5 km. Rain, snow, hail and lightning were reported along with ground level fire whirls and water spouts on adjoining lakes." This mass fire behavior is not currently predicted by any fire behavior model, as all fire models only consider a line of fire moving across a landscape. Wildland fire models also typically assume that these long-duration fuels are not "available" and are not counted in fuel load estimates, and the complex two-way coupling between the fire behavior and the larger atmospheric conditions are not well understood. These experiments reported in this paper are the last effort to my knowledge to experimentally study this behavior, and the first to incorporate LIDAR and FLIR imaging. Experiments such as these are critical to our understanding. As pointed out in the text "Significant large scale phenomena have been identified that could not necessarily been identified by models or with laboratory studies alone." Unfortunately, such experiments are also extremely difficult to conduct. There are logistics issues, like coordinating the huge amount of instrumentation needed, as well as technical issues, such as figuring out how to measure fuel consumption and heat release rate in the field. Not to mention convincing someone to light 1200 acres (480 ha) on fire all at once in the middle of August! One thing that I really appreciate about Jim was that, despite being a total wizard with analytical approaches to solving problems, he understood the need to ground our understanding in experimental research and not let our modeling efforts get ahead of ourselves.

From left to right: Jason Forthofer, Michael Gollner, Mrs. and Mr. John de Ris, Forman Williams, Kozo Saito, Jim Quintiere, Jack Cohen (kneeling), and Sara McAllister standing next to large pine tree in Seeley Lake, Montana, September 2014.

Glowing and flaming autoignition of wood

N. Boonmee and J.G. Quintiere, *Proceedings of the Combustion Institute*, Volume 29, 289–296 (2002).

Abstract

A study of the autoignition of wood by a radiant cone heater was conducted. Insulated redwood samples were exposed vertically to incident heat flux ranging from 10 to 70 kW/m2. IR thermography and normal video recording were used to view the sample surface. The surface temperature and mass loss were continuously recorded. Glowing and flaming autoignition were defined and examined. The times to glowing and flaming autoignition were measured and compared with the times to flaming piloted ignition. The study found that for incident heat fluxes less than 40 kW/m2, in some cases, the sample surface started to glow (glowing ignition) before a visible flame (flaming ignition) was eventually seen. However, for incident heat fluxes greater than 40 kW/m2, flaming ignition occurred very quickly (within 30 s). The measured ignition time, ignition temperature, and surface temperature history were compared with theoretical values. The mass flux (pyrolysis rate) was assumed to follow an Arrhenius reaction rate. The activation energy and the pre-exponential factor were determined from a best curve fit of the experimental data.

Commentary by Professor Nathasak Boonmee, Kasetsart Univeristy, Thailand

Back in 1998, when I was a new lecturer in the Department of Mechanical Engineering at Kasetsart University, Thailand, Dr. James Milke came to give a seminar on Fire Safety Engineering. That was the first time I learned about the science of fire safety, and it really fascinated me. Dr. Milke also offered a new lecturer in my department the opportunity to go to UMD to pursue a master's degree in Fire Protection Engineering. I immediately took that chance. And that is how my journey into the world of fire safety engineering began.

I arrived at UMD in the fall of 1999. My first class with Dr. Quintiere was ENFP415, Fire Dynamics. As I recall, I received a very good score on the midterm exam. After the exam, Dr. Quintiere approached me and mentioned that he had some wood samples left over from Michael Spearpoint's work, which was a study on the piloted ignition of wood. He was looking for a student to extend the work from piloted ignition to autoignition of wood and offered me the opportunity to work on this topic for my master's thesis research. I accepted the offer, even though I was unsure of the path forward.

Throughout my work on my master's thesis, Dr. Quintiere consistently encouraged me to do my best. He explained the main research objectives but allowed me to pursue them freely, based on my own ideas. However, whenever I encountered a problem and sought his guidance, he always found a solution for me. I was truly impressed by his ability to simplify complex problems. I remember him always saying, "Don't get lost in the numbers. They're just numbers. They aren't more important than the physics of the problem." He was a genuinely optimistic man.

Dr. Quintiere was incredibly kind to me. Most of my master's thesis work was experimental, and I had to burn a lot of wood samples in a cone calorimeter. I remember a time when I ran out of wood samples for my experiments, and, being new to the US, I didn't know where to find more. When I spoke with Dr. Quintiere, he told me not to worry and that he could help me find some. He actually drove me to the wood shop and helped me pick up the samples, as I didn't have a car at the time. That gesture really touched my heart.

The main findings of my master's thesis later formed the basis of my first publication with Dr. Quintiere, titled "Glowing and Flaming Autoignition of Wood." After completing my master's degree, I continued my studies toward a doctoral degree in Mechanical Engineering at UMD, with Dr. Quintiere remaining my Ph.D. advisor. My Ph.D. work focused on developing a theoretical model to explain the surface glowing ignition of wood and how glowing ignition leads to gas-phase flaming autoignition. My Ph.D. dissertation was subsequently developed into two papers: "Glowing Ignition of Wood: The Onset of Surface Combustion" and "A Theoretical Investigation of Surface Glowing Ignition Leading to Gas Flaming Autoignition."

I am deeply indebted to Dr. Quintiere for his teaching and support during my studies at UMD. Without his help, I don't think I would have been able to earn my Ph.D. He taught me to look at fire in a way I had never considered before, and it was truly fascinating.

Commentary by Dr. Sara McAllister, Rocky Mountain Research Center

Despite wood being a common building material and a naturally occurring fuel in wildland fires, and studies of its fire behavior going back to some of the initial modern fire research conducted (e.g. Lawson, Simms, and Law in the 1950's and 1960's at the Fire Research Station), there are still some major gaps in our understanding of its behavior in fire. The series of work by Boonmee and Quintiere, beginning with this paper, includes some truly unique data and observations that fill some of this gap. There was very little previous work done on the effect of wood grain orientation on ignition behavior – i.e. heating perpendicular versus parallel to the grain. The other literature on the subject was also by Quintiere (see [1]). This paper in particular contains the only work that I am aware of that looks at the effect of wood grain direction specifically on autoignition. Wood is a complex, anisotropic material. The thermal conductivity can vary by a factor of up to three between grain directions. As shown in this paper, this can result in notable changes in ignition times and temperatures. Even at high heating rates and piloted ignition, the ignition temperature of wood heated perpendicular to the grain is about 100°C higher than for wood heated parallel to the grain. The other particularly important contribution of this work is that it considered glowing ignition times and criteria, which is a topic generally missing in the fire literature. I find it very interesting that glowing ignition was favored at heat fluxes below 40 kW/m^2, and flaming ignition above. The clear demonstration that the autoignition time curve merges with the piloted ignition time curve at high heat fluxes is excellent (Figure 4). Additionally, the variation in ignition temperature with incident heat flux and ignition mode in Figure 6 is really helpful to drive home the point that a constant ignition temperature for a material just doesn't exist. Wrapping up the paper using a simple integral model to help explain this great fundamental experimental work is a classic move that Prof. Quintiere was known for.

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Commentary by Dr. Michael Spearpoint

As I alluded to in my commentary on the work I carried out with Dr Quintiere on the ignition and burning of wood there were ignition mechanisms that were observed that were beyond the scope of that research. The work subsequently carried out by Boonmee under the guidance of Dr Quintiere explored the differences between glowing and flaming autoignition of wood. The paper describes a series of ignition experiments conducted on samples of redwood using a cone heater at a range of incident heat fluxes, and at different grain orientations. Measurements were made of time to ignition, mass loss rates and surface temperatures.

The paper examines the performance of the integral model that had been initiated by Dr Quintiere and then assessed through the work of Brian Rhodes [1], Don Hopkins [2], and then me in subsequent work. Boonmee showed where the integral model would give good predictions but also where it showed disagreements. An interesting analysis of the Arrhenius reaction rate was carried out in this paper in which results for the activation energy from Boonmee's experiments were compared to the literature. A follow up paper by Boonmee and Dr. Quintiere was published in the 2005 issue of the Proceedings of the Combustion Institute [3].

Work such as that of Boonmee and Dr Quintiere more broadly has seen a renewed interest with the increasing demand in the building industry to use mass timber construction. Understanding the mechanisms of ignition, burning, and potential re-ignition are important topics in assessing the fire safety performance of buildings that include products such as cross-laminated timber (CLT) etc. Standard test methods typically use piloted ignition to determine product classifications and therefore research such as that by Boonmee and Dr Quintiere helps to fill an important knowledge gap.

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Professors Toshisuke Hirano and Jim Quintiere

Scaling applications in fire research

J.G. Quintiere, *Fire Safety Journal*, 15(1), pp.3-29, 1989.

Abstract

The principles for scaling fire phenomena are examined from the dimensionless groups derived from the governing differential equations. A review of the literature shows examples of where correlations have been successfully developed for a wide range of fire phenomena in terms of the significant dimensionless groups. Scaling techniques based on Froude modeling, pressure modeling and analog modeling are described and illustrated. The use of small geometric models ranging from fire plumes to enclosure fires are illustrated by many examples.

Commentary by Professor Kozo Saito, University of Kentucky

The following excerpt from his introduction of this paper describes well his intention to use and promote scale modeling in fire research. "The study of fire phenomena in reduced-scale systems has been a pursuit of expedience and scientific strategy. It is apparent that accidental fires in the built and natural environments occur at a physical scale to prohibit their experimental study at realistic scales. Furthermore, the complexities of fire preclude complete mathematical solutions to its problems. Consequently, a deliberate strategy of scale modeling, based on the governing laws of physics, is both an essential and practical means of obtaining general results. The use of dimensional analysis leading to the significant dimensionless parameters is a well-known technique for generalizing experimental results and for establishing the 'laws of scaling' for a system. The study of fire phenomena at a scale suitable for laboratory observation can also give insight on the mechanisms and behavior of the system, even if it does not give exact quantitative results."

In this paper Jim Quintiere, who devoted his long successful career in fire research, examined principles for scaling fire phenomena from the dimensionless groups derived from the governing differential equations. There are three known approaches to develop scaling laws, parameter approach, governing equation approach, and the law approach [1,2]. Each approach has pros and cons as explained in [1,2], while the equation approach offers the most straightforward way to derive dimensionless numbers (also called pi-numbers) when the governing equations are available, since it gives physics-based meaning to them. Forman Williams [3] developed the basic governing equations for combustion phenomena including fire, based on which a total of 28 pi-numbers were derived. The scaling criteria demand that all 28 pi-numbers must be satisfied; however, it is practically impossible to do this task in scale modeling. It is important, therefore, to reduce these 28 pi-numbers to just a few of them which can satisfy scaling requirements. To that end, Quintiere selected three well known scaling modeling techniques, Froude modeling, pressure modeling and analog modeling, and provided physical meaning to each technique. Froude modeling emphasizes the convective processes, pressure modeling allows diffusive effects to be included, and analog techniques have advantages for visualization and avoidance of combustion effects.

Then he applied partial scaling (or relaxation) technique that ignores the minor influencing physics and keeps only the major influencing ones to obtain each of these three-modeling techniques. Note that partial scaling (the most difficult technique in scale modeling) requires "deep understanding" of phenomena of interest to us, thus it is said to promote our understanding of the phenomena [1.2].

He carefully reviewed authentic studies of pioneer fire researchers including P.H. Thomas, H, Hottel, F.A. Williams, S. Yokoi, J. de Ris, G. Heskestad etc., just to name a few, to find examples of where correlations had been successfully developed for a wide range of fire phenomena in terms of the significant dimensionless groups. The review was largely based on his rich experience in fire research and scaling. Note that in fire research, it has been common that experimentally obtained empirical correlations led the study and scaling analysis followed to provide physical meaning of these correlations. He concluded his paper by giving warning to fire researchers for the limitation of partial scaling, although it is useful but incomplete, since it does not model all the phenomena consistent with the governing dimensionless groups. Because of this reason, D.B. Spalding once called it "the art of partial modeling" [4]. Quintiere also published his second scaling article [5] in Progress in Scale Modeling an International Journal in 2020. It has already been downloaded more than 600 times claiming the most downloaded article in this journal.

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Commentary by Professor Hsin-Hsiu (Matt) Ho, National Chung Hsing University, Taiwan

Despite never having met Dr. Quintiere in person, the significance of his work extends beyond physical limitations. Every student of Fire Protection Engineering will inevitably encounter and utilize his work in some way or form along their academic journey, particularly when it comes to scaling laws and plume theory. Though "Scaling Applications in Fire Research" is now over 35 years old, predating myself, in fact, we would not have many of the current experimental results on tunnel fires without first considering the scaling laws brought to us by Dr. Quintiere. Fabricating and testing full-scale tunnels whenever research opportunities arise presents some obvious challenges and impracticalities. Work by Chang et al. [1] on full-scale tunnel fires would not have been as successful without the preceding model-scale experiments by Chen et al. [2], which relied heavily on the results from Dr. Quintiere's 1989 study for proper scaling considerations.

As a relatively new assistant professor who just passed the one-year mark at his new appointment, I cannot begin to count the number of times I reread "A unified analysis for fire plumes" over the course of my Ph.D. studies and at my current position. Dr. Quintiere's advancements in plume theory by striving for a "unified solution" served as the platform upon which my own Ph.D. work was built [3], demonstrating a renewed interest in extending early plume theory studies. My current graduate students are pursuing related topics, and this paper, without question, is on the list of required reading assignments. This also shows that some influential work is never genuinely outdated and cannot be critiqued solely over a matter of years; it requires decades for the full impact to be seen. It is now our turn to advance the field of fire science. However, similar to classical novels that are still mentioned hundreds of years after publication, the papers by Dr. Quintiere will always be regarded as classical works destined to be referenced by fire scientists for generations to come.

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Prof. Hirano's retirement party.

Compartment fire phenomena under limited ventilation

Utiskul, Quintiere, Rangwala, Ringwelski, Wakatsuki, and Naruse, *Fire Safety Journal*, 40, 367-390 (2005)

Abstract

Fire behavior of heptane pool fires were investigated in a small-scale 40 cm cubic compartment with wall vents at the ceiling (top vent) and the floor (bottom vent). The measurements included pressure, mass loss, temperature, heat flux, and gas mole fraction. Flame oscillations, ghosting, and burning at the air inlet were seen. The regime of limited ventilation was examined to study the effect of extinction and the influence of oxygen. A theory based on a critical flame temperature showed that extinction depends on heating as well as oxygen concentration. A complete uniform property model was developed and its solution agrees qualitatively with the measurements.

Commentary by Dr. Yunyong (Pock) Utiskul, US Coast Guard

As this paper's first authors, my commentary below is not intended to focus on its technical aspect, but rather to pay tribute to Dr. Quintiere's impact, both on me personally and on this work. In summary, we presented a set of experimental data and observations on flame phenomena in small-scale compartment fires under low ventilation conditions. It provided a unique visual documentation of transient and unstable fire behaviors such as oscillating and ghosting flames and showed how these phenomena can be generalized largely based on the key parameters governing the burning processes. We also demonstrated consistency of the experimental results with a mathematical theory.

Much work culminated in this paper. While most of the experimental work was based on my MS thesis, the study benefited from the solid groundwork done in part by the co-authors, all of whom contributed to the completion of the study. But more importantly, it would not have been published without Dr. Quintiere's guidance especially this being my first peer-reviewed publication. But his influence expands well past this publication; in fact, much of my overall personal and professional accomplishment wouldn't have been possible without Dr. Quintiere's guidance and encouragement.

The most memorable moment I had of Dr. Quintiere was when I first met him in Fire Dynamics class. "Fresh off the boat" as one may say, I had just arrived in the US to begin my first semester as a graduate student at the department. In that first lecture, Dr. Quintiere conducted the well-known "candle flame experiment", a simple yet powerful illustration of principles of flames and its implication to the science of fire. As intrigued and excited as I was about what was to come after that first lecture, the follow-on lectures and coursework were not always as easy or stimulating as I'd hoped given the lack of some pre-requisite knowledge from my undergrad background. Despite those challenges, I managed to succeed in that class thanks to Dr. Quintiere's patience and skill as an educator. Not only did he generously offer his time to help me academically, he became my advisor and gave me a job as a research assistant working for him and Dr. Tomohiro Naruse, one of this paper's co-authors. The opportunity Dr. Quintiere granted me led to my MS thesis and also to this paper, which helped found my Ph.D. dissertation.

As an advisor and a mentor, Dr. Quintiere taught me one of the most useful lessons in graduate school – it's not always about getting the right answers, but more about asking the right questions and defining a solid methodology to reach the answers. Early on in the work, while I was working on our small-scale test data for this paper, I recall sitting in Dr. Quintiere's office complaining about how I was struggling with a too-large set of controlling variables which was preventing any immediate trends from breaking out of the data. He asked me to list out all the governing equations that I could think of for what was going on in that compartment. He then challenged me to describe how they were related and scribble some notes, after which I arrived on my own at the dimensionless parameters we used for generalizing the data. These parameters were far from being any scientific breakthrough or new discovery, but to me the process through which he guided me was deeply valuable. It would have been much easier and less effort for him to just tell me what to do; instead, Dr. Quintiere gifted me with the chance to learn. Like the "candle flame experiment", Dr. Quintiere often approached complex scientific problems using simplified methods, yet had a knack for powerfully and adequately capturing the physics. That balance of being able to see through the nuances while not losing sight of what is important was one of the many inspiring qualities Dr. Quintiere possessed as an advisor, a researcher, and most importantly as a teacher. To the extent this paper exhibits those qualities it was all because of my professor and friend, Dr. James Quintiere.

Commentary by Dr. Li Chang

The study investigates the behavior of compartment fires under limited ventilation, focusing on the dynamics of flame extinction, oscillations, and burning regimes. The results are important for understanding fire safety in enclosed spaces, where ventilation plays a critical role in fire development and suppression. A uniform property compartment model was provided to correlate key parameters for the prediction of the compartment fire.

It is important to understand and predict the compartment fire behaviors to value the impact on structural elements and the dynamics of fire growth. The study focused on the ventilation effects, and particularly the region of limited ventilation, which was controlled by the ventilation or the opening area of a compartment [1-3]. Three main objectives are addressed: 1) to investigate the behavior of the wall-vent compartment fire, 2) to determine the important parameters which govern the burning processes, and 3) to demonstrate the consistency of experimental results with a mathematical theory.

The study carries out comprehensive measurements of mass loss, gas temperature, pressure, heat flux, and gas mole fractions (oxygen, carbon monoxide, and carbon dioxide). The use of a bench-scale compartment with controlled ventilation conditions allows for precise observations of fire behavior under limited ventilation. The authors identify four distinct burning regimes based on ventilation conditions: 1): Extinction due to compartment filling with smoke and insufficient oxygen. 2): Extinction due to blow-off, with oscillating and ghosting flames. 3): Sustained oscillations and burning at the vent. 4): Steady burning until fuel exhaustion. This classification provides a clear framework for understanding how ventilation affects fire behavior, particularly in scenarios where oxygen supply is restricted.

An extinction model based on a critical flame temperature is presented, which captures the extinction behavior parameters in the experiments. The model incorporates key factors such as oxygen concentration, heat flux, and flame temperature, offering an effective approach to predicting fire extinction under limited ventilation. The model predicted flame extinction at a critical flame temperature of 1300°C.

The study is conducted in a small-scale apparatus, which may limit the generalizability of the results to larger, real-world scenarios. While the authors acknowledge that radiation feedback is stronger at smaller scales, the extent to which these findings apply to larger compartments or different fuel types remains unclear. The study focuses exclusively on heptane as the fuel. Future studies could explore a wider range of fuel types to provide a more detailed understanding of compartment fires.

This comprehensive work provides valuable insights into the behavior of compartment fires under limited ventilation, particularly the role of oxygen concentration and heat flux in flame extinction. It makes a significant contribution to the field of fire safety research by providing detailed experimental and theoretical analysis of compartment fires under limited ventilation. The study's identification of distinct burning regimes and development of a simplified theoretical model offer effective approach for predicting fire risks in enclosed spaces.

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Ken Steckler, Yunyong (Pock) Utiskul, and Jim Quintiere

Upward turbulent flame spread

Saito, K., Quintiere, J. G., & Williams, F. A., *Fire Safety Science – Proc. First International Symposium* (1985)

Abstract

Mechanisms and rates of upward spread of turbulent flames along thermally thick vertical sheets are considered for both non-charring and charring fuels. By addressing the time dependence of the rate of mass loss of the burning face of a charring fuel, a linear integral equation of the Volterra type is derived for the spread rate. Measurements of spread rates, of flame heights and of surface temperature histories are reported for polymethylmethacrylate and for Douglas-fir particle board for flames initiated and supported by a line-source gas burner, with various -rates of heat release, located at the base of the fuel face. Sustained spread occurs for the synthetic polymer and not for the wood. Comparisons of measurements with theory aid in estimating characteristic parameters for the fuels." This paper was structured as follows: giving first theoretical development which included consideration of spread along charring fuels, then experiments and their results, and finally comparisons with theory (a nonlinear integral equation for spread rate of the pyrolysis front and deduced to non-homogeneous Volterra type equation).

Commentary by Professor Kozo Saito, University of Kentucky

Because there was no general test prescription which allowed the prediction of a material's performance in upward flame spread, studies to provide some guidance for achieving a generally applicable predictive model for upward spread was needed. At that time, upward flame spreading study over PMMA slabs 356 cm high by Orloff et al. [1] was only the relevant large-scale study to the authors' interest, therefore, the authors were motivated to extend the turbulent-spread measurements to different materials, different scales, and to different conditions of ignition. A methane diffusion-flame line-burner was newly designed and was placed at the bottom of the sample to promote sustained spread. The authors conducted upward spread of turbulent flames along vertically oriented flat walls for PMMA and particle board samples. These thermally thick samples were chosen since they represented realistic building wall materials. Some experiments were done with keeping the burner on, while for other tests the burner was turned off after a sustainable spread was established. The study found the burner heat effect on the spread rate was minimal.

This research was jointly coordinated by Forman Williams (Princeton University) and Jim Quintiere (National Institute of Standards and Technology). Under the intergovernmental personnel act agreement, Saito visited NIST's Fire Research Laboratory for a total of six months over 1984 to 1985, to design the upward flame spreading experiments for establishing reliable and accurate experimental data. Williams was responsible for development of theory based on the expected accurate flame spread rate data. Quintiere sponsored this whole project and allowed Saito to visit NIST from Princeton to access fire research facility, equipment, and technical staff members' support. The most challenging task for Saito was how to accurately measure the spread rate of upwardly spreading unsteady pyrolysis front, since the conventional video camera recording and visible observation lacked accuracy.

Takashi Kashiwagi of NIST suggested Saito the use of fine thermocouples, heat its junction bead electrically and hot-press it into PMMA surface. After several unsuccessful trials, it finally worked and the first PMMA sample with equidistantly embedded thermocouples showed promising data. After further improvement, the accuracy of this thermocouple technique reached the highest level, which satisfied our expectation. Then, a series of multi-thermocouple embedded samples were prepared for a series of upward flame spreading experiments. Note, if the thermocouple junction was even slightly exposed to the air, it picked up convective air temperature, which was much higher than pyrolysis temperature of PMMA, thus, the accuracy of this technique could have failed.

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Professors Jim Quintiere (UMD) and Forman Williams (UC San Diego)

A theory for flame extinction based on flame temperature

Quintiere, J. G., and Rangwala, A. S. *Fire and Materials*, 28(5), pp: 387-402 (2004)

Abstract

The extinction and suppression of diffusion flames is examined theoretically. The effects of oxygen reduction and external heat flux are examined compared to data in the literature. An application of extinction in compartment fires is also examined. The theory developed is based on a critical flame temperature, and that theory includes transient effects and the addition of water as well.

Commentary by Dr. Jon Zimak, Worcester Polytechnic Institute

In a critically important analysis of extinction, Quintiere's and Rangwala's 2004 paper, *A theory for flame extinction based on flame temperature,* sets up the fundamental thermodynamic and burning rate equations to study gas phase extinction from a critical temperature and mass flux perspective. The derived model simplifies extinction to a critical flame temperature and makes use of the B-number to calculate a material's burning rate at a prescribed external heat flux and oxygen concentration. While the equations are primarily derived for one-dimensional steady-state dry non-charring fuels, such as liquid pool fires, the fundamental framework is applicable for understanding the extinction of a variety of solid fuels, including plastics and wood. A true credit to the paper is the application of the model to the two distinct real-world extinction scenarios of heptane pool fires in poorly ventilated compartments and materials exposed to variable heat flux and oxygen concentrations. In both complex scenarios, the paper clearly states the assumptions and presents a simplified framework to solve for the extinction conditions.

The true value of this work is the description and subsequent derivation of a 1-dimensional control volume that is representative of a regressing liquid, non-charring solid, or charring solid and its application with the B-number. This control volume, which is also the basis for Quintiere's *Fundamentals of Fire Phenomena* textbook, is how a generation of fire protection engineers have and will continue to learn about burning rates for complex materials. The use of the B-number to calculate the burning rate has further solidified this approach as the primary method for calculating the burning rate of solid materials under variable oxygen concentrations, heat fluxes, and gas flows even outside of extinction scenarios.

The central theme of the paper was simple: the reaction rate kinetics are controlled by the flame temperature. However, the application and value added from studying extinguishment from the burning rate perspective greatly enhance the fire protection engineering communities' ability to conceptualize and calculate the extinction of complex materials.

As a student, I knew the Quintiere name only through his textbook. I was never able to meet Quintiere personally, but I was able to view some of his final conference presentations on video. What struck me most about him was how simple, yet robust, his explanations and analysis were of complex fire dynamics problems. As I continue to study at Worcester Polytechnic Institute and read through his literary legacy, it becomes clear that it was not just fire dynamics Quintiere wanted students to learn but rather how to think about fire from a simple yet robust perspective

Flammability maps for microgravity burning of a small flat material in a quiescent ambient

Parham Dehghani, James G. Quintiere, *Combustion and Flame*, Vol 253, 2023

Abstract

A gas fuel supplied burner (BRE) was used to emulate burning of real solid and liquid fuels in microgravity to address the fire safety concerns of spacecrafts. The analytical solution of these flames was utilized to predict the steady flame temperature, and a critical temperature range of 1100–1200 K, was chosen to distinguish between self-extinguished and steady flames. Steady flames are examined on a flammability diagram composed of the emulated heat of combustion and heat of gasification. It is shown that for a given heat of combustion, there is an upper and a lower limit value of heat of gasification that will allow steady burning. The theory and the boundary of extinction experimental data support the limits. The upper limit is classed as radiation extinction with the lower like the fire-point in Earth gravity and is called small flame extinction limit. A theoretical prediction for steady burning is demonstrated to within 10% for a given atmospheric condition of pressure and oxygen, material diameter, and external radiative heat flux. The material properties of Δhc, heat of combustion; L, heat of gasification; and Tb, burning temperature allow for the prediction of burning in microgravity, and can serve as a method to evaluate fire safety of spacecrafts.

Commentary by Dr. Parham Dehghani, UL Fire Safety and Research Institute

The Burning Rate Emulator (BRE) project was a unique extension of Dr. Quintiere's research, as it was designed for both normal and microgravity conditions. This project began long before I started my Ph.D. at the University of Maryland under the supervision of Drs. Sunderland, Quintiere, and de Ris. The core idea was to simulate real condensed-phase material pool fires by matching four key properties: (1) heat of gasification, (2) heat of combustion, (3) laminar smoke point, and (4) surface radiation. The first phase successfully established this approach in normal gravity, and later, the same principles were applied in microgravity. Using a burner with a controlled gas mixture, this method allowed researchers to simulate dozens of materials without actually using them, saving significant time and cost.

In my view, the two papers discussed here represent the most significant outcomes of this project, each in its own way. The transient ellipsoidal combustion model provided the theoretical foundation for the microgravity BRE experiments. Dr. Quintiere often credited this idea to one of his closest colleagues, Dr. Howard Baum, and the theoretical development was carried out by the PhD student of that time, Akshit Markan. I had the chance to meet Akshit in 2018 before he moved on to his new career. My first impression of the research team—Jim, Howard, Peter, and John—was their professional yet friendly and respectful work environment.

I officially started my Ph.D. in August 2018 and soon became responsible for developing the International Space Station (ISS) experiment test matrix under the supervision of Drs. Quintiere, Sunderland, and de Ris. A major challenge arose on the first day of ISS experiments in January 2019, when we realized that the burner's void volume had not been properly accounted for in ignition timing. The burner needed to be flushed and filled with fuel before ignition, but the flush time was approximately 10 seconds, while the igniter could only remain active for 3 seconds. While Peter remained calm and confident, the rest of us were nervous as the test time approached. Fortunately, an Excel-based ignition calculator I developed worked perfectly, and this was the first time Jim acknowledged my work. His approval was not easily earned, so it meant a lot to me.

The ISS experiment analysis took longer than Jim had initially expected due to unexpected findings—particularly the excessive heat absorption from the burner's sides, which was not anticipated. My first extended one-on-one collaboration with Jim was in January 2020, just before the COVID-19 outbreak. For two weeks, we worked closely in his office, organizing and refining my analyses. It was after this period that Jim fully trusted the accuracy and integrity of my work. Our efforts resulted in two papers published in Combustion and Flame [1,2].

From then on, we had weekly meetings where I presented my progress to Jim, Peter, John, and occasionally Dr. Alexander Snegirev and Dr. Howard Baum. The COVID-19 pandemic changed our working environment, but I had already built a strong rapport with my advisors. They supported my temporary relocation to Iran due to the U.S. travel ban preventing my wife from joining me in the U.S. Jim was always understanding and even took the time to chat with my wife, discussing politics, art, history, and philosophy. Being a medical doctor, my wife also occasionally answered Jim's medical questions.

When my wife and I finally returned to the U.S. in May 2022, I introduced her to my advisors, and they warmly welcomed her. Jim invited us to his home in Gaithersburg multiple times. During this time, we worked on finalizing my Ph.D. thesis and my last paper, which is referenced here. Focusing on the idea of a flammability limit for microgravity fires just like in normal gravity, initially suggested by John and Peter, evolved into a generalized flammability map based on critical flame temperature criteria. The theoretical framework, combined with radiative heat loss data from my third paper with Jim [3], helped us achieve a comprehensive understanding of flammability in microgravity. According to Jim, this work brought a strong conclusion to the BRE project, integrating knowledge from its early phases to the very last study.

My last conversation with Jim was a few days before his passing. I had asked whether he wanted to contribute to our upcoming presentation at the 14th U.S. National Combustion Meeting. He responded, "I have some health issues and cannot contribute." I replied, "Since you have led this project long before I started my Ph.D., you have already contributed so much. I will add you as a co-author unless you think otherwise." He responded, "I am glad you are doing this… I trust you." Those were his last words to me, and they will always stay with me.

Jim was an exceptional scientist, a brilliant thinker, and an inspiring mentor. His sense of humor was legendary among his colleagues, and he had an incredible talent for art and music, particularly the piano. He will be deeply missed! In Iranian culture, it is customary to honor the deceased with poetry as a sign of respect. I would like to dedicate this beautiful verse, which perfectly describes our esteemed professor:

"Saadi Shirazi says: A virtuous man never truly dies;

Only those who leave no good name behind are truly gone."

In Farsi:

سعدیا مرد نکونام نمیرد هرگز/مرده آن است که نامش به نکویی نبرند

Photo taken after my PhD defense. From left: Drs. A. Trouve, J. Quintiere, H. Baum, P. Dehghani, J. deRis

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Room-corner fire prediction for textile wall materials

Quintiere, J.G., Hopkins, M., and Hopkins, D, *Proceedings-International Conference on Fire Research and Engineering*, 1995.

Abstract

The results of applying a simulation model for fire growth on wall lining material is described. The model considers the room corner test scenario and is compared to data on wall coverings using the Uniform Building Code (UBC) Standard 42-2. The room test data comprise work performed at the California Bureau of Home Furnishings (CBHF) on three fabrics, and work performed at the University of California (Berkeley) (UCB) on ten fabrics. The latter tests consisted principally of strip test rather than fully covered wall tests. Experimental data were developed using the Cone Calorimeter and the LIFT apparatus to obtain the needed property data for the simulation model. Simulated results are compared to the measured results from the room-corner tests consisting of the rate of energy release and the average room gas temperature as functions of time. The results are mixed, ranging from good to poor. The thin nature of the material probably contributes to the accuracy of the results. The results are found to be very sensitive to the ignition burner, in terms of its heat flux and duration. Also, the model was found to be deficient in its ability to predict lateral and downward flame spread near the corner. This does not contribute to the inaccuracies in the textile wall covering results.

Commentary by Mark Hopkins

I first met Dr. James Quintiere (JQ as he was affectionately known to us at the time) as an undergraduate student while studying fire protection engineering (FPE) at the University of Maryland, College Park (UMCP) during the late 1980's and early 1990's. This also pre-dated the graduate program at UMCP. JQ taught the much-feared *Heat Transfer* and *Fire Dynamics* classes. He was known to be an extremely challenging professor. Yet, he was well revered, respected, and appreciated. He challenged us and was a master at breaking problems down into first principles and helping us to reconstruct them in a manner to both understand the problem, but also how to understand each variable, appropriate boundary conditions, and magnitude of the numbers. This interaction with the "Master" was critical in establishing an understanding of the materials.

After graduating, I worked for a year and suddenly found myself unemployed due to circumstances beyond my control. I visited the FPE department and spoke with JQ about this. He quickly said, "I have a job for you". In fact, he gave me several. I was tasked with running experiments in the lab and quickly found myself operating the LIFT apparatus and others. I also helped with Fortran programming for a room corner predictive model, and used data from testing by Dr. Brady Williamson, Dr. Nicholas Dempsey and others. JQ was an endless source of information and resources. Finally, he pulled me into some litigation cases that he was working on, and I assisted in terms of running experiments both individually and with others and continuing to calibrate and adjust the room corner model. At one point, I recall incorporating a vent component to simulate window breakage and other openings into the compartment. I watched JQ as his masterful mind worked, and ended with him scribbling a group of equations on a sheet of paper and his asking can you develop the coding for this.

I for one would not have had the career that I have had if it was not for JQ's influence. JQ asked me why I wasn't enrolled in the FPE Master of Science program. His influence and the other awesome professors at the UMCP, including but not limited to Dr. John L. Bryan, Dr. James Milke, Dr. Fred Mowrer, and later Dr. Stephen Spivak and Dr. Vincent Brannigan. Next thing I knew, I was a graduate student working on a master's thesis involving room corner modeling. I spent well over a year following up on work by other students (Brian Rhodes, Donald Hopkins, Jr., Bjarne Hagen, and others). I also continued to work in the lab supporting research and litigation for JQ.

JQ was not only a brilliant man, but a kind and caring one as well. He introduced students to the idea that fire, fire science, and fire protection engineering was not limited to our local or national environments but rather were experienced globally. He would share his experiences from a around the world (China, Europe, and Japan). He would also demonstrate innovative tests and talk about the gifts that he received. After visiting Italy and the Vatican, JQ explained that he had been victim to a pickpocket but only after he had gotten some gifts for some his students, including me. He had purchased small rosaries and gave them to us; I still have it, and it is a reminder of JQ's generosity and influence.

JQ helped so many students to push the envelope and to recognize that we could accomplish big things. My first publication was with JQ and my brother Don. In addition, I was able to deliver poster presentations and speak at a variety of conferences for the textile wall manufacturers, and fire science groups such as the IAFSS. Without JQ's influence, I know that my path in fire protection engineering would have been very different. I am very thankful to have known him, and to have had his influence in my life. May he rest in peace!

Commentary by Don Hopkins

This paper was one of several papers I was fortunate enough to co-author with Dr. Quintiere (JQ) during my time as an undergraduate and a graduate student at the University of Maryland. It was also the first opportunity to publish a peer reviewed technical paper with my brother, Mark.

As was the case for many students studying fire protection engineering in the early 1990's, I first met JQ when he taught several of my undergraduate courses. JQ had a unique teaching presence and was clearly a brilliant man. I was honored when he approached me and asked me if I would like to work for him performing small scale fire testing, which led to my senior research project. He then encouraged me to attend graduate school, where I worked very closely with him, both performing research and developing a model to predict burning rates of materials.

JQ was an excellent mentor, and as I learned very quickly, a very kind and generous person. I consider myself fortunate that he was willing to serve as my thesis advisor. When tasked with building a test apparatus, purchasing and setting up a data acquisition system, performing countless fire tests, and developing a fire model to predict ignition and burning rates of materials, I would have been overwhelmed without his support and guidance.

JQ also demonstrated true integrity in his work and instilled that in his students. When Mark and I worked on the Room-Corner Fire Prediction for Textile Wall Materials testing and analysis, we were not encouraged by the initial results; however, JQ encouraged us to report our findings honestly and accurately, and more importantly, to write a paper documenting the findings to encourage further study and advance the field of fire protection engineering.

In addition to this paper, I co-authored three additional publications as a result of my work with Dr. Quintiere, as follows:

Hopkins, D. Jr., and Quintiere, J.G., "Material Fire Properties and Predictions for Thermoplastics," *Fire Safety Journal*, **26** (3), April 1996, pp. 241-268,

Hopkins, D. Jr., "Predicting the Ignition Time and Burning Rate of Thermoplastics in the Cone Calorimeter, NIST GCR 95-677,

Hopkins, D. Jr., Rhodes, B.T., and Quintiere, J.G., "Predicting the Burning Rate of Thermoplastic-Like Materials in the Cone Calorimeter," *National Institute of Standards and Technology Annual Conference on Fire Research: Book of Abstracts*, Gaithersburg, MD, October 17–20, 1994, pp. 113-114.

Quintiere with a group of visiting scholars. On the left next to Quintiere is Prof. Jose Torero and on the right is Prof. Pierre Joulain.

Flow induced by fire in a compartment

K.D. Steckler, J.G. Quintiere, W.J. Rinkinen, *Proc. Combust. Institute*, Vol. 19, pp. 913 – 920, 1982

Abstract

Fifty-five full-scale steady-state experiments were conducted to study the flow induced by a simulated pool fire in a compartment under conditions characteristic of the developing fire period. The mass flow rate through the door or window opening and bounds on the fire plume entrainment rate are presented as a function of opening geometry, fire strength, and fire location. The characteristics of the measured opening flow rates are explained by a simple hydrostatic model based on temperature distribution. A good correlation between the measured results and the idealized flows, taking into account the complete temperature distribution, is demonstrated. Entrainment results for fires near walls are in reasonable agreement with results from free-standing plume models. Except for the smallest openings, fires in other locations entrain at a rate two to three times the rate predicted by these models. This phenomenon is attributed to room disturbances caused by the opening flow and is similar to the behavior of a fire plume in a cross wind.

Commentary by Dr. Li Chang

This study investigates the characteristics of the mass flow rate induced by a fire in a compartment with various opening geometry and fire configurations. A total of 55 full-scale burns were conducted and a flow rate model established using hydrostatic theory was validated by the experimental results. The work is significant as it provides a simple and refined theoretical model of predicting compartment fire mass flow rate. This is critical for fire safety engineering and building design.

The flow of air and gases in room fires has a significant bearing on the development and state of the fire. In developing fires, it controls the temperature and heat transfer and thereby influences the spread of the fire. The authors addressed the previous theories on buoyancy-driven flows in compartment fires [1,2] and the fire prediction by zone models [3]. However, there was no systematic experimental study of fire induced flows. This was because of the difficulty of making accurate and sufficient velocity measurements to arrive at a mass flow rate for a door or window.

The work is noble for its systematic experiment design of compartment fire geometry and the use of full-scale burning experiments, which provide realistic and reliable results. Advanced bidirectional flow velocity probes and thermal couple arrays are applied to calculate the mass flow rate accurately. The level of detail helps to understand complex interactions between fire size/location, flow rate, and opening geometry. The discussion presents the influence of ventilation parameters, fire load on the opening mass flow rate for flush burners located at the center, wall, and corner. Overall, the fire at the center of the compartment leads to higher opening mass flow rate than the wall and corner cases. The author compared the entrained mass flow rate under a wide range of variables, which allowed them to explore the effects of these factors on flow rates. The inclusion of doorway and window opening adds depth to the study.

The study correlates experimental results the hydrostatic model for flow through openings and the point source plume model for entrainment. Good agreement has been reached with gas temperature measurements at different heights. The model is of great practical value in fire safety engineering for ventilation system design, highlighting how fire location and opening size affect airflow. The results also provide data to improve zone models for fire dynamics predictions.

Valuable insights focusing on steady-state conditions and controlled burners are provided in the paper, while dynamic fires might need to be considered for real-world fire scenarios. The authors acknowledge that the entrainment rates derived from the experiments have significant uncertainty, particularly for fires near walls or corners. This uncertainty stems from the difficulty in precisely determining the thermal interface height and the effects of room disturbances. Future studies could explore more precise methods for measuring entrainment rates. Finally, a more detailed explanation on the velocity measurement probes might be helpful to further strengthen the study.

Steckler, Quintiere, and Rinkinen make a significant contribution to the field of fire dynamics by providing empirical data on flow rates and entrainment in compartment fires. Their findings validate existing theoretical models and offer practical insights into fire safety engineering. While the study has some limitations, particularly in terms of generalizability and measurement uncertainty, it lays a strong foundation for future research in this area. By addressing these limitations and exploring new directions, researchers can build on this work to further advance understanding of fire behavior in enclosed compartments.

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Phillip Thomas, Sybil Thomas, Ray Friedman and Jim Quintiere

A general formula for the prediction of vent flows

J. G. Quintiere and L. Wang, *Fire Safety Journal* Vol. 44, pp. 789-792 (2009)

Abstract

A new formula for fire-induced wall vent flow rate is developed based upon a theoretical derivation and mathematical fit to data. Previous research had developed a formula of mass flow rate for fire-induced doorway flows only. Here it is extended to include window flows. A theoretical model based on an ideal point source fire plume is used to guide the form of the empirical correlation. A thorough examination concerning the difference between the window and doorway flow modes is conducted. Both sill height and width of the windows pose key influence on the formula. The two vent configurations are merged into one equation. The results were compared to available flow data and shown to be within 15% accuracy for a wide range of fire conditions.

Commentary by Professor Naian Liu, University of Science and Technology, China

From the moment I stepped into the field of fire science research at a tender age, Prof. James Quintiere has been my unwavering idol. I have delved into countless papers and books authored by him, each one a cornerstone in the realm of fire science that I hold as irreplaceable classics. His profound insights into the physical processes of fire, meticulously articulated across a series of works, leave me in awe. Moreover, his groundbreaking contributions to the theoretical modeling of fire have set new benchmarks in the scientific community.

My esteemed supervisor, Professor Weicheng Fan, founder of the State Key Laboratory of Fire Science (SKLFS), once recounted to me the cherished moments of his interactions with Prof. Quintiere. Through these stories, I came to admire Prof. Quintiere's selfless dedication to fostering international collaboration in the establishment of fire science laboratories. In him, the noble ethos that "scientists may be bound by national borders, but science knows no boundaries" is vividly personified.

I vividly recall the moment in 1991 when I first stepped onto the campus of the University of Science and Technology of China as an undergraduate. In the grand conference room of the SKLFS, my eyes were drawn to a striking photograph on the wall, capturing Professor Quintiere's visit to the laboratory. It was then that Professor Weicheng Fan shared with us a profound story: during his visit, Professor Quintiere not only expressed immense admiration for the laboratory's work but also offered words of encouragement that resonated deeply. These inspiring remarks became the beacon guiding the SKLFS through countless challenges, fueling its relentless pursuit of excellence. Professor Weicheng Fan's narrative left an indelible mark on my heart, igniting a passion within me. This fervor later propelled me to join the SKLFS during my postgraduate studies, dedicating myself to the critical field of fire safety research.

Both Professor Quintiere and Professor Weicheng Fan, as preeminent luminaries in the realm of fire safety science, placed paramount emphasis on the seamless integration of fundamental research with practical application demands. They advocated commencing from an in-depth exploration of the intrinsic mechanisms and governing laws of fire phenomena, thereby distilling universal knowledge advancements and catalyzing the evolution of cutting-edge fire protection technologies. This visionary philosophy has consistently served as the cardinal guiding principle underpinning the progression of the SKLFS.

In 2016, Prof. Quintiere graced the SKLFS with his presence and delivered a profound academic lecture titled "Scale Modeling Fire: Design and Investigation." During his visit, he engaged in extensive and insightful exchanges with the young faculty members of the laboratory. He wholeheartedly praised the remarkable accomplishments of the SKLFS over its three-decade journey and personally inscribed words imbued with encouragement for the lab. These inspiring words now reside in the exhibition hall of the SKLFS, serving as a beacon to motivate budding scholars passionate about fire safety research to relentlessly pursue groundbreaking and innovative endeavors.

Prof. Quintiere and I also engaged in numerous profound exchanges regarding the theoretical analyses of intricate fire processes during international fire conferences. One notable instance is the 2009 CCTV fire, which not only ignited my research group's fascination with enclosure fires but also profoundly deepened my commitment to this specialized field. A pivotal factor in the CCTV fire was the influence of ambient wind on fire dynamics. Consequently, Dr. Gao and I embarked on the development of a predictive model aimed at elucidating how wind enhances flow through openings within burning structures. Our experimental investigations revealed that ambient wind dramatically transforms flame morphology, giving rise to a myriad of complex phenomena in flow dynamics and heat transfer across multiple scales. This inherent complexity presented significant challenges in identifying an effective starting point for our inquiries. Through enlightening discussions with Prof. Quintiere, he graciously suggested that, given the interdependence of these mechanisms, we could construct an initial framework to systematically incorporate several critical mechanisms. Building upon this foundation, we were able to meticulously analyze our findings to uncover potential pathways for model optimization. His zone model provided an exemplary framework as we progressively integrated additional considerations, ultimately achieving satisfactory predictive capabilities.

A notable advantage of his model lies in its ability to derive critical parameters—such as the smoke layer temperature, mass flow rate, and neutral plane height—from a limited set of readily accessible input variables. Although Eqs. 1-4 (J. G. Quintiere and L. Wang, Fire Safety Journal Vol. 44, pp. 789-792) incorporate some non-universal constants, they also allow for further refinement and adaptation. For example, Eq. 1 can transition from a point-source framework to a finite-source model, thereby more accurately capturing the geometry and positioning of the fire source. Meanwhile, Eq. 4 facilitates the integration of heat feedback mechanisms from the smoke layer, enhancing the model's realism and applicability. This system of ordinary differential equations empowers researchers to swiftly assess variations in outcomes resulting from alterations in input parameters, all while minimizing computational demands. By simplifying the solution process without sacrificing theoretical rigor, this approach achieves an elegant balance between practicality and precision.

This seminal paper has acted as a powerful catalyst, inspiring researchers to delve into the intricate fundamentals of enclosure fires and vent flows. Notably, Utiskul et al. [1] advanced the model by integrating the sophisticated "near vent mixing" effects. In recent years, we have pioneered an analytical model that elucidates how flame tilting influences air entrainment, with the ultimate goal of refining the precision of mass flow rate calculations.

Prof. Quintiere has indelibly shaped my methodology in tackling fire-related challenges. He will be cherished not merely as a trailblazing luminary in the realm of fire science but also as a cherished confidant whose wisdom and kindness left an everlasting mark on all who had the privilege to know him.

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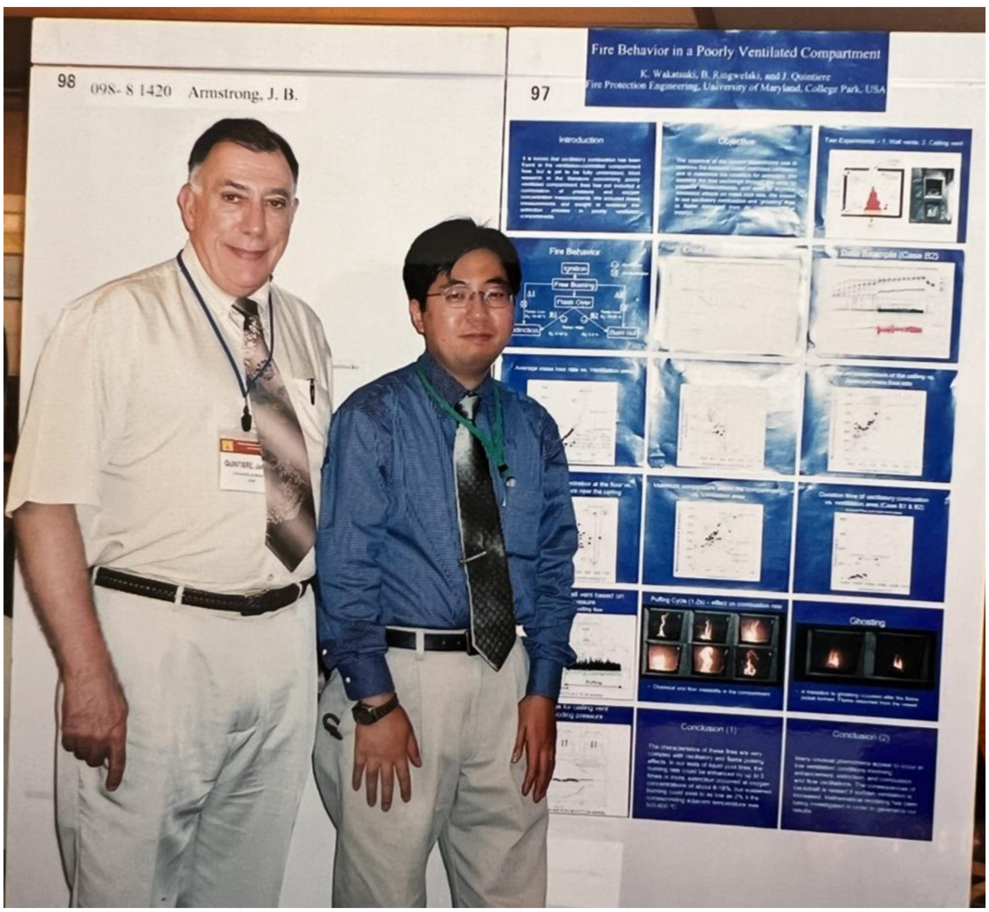


Professor Quintiere and Kaoru Wakatsuki

Investigating materials from fires using a test method for spontaneous ignition

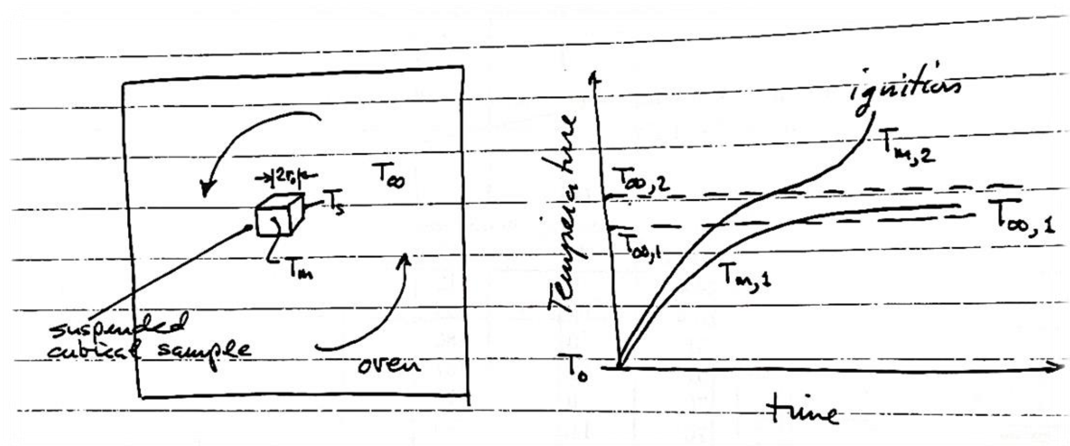
S.M. Hill and J.G. Quintiere, *Fire and Materials*, Vol. 24, pp 61 – 66, (2000)

Abstract

The purpose of this study was to utilize the oven test method described in past literature by Bowes to predict the propensity of bulk materials to ignite spontaneously. The results of small-scale laboratory oven tests were analyzed and compared with large-scale 5re incidents involving several materials in question, including latex examination gloves, residue from an aluminum polishing process, polyurethane purging, and various other plastic products. Where possible, an indication of the role of spontaneous ignition in the 5re incidents was identified.

Commentary by Professor Ali S. Rangwala, Worcester Polytechnic Institute

Spontaneous combustion was one of Dr. Quintiere's favorite topics when he taught Fire Dynamics. He would derive the theory from scratch—no notes—then show how it could solve real-world fire cases. This paper captures that perfectly: theory meets experiment, and both come alive through compelling case studies.



Dr. Q's drawing from his notes on Spontaneous Combustion

The paper applies spontaneous ignition theory and the oven test method to real incidents, including a fire at a warehouse in Brooklyn, New York, storing hundreds of cases of powder-free latex gloves. The gloves were packed tightly in cardboard boxes and stacked on pallets—an arrangement that, under hot and humid conditions, raised the question of whether self-heating could have triggered the fire. Using inferred critical temperatures and scaling analysis, the authors showed that spontaneous ignition was not only possible—it was likely, given the ambient conditions and storage configuration.

This was Dr. Q's favorite exam problem. He would present the scenario just as it happened—warehouse layout, glove box dimensions, ambient temperature—and challenge students to determine whether ignition conditions could be reached. It felt like a Sherlock Holmes story, with science as the detective's toolkit. The elegance lay in how something so theoretical—Frank-Kamenetskii's criticality condition—could be applied to reconstruct the cause of a devastating fire.

That was Dr. Q's gift: turning complex, real-life cases into teachable, solvable problems. I aspire to do that in my own teaching: to make theory practical and problems meaningful.

Predicting polymer burning using TGA/DSC

Mekyoung Kim, J.G. Quintiere, *5th International Seminar on Fire and Explosion Hazards*, Edinburgh, Scotland, 23-27 April 2007

Abstract

The flammability properties of pure Nylon 6 and Nylon with nano-clay of 5 % are examined in this study. Thermo-gravimetric Analysis (TGA) and Differential Scanning Calorimeter (DSC) data were obtained with a variety of heating rates. The rate of reaction was described by a first-order Arrhenius equation in terms of the active species. A model was formulated for thermally thin samples subjected to uniform irradiation. The model was based on melting and decomposition as modeled from the TGA/DSC data, a criterion for ignition based on critical mass loss, and estimated flame heat flux from fire experiments. The theoretical results are in good agreement data from previous Cone Calorimeter experiments. A theoretical basis for thermally thin was confirmed by the data.

Commentary by Dr. Mekyoung Kim

At the University of Maryland (UMD), my master's journey marked a return to academia after nearly 14 years since completing my undergraduate studies. As an international student, everything at UMD felt unfamiliar. About two months into the semester, Dr. Q suggested that I participate in research, believing that my background in chemical engineering made me a good fit. Without fully understanding the scope of the research or what lay ahead, I agreed without hesitation. The research, funded by the FAA, was a continuation of studies Dr. Q had previously conducted with other students.

Balancing coursework and research, as expected in a master's program, was quite demanding. My research focused on modeling the thermally thin burning rate of polymers (nylon) using TGA and DSC. The study involved pure nylon samples of varying thicknesses and nylon mixed with 5% clay. The goal was to analyze combustion patterns and burning rates based on thickness while quantitatively assessing the fire-retardant role of clay. Accurate results required extensive TGA and DSC data, but UMD lacked the necessary equipment. Consequently, Dr. Q arranged for the experiments to be conducted at the FAA and a private research facility, VTEC, during both academic terms and breaks.

At the FAA, Dr. Richard E. Lyon and Dr. Stanislav I. Stoliarov taught me how to operate the equipment and assisted with experiments. Their support was invaluable, and I remain deeply grateful. VTEC, located in Brooklyn, New York, was run by a friend of Dr. Q. I traveled there with Dr. Apinya, a visiting professor from Thailand at UMD. On the final day of experiments at VTEC, Dr. Q arrived, greeted me with his signature wide-eyed smile, and said, "You survived!" That evening, we attended an opera performance of La Bohème in New York City, featuring Korean prima donna Hong Hei-Kyung.

Additionally, I visited NIST, where Dr. Kashiwagi provided a substantial amount of TGA data for my modeling. When Dr. Q and I struggled to interpret DSC data, we had a meeting with Dr. Lattimer, who provided significant insights. As a result, I derived kinetic parameters from TGA data and thermodynamic parameters from DSC data. Using Mathematica and Excel, I modeled the thermally thin burning rate of polymers and compared the results with cone calorimeter experimental data obtained by Xin Liu. The predictive accuracy of the model was outstanding, and Dr. Q and I were thrilled with the results.

Throughout this research journey, my discussions with Dr. Q extended beyond the classroom. If an idea struck me or I had questions—even on weekends—I would call him, and when a phone call wasn't enough, I would visit his home. Dr. Q was always open and willing to help.

During the summer break before my final semester, I dedicated my time to writing my thesis. When I handed the draft to Dr. Q at the end of the break, he glanced at it and asked, "Have you never written a thesis before?" His disappointment was evident. I vividly recall that rainy Saturday—I mumbled that I would rewrite it and quickly left. At the Potomac laboratory, where Ph.D. candidate Pock (Dr. Yunyong Utiskul) was working, he consoled me. The following week was a blur; I thought about my thesis almost 24/7. I even kept a notepad by my bed to jot down ideas while sleeping. Exactly a week later, I presented a rewritten thesis to Dr. Q. He looked at it and exclaimed, "Monique, what did you do? This is magic! In just one week!" My secret? I discarded my entire summer's work without hesitation and started fresh from the first page. From that point, the thesis-writing process went smoothly, and I finally completed my master's thesis.

After my defense, one of my committee members, Dr. Sunderland, kindly remarked that my master's thesis was equivalent to a Ph.D. dissertation. Following my graduation, I presented my research at the 5th International Seminar on Fire and Explosion Hazards in Edinburgh. Out of 1,000 papers presented, only four received the Best Paper award—an honor I never expected. I hadn't even attended the award ceremony, much to Dr. Q's regret. This achievement remains one of the greatest honors of my life, and I can confidently say that it was only possible because of Dr. Q.

Actually, I had worked as the first female fire protection professional engineer (PE) in Korea for a significant period. However, I eventually realized that despite my background in chemical engineering, I had never formally studied fire science in an academic setting. This realization led me to pursue a master's degree in fire protection at UMD. Dr. Q only learned of my prior work experience after my graduation. When I later established my company, he introduced me to his Japanese colleagues and even posted about my company on the UMD bulletin board. After graduating from UMD, my connection with Dr. Q continued across China, Japan, and Korea. Like other students, I received his annual year-end cards, which included photos capturing his life throughout the year. Even after leaving UMD, despite the long distance between Korea and the United States, he always felt close.

When Dr. Q visited Korea, he met my Ph.D. advisor, Dr. Yoon, and took a deep interest in my doctoral research. During my Ph.D. journey, I frequently sought his advice, and he generously provided his insights along with relevant research papers. His influence on my Ph.D. was profound.

This brief commentary on our research may extend beyond its intended scope, but I want to share this: Dr. Q was always giving. Whether in research or business, he connected people, hoping they would help one another. Though our relationship began as that of a student and professor, over two decades, he became my mentor, advisor, and friend. I remember him as a man with a great soul. Calling him a world-renowned authority in fire protection engineering seems too limiting—his impact was far greater.

If I were to define the luckiest part of my life, it would be meeting Dr. Q. We tend to believe that each of us has our own mind. in truth, we share a single common mind; that is, universe. His physical presence like surface tension on water has disappeared, but he is still with us in this vast universe.

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Quintiere in his study at home in Margate, NJ

Memories about my American friend Jim Quintiere

Commentary by Professor Vladimir Molkov, University of Ulster, UK

Speaking to doctoral students and postdocs I usually say them: "try to be a high professional in your area as well as a nice person to let people enjoy time spend with you during and beyond the work time". This is exactly about Jim. It is impossible to describe how happy I am to meet this lovely and soul person in my life. I am proud to know one of the fathers of fire safety science. Since meeting Jim, I enjoyed any moment we spent together.

I met Jim for the first time in 1994 in Ottawa when he was chairing the International Association for Fire Safety Science (IAFSS). With two colleagues from Russia, we attended IAFSS Symposium to see how international events on fire science are organized. It was my first trip to the Western country. One of the memories relates to the IAFSS Symposium banquet led by Jim. People enjoyed it when he at the end of the event was asking each country group to stand. Colleagues applauded each nation present in that huge hall. This was demonstration of Jim's internationalism and his love to all people around the globe. On our return to Russia from Ottawa, in 1995 and 1997 the first and the second International Seminars on Fire and Explosions Hazards were organized (ISFEH). It is worth mentioning that the next ISFEH 11 will be held in Rome 15-20 June 2025. Unfortunately, Jim did not attend those two events in Moscow by a simple reason "probably it was not safe to travel?". This wrong impression was corrected later, and we enjoyed attending international scientific events in Novosibirsk, Chernogolovka, and Sankt-Petersburg.

Quintiere in Chernogolovka.

Jim wrote the books we all know. He was reading different books, recently one by Jim Shields (former FireSERT Director). Before visiting Moscow, he recommended me to read (it is still on my shelf waiting for retirement time…) a book "A gentleman in Moscow". This is why he stayed in Metropole Hotel in Moscow where the book events were happening.

All knows his incomparable sense of humor. I loved my granddad who was an example of proud and respectable by people man. When I met Jim for the first time I said: "You remind me my granddad". The answer was: "Do I look so old?".

In 1999 I moved from Russia to the University of Ulster in Northern Ireland (UK). The photo below shows Jim, Derek Bradley and I in a pub in England with "I'm going…".

Vladimir Molkov, Derek Bradley and Jim Quintiere (L to R)

After the move to UK as Professor of Fire Safety Science I found that there is "no money" for fire research and I switched to hydrogen safety trying to continue bringing together research problems of fire and explosions (the main underpinning idea of establishment of the ISFEH symposium). Jim shared this vision and often mentioned works of Semenov and Zeldovich in our discussions. Due to my deep involvement in hydrogen safety and his love to fire science we published only a couple of papers together. His theoretical skills were brilliant.

Knowing the effect of his books on the establishment of fire safety science discipline, Jim inspired me to write a book "Fundamentals of Hydrogen Safety Engineering" 2012) that is used for delivery of the first in the world higher education course in hydrogen safety at the University of Ulster. Probably I should write another one devoted to Jim as apologies for missing to meet him in May 2024 in Imperial College in London where he gave invited lecture (I was hoping to see him again to Cyprus). In autumn 2024 he were spoken by phone, and he said that consequences of Lyme disease are gone, and all "problems" are probably simply age… And then sad news in December 2024.

The pleasure of being with Jim was not only discussions of scientific problems but all aspects of life. We could share the same ideas, argue and disagree. Yet he was an extremely gentle debater in my case, and we continued to be in touch up to moment when he left us. Hopefully I did not hurt him by my arguments as he didn't hurt me. Jim for me is an example of American person the country could be proud of. He always had his opinion and did not afraid to express it even I know sometimes it "hit" him back. Jim was easily hurt yet he loved even those doing it to him. He is an example of one of the best Human Beings I met, free person of a free country with a big heart to people around him.

Few times we had a great time in Cyprus enjoying weather, sun, dinning, visiting castles, etc.

Jim was giving invited lectures at several events organized by the University of Ulster, including European Summer Schools on Hydrogen Safety. I remember how he was enjoying the presentation by Toshisuke Hirano with huge number of equation derivation, which probably only he fully understood.

I visited Jim's house and family in New Jersey and unfortunately did not manage to stay with him in Atlantic City being invited multiple times. We had good time in our house in Belfast with other colleagues.

There is another book (not related to fire science) Jim presented me a couple of years ago: "Victory through air power" by Major Alexander P. de Seversky (born in Russia in 1894, decorated by President Roosevelt in 1940 for outstanding achievements in the field of aviation). Jim's inscription on the book "To Vladimir. Once "WE" were friends. Love. Jim". Love you too Jim and hope on the global friendship sooner than later. These days I often go through my memories and Jim is always smiling there… Thank you for being and continue staying with me, Jim!

Yuri Shebeko, Vladimir Molkov, Jim Quintiere, Anatoly Baratov, Ritsu Dobashi

Passive ventilation of a sustained gaseous release in an enclosure with one vent

V. Molkov, V. Shentsov, J. Quintiere, *Int. J. Hydrogen Energy*, Vol. 39, pp 8158–8168 (2014)

Abstract

A model for prediction of steady-state uniform concentration of a sustained gaseous leak in an enclosure with passive ventilation through one vent is described. Theoretically natural ventilation models under-predict up to twice lower concentrations of releasing gas and over-predict up to twice higher concentrations compared to the model of passive ventilation. The distinctive feature of passive ventilation is positioning of the neutral plane anywhere below the half of the vent height whereas it is located at about half vent height in the case of natural ventilation. The model is compared against experimental data on uniform and non-uniform distribution of helium concentration in the enclosure with one vent of different size and various release flow rates. The model predictions of maximum concentrations of helium observed in the experiments with the conservative discharge coefficient value $C_D = 0.60$ (the best fit range is from 0.60 to 0.95) are closer to measured data than calculation by a model based on the natural ventilation assumptions even with "tuned" $C_D = 0.25$. The engineering nomogram to calculate a release mass flow rate leading to 100% concentration of gas in an enclosure as a function of vent width and height is presented. The equation behind the nomogram is verified by CFD simulations and the appropriate discharge coefficient is derived for use in the equation as $C_D = 0.85$. Effectiveness of different vent configurations is compared based of the ventilation parameter A*Sqrt[H]. A new criterion for mixture uniformity in a ventilated enclosure is suggested and applied to available experimental data. It is concluded that the maximum and minimum mole fractions deviate from the average mole fraction by no more than 20% when the criterion is above 4.

Commentary by Andrew Goetz, Worcester Polytechnic Institute

This paper published by Dr. Vladimir Molkov, Dr. Volodymyr Shentsov, and Dr. James Quintiere was part of the foundational research of the Hyindoor project aimed to develop state-of-the-art engineering tools to allow for the safe indoor use of hydrogen as fuel and hydrogen fuel cell systems. At the time of publication, limited tools existed for hydrogen safety engineering relevant to leaks inside naturally ventilated compartments with vents located on the compartment walls. The goal of this work was to develop a tool that could help engineers accurately predict the steady-state concentration of hydrogen inside a compartment with a single vent on one wall for a wide range of realistic accident scenarios.

The passive ventilation model presented was based a new approach to handling natural, or unforced, ventilation inside a compartment with vents in the walls. Previous work assumed equal volumetric flow rate through each half of the single rectangular vent. The authors relaxed this assumption to more accurately handle the release of hydrogen, or more generally a gas lighter than air, into the compartment. This allowed the neutral plane, the horizontal plane where the pressures inside and outside the compartment are equal, to move in height as a function of the gas release inside the compartment. The model results followed experimental data for helium significantly closer than previous ventilation models. Across a range of both varying leak rate and vent sizes, the model slightly overpredicted concentrations highlighting its potential usefulness as a conservative engineering tool.

To further the usefulness of the model, the authors focused on determining the minimum flowrate to achieve 100% accumulation of hydrogen inside the compartment. At this flowrate and above, engineers must evaluate the pressure peaking phenomenon caused by hydrogen. This physical phenomenon occurs during the transient buildup of pressure in a vented enclosure where only hydrogen is flowing out of the vent and air cannot enter the compartment. This phenomenon can cause an order of magnitude higher pressure peak inside the compartment than the steady state overpressure. Thus, careful evaluation must occur to ensure that the compartment will not sustain structural damage due to overpressure. The authors presented an engineering nomogram for determining when 100% hydrogen accumulation may occur inside the compartment based on flowrate and ventilation parameters. However, the power of the model goes beyond the 100% accumulation condition. The nomogram can be expanded to provide an extremely powerful engineering tool to cover both the 100% accumulation scenario as well as predict the full range of potential hydrogen concentrations inside a compartment based on leak rate and ventilation sizes.

Additionally, the work published the first mixture uniformity criteria for a ventilated compartment. The authors assumed that due to the high pressures in real-world hydrogen systems, the hydrogen jet encountered in an accident scenario would be momentum dominated. The uniformity criterion is derived to be the ratio of the entrainment flow of the hydrogen-air mixture into the hydrogen jet to the flow of air into the compartment. It was applied to the helium concentration experimental data alongside solutions to their passive ventilation model. The results showed that above a uniform mixing criteria of 4 the results of the passive ventilation model predicted an average mole fraction inside the compartment within 20% of the experimentally measured maximum and minimum values.

Even outside conditions where the mixture is uniform throughout the compartment the concentrations predicted by the passive ventilation model are still accurate and only slightly overestimate the maximum concentration values experimentally measured. This further cemented its usefulness as a conservative engineering tool. The nomogram was ultimately published in the Hyindoor final report for use as a state-of-art tool to help hydrogen engineers [1]. The thoroughness of the work for simplified geometries set the foundation for future highly impactful work analyzing significantly more complex geometries and scenarios involving hydrogen powered vehicles [2].

The extensive talent and skills of Professor Quintiere shine throughout this work. His expertise in plume modeling, dimensional analysis, and scaling techniques are applied extensively to tackle this new and emerging problem. He easily couples techniques he championed in the early part of his career with modern CFD techniques to completely envelop and thoroughly examine this problem. It highlights not only the unbelievable depth and breadth of his knowledge but also his willingness to learn, adapt, and embrace new techniques that evolved throughout his career.

As a new member of the fire research community, I first learned of Professor Quintiere's immense contributions to the fire community through his seminal texts on fire modeling and compartment fire dynamics. As I have continued to explore and learn about the field, I find Professor Quintiere's fingerprints everywhere. The theme of his entire career is an intense and highly successful pursuit to solve some of the most critical fire research problems over the span of multiple decades. It is truly impressive to see the range of problems he has worked and solved through constant learning, curiosity, and inquisitiveness. His illustrious career and immense, lasting impact are truly a model to follow.

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Flashover and instabilities in fire behavior

Thomas, P. H., Bullen, M. L., Quintiere, J. G., & McCaffrey, B. J, *Combustion and Flame*, Vol. 38, 159-174 (1980)

Abstract

One kind of flashover in compartments can result from a thermal instability caused by the energy generation rate increasing faster with temperature than the rate of aggregated energy losses. This paper describes qualitatively how various factors affect this instability, and demonstrates a quasi-steady approach that can be used to explain the growth of fires in enclosures. Thermal radiative feedback from the enclosure is considered to be the significant factor in determining the fuel gasification rate and is the primary cause of the instability. For a plausible expression for thermal feedback, it is found that the upper enclosure mean gas temperature at the onset of instability can range from 300°C to 650°C in most cases. However, the corresponding fuel gasification rate for a fixed surface area fuel at criticality is only roughly 50% greater than the free or open burn value. Finally, the possibility of an "extinction" instability for ventilation controlled fires is also indicated.

Commentary by Dr. Ricky Carvel, University of Edinburgh

I met Jim at various conferences, and on his visits to Edinburgh over the past couple of decades. But my main interactions with him were generally by email, and often following my suggestion of him as a reviewer when submitting an article to a Journal.

When you submit a paper for consideration in a Journal, you need to suggest names of people who know something about the subject, and when you find yourself attempting to publish a work on an obscure sub-discipline in fire, it is often hard to identify three people who know enough about the subject. Except Jim, of course. He not only knew more than enough about obscure sub disciplines, quite often he had already published multiple papers on those topics! What I found with Jim was that not only was he happy to review a lot of papers, he would also sometimes break reviewer anonymity, so he could get directly involved with the ongoing work.

One of my students was inspired by 'The "Extinction" Criticality' section at the end of his 1980 paper with Thomas, Bullen & McCaffrey. We attempted to publish a paper on this in 2021 (41 years after his original paper was published!), and suggested Jim as one of the reviewers. Very rapidly, I received an email saying:

> *"I should not tell you this, but I am a reviewer on your paper. I am sure it will be a favorable review as I see what has been done, and I have always been deeply interested in this subject. So I wanted to share with you some conference presented work. I am always interested to discuss."*

Attached was a conference paper we had not come across before, and which was very useful in furthering the work. Sadly, despite his optimism, on that occasion our paper was rejected. This news was followed almost immediately by further emails from Jim, with more suggestions and always signing off with various encouragements such as:

> *"Don't be discouraged."*

and

> *"Don't give up."*

We have lost a consistently interested and interesting man, who was a great encourager. Who will I suggest as a reviewer from now on?

Commentary by Dr. Nate G. Sauer, UL Fire Safety Research Institute

One of the early works on the subject, and among early works to solidify the use of the term 'flashover' to describe the transition of a compartment fire from slow growth to rapid and complete involvement. This article by Thomas, Bullen, Quintiere, and McCaffrey would contribute to the foundation of research on the dynamics of flashover. Popular and frequently cited future works would build on this foundation to establish the regions by which we define flashover today, particularly the follow-up work by McCaffrey Quintiere and Harkleroad Estimating Room Temperatures and the Likelihood of Flashover Using Fire Test Data Correlations published in Fire Technology in 1981 [1]. As well as Peacock, Reneke, Bukowski and Babrauksus Defining Flashover for Fire Hazard Calculations and its follow-up work …Part II published in Fire Safety Journal in 1999 and 2003 respectively [2], [3]. The method along with figures from this work were also reproduced in Dougal Drysdale's An Introduction to Fire Dynamics a book that many researchers and engineers have relied on and assuredly spent many late-night hours learning from [4].

This work aimed to examine the role of thermal feedback from combustion and the enclosure to the burning fuel, and how these relationships might affect flashover. Using a theoretical approach and results focus on the impact of radiation on a quasi-steady state energy balance for compartment fires. The relationship between fire energy gains and losses is examined through three equilibrium states (A,B, and C) as intersections of these losses and gains, where the relation defining losses is tangential to the relation defining gains. Two of these intersections, A and C, are stable, ventilation limited, and fuel limited respectively. The third, state B is unstable denotes the region of fuel-limited fire condition, where heat feedback is beginning to drive accelerated fuel gasification and excess ventilation allows for un-checked fire growth. Increases in temperature, driven by heat feedback, increase fuel gasification and thus the rate of energy release and therefore temperature again, energy gains remain higher than energy losses in this region, steadily pushing the fire towards point A (ventilation limited). Similarly decreases in temperature produce resulting lower amounts of gasified fuel, and in this region energy losses remain higher than gains. This continues and pushes the fire towards state C (fuel limited). As such state B is unstable, moving either up in energy state (toward A) or down in energy state (toward C). The feedback and resulting jump in temperature and energy release from state B to A defines the phenomenon of flashover. Five potential flashover processes are given, each with relevant implications still today in modern compartment fires.

I met Dr. Quintiere and Dr. Babrauskas almost simultaneously at an IAAI conference in Frisco Texas in 2018, the summer before I started my own doctoral studies. Quintiere, Babrauskas and I were three of maybe ten or so in attendance with a fire protection or research background. Two names who I had only ever read on the page of a textbook, a sort of fortuitous timing in my own academic career. I talked to Jim for a few minutes, coincidentally just after he had given a presentation on compartment flashover and its characteristic behavior as a thermal instability. He asked me who my advisor was, the answer to which had not yet been determined. And he encouraged me, noting that there was good research happening at WPI, and that fields like arson investigation needed more of it. In hindsight I imagine he was hoping my advisor was his former student Ali Rangwala, an eventuality that became true later that fall. Dr. Quintiere would never hesitate to support our work in the Combustion Lab at WPI, still offering his perspective and serving as a trusted advisor to Prof. Rangwala and his students. I think it is undoubtable that Dr. Quintiere left his mark on all of us in one way or another. Through the sheer volume and significance of the work he accomplished, or the personal stories and mentorship he provided to so many. I imagine we all strive to have as much impact on the field and people of fire protection and fire research as he did.

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Professor Jim Quintiere (U Maryland) and Professor Dougal Drysdale (U Edinburgh)

On methods to measure the energetics of a lithium-ion battery in thermal runaway

Quintiere, J. G., *Fire Safety Journal*, Vol. 111, (2020)

Abstract

Methods are described for measuring the energy released by a Li-ion battery in thermal runaway. A calorimetry technique is described to measure the exothermic energy released during thermal runaway. The technique uses the battery as a calorimeter with temperature and mass loss measurements to analyze the energetics. Runaway is induced by heating of the battery. Only one battery is investigated over a range of heating power and state of charge (SOC). The dynamics of the battery are investigated including time events, temperature, mass lost and energies. The total energy in runaway is manifested by the internal energy stored in the battery and the enthalpy of the ejected mass. Combustion of the ejected gases is described by a technique using the Cone Calorimeter. Results are reported. Both of these techniques are considered less desirable because of the rapid release of energy therefore two new techniques are proposed. The technique of Lyon & Walters using a standard Bomb Calorimeter with nitrogen instead of oxygen to measure the runaway exothermic energy, and measurement of the resulting ejected gas composition to measure the combustion energy.

Commentary by Dr. Veronica Kimmerly, Underwriters Laboratories

This paper provides an over view of several methods to measure the energetic of a lithium-ion battery in thermal runaway. Quintiere starts by explaining the initial method, using an ARC, is not able to accommodate the high temperatures (>200 °C) seen in thermal runaway. Then Quintiere et al developed a second method where the battery itself acts as a calorimeter and the flammable vent gases are analyzed with a Cone Calorimeter. This method can address the high temperatures but it does not have the time resolution needed for how fast thermal runaway can occur. Quintiere then explains that this issue was addressed by Lyon and Walters who developed a method using a bomb calorimeter with a nitrogen atmosphere and quantification of vent gas concentrations to calculate the combustion energy of the vented gases.

Awareness of the fire hazard presented by thermal runaway in lithium-ion batteries has been known by industry and the fire safety field since their widespread adoption in the 1990s, but public awareness has been slow to spread. Several landmark events heralded growing public concern in the 2010s. Quintiere et al.'s 2013 presentation on their method for determining energy rates and total energy from lithium-ion batteries in thermal runaway marked a significant advance in quantifying the fire hazard of thermal runaway. Further developments came in 2016 from Lyon & Walters as the focus shifted from energy rates to total energy released given the rapid nature of thermal runaway.

Quintiere shows the importance of returning to first principles when designing a new measurement method. In this paper he chose to show the energy balance derivation for each method even if it was not included in the original paper. This illustrates how he continues to provide learning opportunities even after his retirement from teaching. I appreciate his candor in highlighting work that offers improvements over his method. A good scientist welcomes being proved wrong. Finally, I greatly enjoy his use of more casual language in this paper. "Nearly 100 kW can be released in 1/2 second!" This is an excellent distillation of the hazard in simple terms for a layperson.

Commentary by Dr. Nate G. Sauer, UL Fire Safety Research Institute

This work was the first of two produced by Quintiere to investigate the energetics of lithium-ion batteries in thermal runaway. Knowing the significance of energy release and its impact on behaviors such as fire growth and compartment fires, the unique behavior of lithium-ion batteries surely sparked interest in Quintiere to quantify their heat release accurately. Up to the time of publication of this paper Accelerating Rate Calorimeters (ARC) were used to measure heat generation in batteries up until thermal runaway. Quintiere examined three types of calorimetry and their ability to measure the extremely rapid and violent process of thermal runaway and cell venting. The first method used the battery itself, which Quintiere named the battery calorimeter. An energy balance considering the internal heat, ejected gas enthalpy, and combustion energy is used to calculate the total energy released. However, finding difficulty measuring or estimating the specific heat of ejected products. The second method considers combustion of the ejected gases using a cone calorimeter. However, this method was found to be problematic due to the exceedingly fast rate of release of gases making complete capture of products difficult. Another method developed by Lyon and Walters 2016 involved an Oxygen Bomb Calorimeter with a nitrogen atmosphere, noting that this technique addresses some of the shortcomings of the battery calorimeter method, especially at higher SOCs [5]. The final method called 'combustion energy' involves the investigation of the composition of the gas captured in the Bomb Calorimeter tests. The theoretical complete combustion energy can then be obtained from each component heat of combustion. While each technique has its own strengths and addresses slightly different portions of the hazard of a lithium-ion battery in thermal runaway, each is important and certainly understanding of the hazards of batteries is of vital importance for the field of fire protection moving into the future.

Although from a younger generation of fire researchers, I was still very much aware of Dr Quintiere from the moment I first opened a fire protection textbook. Of course, Quintiere's own Fundamentals of Fire Phenomena was a keystone work at my alma mater Worcester Polytechnic Institute during my masters classes. This work would also become well known throughout my doctoral studies as it was a reliable reference for what has already been done to solve some of the problems we were trying to address. If Quintiere hadn't already paved the path in front of you, he had certainly started finding the bricks you would need to lay that path yourself.

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More on methods to measure the energetics of lithium-ion batteries in thermal runaway

J.G. Quintiere, *Fire Safety Journal* Vol. 124 (2021).

Abstract:

Experiments have been conducted on a variety of lithium ion batteries to measure their energy output in thermal runaway. Techniques were developed to measure the internal energy release as decomposition of the battery takes place, and combustion energy that can arise from ignited battery gases released in runaway. A nitrogen bomb calorimeter was designed, constructed and utilized to measure the internal energy in runaway. Three techniques were examined for measuring the combustion energy: (1) the Cone Calorimeter, (2) the Oxygen Bomb, and (3) the using a Gas Chromatograph to measure combustion species. The results from these measurement techniques are discussed and compared to the literature for similar batteries. Results generally show for 18650 batteries that the energies in runaway depend on chemistry, decomposition tends to increase with the SOC and can exceed its electric energy by 2-times, while combustion energy can reach 6-times.

Commentary by Dr. Yi Wang, FM

This study builds upon Quintiere's earlier work on methodologies for measuring the energy release from battery thermal runaway [1]. It extensively reviews and investigates the safety aspects associated with lithium-ion batteries, focusing particularly on internal and external (combustion) energy generations from battery thermal runaway.

In this work, a nitrogen bomb calorimeter was designed, constructed, and utilized to measure the internal energy in runaway. The study also revisits different techniques, such as the use of the Cone Calorimeter, the Oxygen Bomb calorimetry, and gas species characterization, comparing their efficacy and accuracy in determining the combustion energy generations. Combined with a review of literature results, the study shows that for 18650 batteries that the internal energy generation in thermal runaway can exceed its electric energy by two times, while combustion energy generation can reach six times. The quantification of these energy generations is crucial for predicting the thermal runaway propagations among batteries and evaluating the associated fire and explosion hazards. This work has been an inspiration to FM's research group to further explore this area and use the calorimetric measurements in both theoretical and numerical modeling to predict the thermal runaway propagation and subsequent fire hazard of battery systems.

The work is not purely academic; it also aims to guide industrial practices. The findings suggest the total energy that must be absorbed by the packaging to prevent the thermal runaway propagation to adjacent batteries. In a follow-up study [2], Quintiere further explored methods to mitigate thermal runaway in battery packages by introducing the use of water-cooling in a capillary flow system within cellulosic sponges as a means to dissipate the high amounts of heat released during thermal runaway.

Collectively, these works contribute significantly to the field of battery fire safety by providing robust methodologies for measuring and mitigating the energetics involved in thermal runaway scenarios. These contributions not only advance scientific understanding but also provide actionable insights for industry practices, aiming to reduce the risk of battery-related incidents.

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Ida Wierzba (University of Calgary), Ghazi Karim (University of Calgary), Jim Quintiere (University of Maryland), Vladimir Molkov (University of Ulster), and Sergey Dorofeev (FM)

A simplified theory for generalizing results from a radiant panel rate of flame spread apparatus

Quintiere, J., *Fire and Materials,* Volume 5, Pages 52–60 (1981)

Abstract

Experimental results on the rate of lateral flame spread and time for piloted ignition under an externally imposed radiant flux were analyzed with a simple theoretical model. The data were developed from a radiant panel apparatus that considers a wall mounted sample with a flux distribution (i.e., of 5 W cm^{-2} at the ignited end to 0.2 W cm^{-2} at the other end). It is shown that after an appropriate preheating time (flux exposure time before sample is ignited) the rate of flame spread (Vr) results can be correlated by $Vr^{-1} = C(q''_{o,ig} - q''_{e})$ where C is a material 'constant' and $q''_{o,ig}$ is the minimum flux for piloted ignition—also a material (and configuration) constant. An extension of this model demonstrates that Vr can also be expressed in terms of an 'ignition temperature' and the surface temperature of the material. Both correlations are derivable from a single flame spread experiment. Results are presented for a number of typical wood and plastic materials.

Commentary by Professor Peter Sunderland, Univ. of Maryland

In 1981 James Quintiere published a seminal paper in Fire and Materials [1]. The apparatus he considered was later named LIFT, the Lateral Ignition and Flame Spread Test [2]. JQ's paper was published while he was at the National Bureau of Standards (NBS), which is now the National Institute of Standards and Technology (NIST). In my opinion it is one of his most significant contributions to fire research.

JQ mentioned that his inspiration came in part from several prominent fire researchers: Howard Emmons, Alex Robertson, and Forman Williams. Robertson [3] of NBS designed the first LIFT apparatus, and then encouraged JQ to explore its scientific underpinnings. In a published comment to Williams [4], Emmons predicted (and Williams agreed) that the success of fire research would require finding "dimensionless correlations of a wide range of fire spread experimental and analytical results." JQ rose to this challenge with his 1981 paper.

Quintiere [1] explains flame spread as a sequence of flame ignition events assuming the gas-phase chemistry is far faster than the fuel heating time. The flame spreads when the fuel surface first reaches its ignition temperature, T_{ig}.

JQ's 1981 manuscript advanced fire research just as Emmons had proposed. As pointed out by Torero [5], previously most fire tests had only allowed materials to be ranked according to flammability. The paradigm shift of [1] was to find the key physical quantities: T_{ig}, thermal inertia ($k \rho c_p$), and what was later named the flame heating parameter (ϕ). These quantities could be measured for any thick solid and were the main parameters in JQ's solution for flame spread rate. Thanks in part to this paper, fire tests were no longer be limited to pass/fail or fuel-ranking tests.

According to Clarivate Web of Science, Quintiere [1] has been cited 71 times. Since 2018 its citation rate has roughly doubled. This can be attributed to several factors, including an increase in fire research worldwide and emerging problems such as façade fires, solids burning in microgravity, and densified wood. But for a paper to be cited 5 times per year 45 years after its publication is a testament to the quality of the work and its impact on our field.

Today the LIFT test is one of the most significant bench-scale fire tests available. Its impact would have been impossible without the clairvoyance of Quintiere [1].

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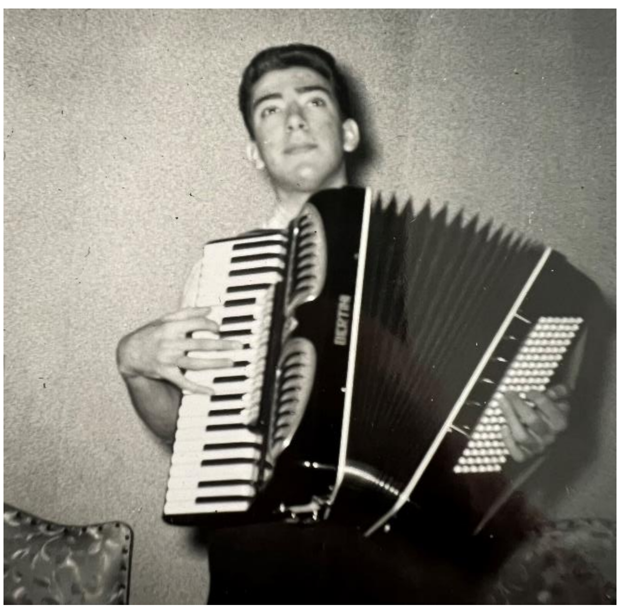

A theoretical basis for flammability properties

J. G. Quintiere, *Fire. Mater. Vol.* 30, pp. 175-214 (2006)

Abstract

Theoretical formulations are presented for the fire growth processes under external radiant heating. They included ignition, burning and energy release rate, and flame spread. The behaviour of these processes with external heating is described along with the critical conditions that limit them. These include the critical heat fluxes for ignition, flame spread and burning rate. It is shown how these processes and their critical conditions depend on a limited number of properties measurable by a number of standard test methods. The properties include heat of combustion, the heat of gasification, ignition temperature and the thermal properties of the material. Alternatively, the properties could be related to parameters easily found from data; namely: (1) the critical heat flux (CHF) for ignition; (2) the slope of the energy release rate with externally imposed flux, defined as heat release parameter (HRP); and (3) the ignition parameter, defined as thermal response parameter (TRP). It is further shown that the flame heat flux differences between small laminar flame ignition sources and larger turbulent flames can affect flame spread due to heat flux and ignition length factors. Finally, it is found that the critical energy release rates theoretically needed for ignition, sustained burning, and turbulent upward flame spread are roughly 13, 52, and 100 kW/m^2, respectively, and independent of material properties.

Commentary by Prof James Tien, Case Western Reserve, University.

Solid flammability is a very complicated phenomena partly because of the existence of large variety of materials (natural and man-made) and the complexity of condensed and gas-phase reactions. There are a few practical tests that measure selected aspects of the solid burning characteristics and rank performance as mentioned in this article. These test results have been used widely by the practitioners. In this paper, the theoretical basis for the tests were explored, and the critical parameters (or relevant material properties) were outlined. The physical processes examined were the limiting conditions of ignition, sustained burning and flame spreads. Since all of these involve gaseous flames, one would expect that the reaction chemical kinetics will be influential. Most practical solid materials may lack kinetic information. Instead, Dr. Quintiere proposed using a number of other criteria to substitute the missing information that can be experimentally determined. These include CHF (critical heat flux for ignition), HRP (heat release parameter), TRP (thermal response parameter), ignition temperature, critical (minimum) burning rate, etc. Physical processes were analyzed using heat transfer principles. The analytic answers contain the key physical mechanisms and the critical parameters. The predicted numerical results were compared with available experiments. Except for a few typos, this is an excellent paper. The authors' approach to these challenging problems is bold and elegant. I found the reading to be very stimulating. On the other hand, although many of the key physical parameters have been identified, additional details can be supplemented as we have seen from the numerous research works on material flammability in the ensuing years.

A framework for utilizing fire property tests

Cleary, T.G, Quintiere, J.G., *Fire Safety Science – Proc. Third International Symposium* (1991)

Abstract

A complete approximate set of equations is developed to describe fire spread over a surface and its resultant energy release. Wall, floor, and ceiling orientations are considered. The needed model data are couched in terms of available test method results, *e.g.*, Cone Calorimeter and LIFT apparatuses. Several applications are presented to show how energy release rates can be predicted and how well they represent real data from full-scale and model room lining experiments.

Commentary by Thomas Cleary, National Institute of Standards and Technology

The simplified theories that Jim had developed for lateral and upward flame spread formed the basis for predicting fire growth hazards from room lining materials using available data from standardized test methods. The solution to the equation for upward flame spread yields two parameters related to heat release rate and burn time that predict acceleratory flame spread behavior. A complete set of cone calorimeter and lateral ignition and flame spread apparatus (LIFT) results along with full-scale room corner experiments for 13 wall lining materials and 9 textile wall coverings gathered in Sweden and the United States respectively, were used to exercise the framework developed. The model results provide a good prediction for experimental fire growth and was one of the first modeling efforts to directly predict fire growth rate from bench-scale test data.

My collaboration with Jim started after I was hired into the materials flammability group located in the Division Jim was the Chief of the Fire Safety Technology Division at the time. Previously I was a student conducting research at NIST on smoke properties. This new role meant I had to learn about solid-phase flammability and materials flammability test apparatuses. The Division office was three doors down from my new office and Jim would walk by several times a day. On one occasion, he passed me some handwritten notes and a handful of reports and encouraged me to take a stab at this problem. I wrote a BASIC program and exercised the model with the numerous bench-scale data. The whole process took about a week, concurrent with my other work, and soon after the paper was written. This effort afforded me the opportunity to present the paper at the Symposium held in Edinburg, Scotland in 1991, and I have fond memories of being treated as Jim's colleague there. Even after Jim left NIST to pursue his second, academic, career at UMD, he was a guest researcher at NIST and several of his students conducted research in NIST labs.

Estimating room temperatures and the likelihood of flashover using fire test data correlations

McCaffrey, B. J., Quintiere, J. G., & Harkleroad, M. F. *Fire Technology*, 17, pp. 98-119 (1981)

Abstract

A simple procedure is presented for estimating room temperature and the likelihood of the occurrence of flashover in an enclosure. The engineer can use the results for quantitative estimations of the effects of building design and fire load, on the tendency for flashover as defined by a temperature limit.

Commentary by Professor Stanislav I. Stoliarov, University of Maryland

This manuscript was published in 1981 in Fire Technology. The manuscript was authored by Bernard J. McCaffrey, James G. Quintiere, and M. F. Harkleroad. All authors worked at the Center for Fire Research of the U.S. National Bureau of Standards at the time of the publication.

As the title of the manuscript suggests, the objective of this study was to develop an engineering approach to the calculation of the gas temperature in the upper portion of an enclosure based on the knowledge of the fire heat release rate, enclosure ventilation and geometry, and thermal properties of the wall materials. To achieve this objective, the authors combined fire plume theory, a theoretical expression for the buoyancy driven gas flow through an opening, and a generalized heat loss representation to define the key non-dimensional parameters that are expected to correlate with the gas temperature. The authors proceeded to use the data from over hundred full-scale experiments to develop an analytical expression that relates these non-dimensional parameters to the upper layer gas temperature. The authors also demonstrated how this analytical expression could be used to determine how the room size, the size of the ventilation opening, and thermal properties of the wall material affect the critical heat release rate that leads to a flashover (with the flashover defined by a critical upper layer gas temperature value).

To me, this work represents one of the greatest examples of Prof. Quintiere's approach to unraveling complex physical problems: the approach that consists of using fundamental physical theory to develop a framework for a solution and high-quality experimental measurements to arrive at a relatively simple analytical formulation that captures enough complexity to deliver meaningful engineering predictions. In the introduction, the authors put forward a rather modest claim indicating that they offer an "interim" solution that will be replaced by more comprehensive physically based models in a few years after the publication. Well, 44 years after this publication, the expression, which became known as "MQH correlation", remains arguably the most widely used engineering approach to estimation of enclosure fire conditions. The longevity of MQH correlation is a testament to the genius of its creators. It is also important to note that this work is one of a series of groundbreaking studies authored by researchers from the U.S. National Bureau of Standards (which later became the National Institute of Standards and Technology or NIST) that led to the transformation of the fire safety science from a purely empirical discipline to a discipline based on a strong theoretical foundation. Prof. Quintiere will always be remembered as one of the founders of the modern fire safety science.

Commentary by Professor Fred Mowrer, former colleague at University of Maryland

This seminal paper, which describes the bases and closed-form equation for what is now commonly referred to as the MQH correlation, was published in Fire Technology in May, 1981. It followed a simpler, but less rigorous method for estimating room flashover potential that had been published by

Babrauskas in 1980 [1] and preceded by a few months an alternative methodology published by Thomas in September, 1981 [2]. Of these three well-known methods for estimating flashover potential, the MQH is the most versatile because it accounts for the heat transfer characteristics of different room lining materials. Unlike the other methods, the MQH correlation also permits the estimation of pre-flashover hot gas layer temperatures. The MQH correlation is more commonly used to make such preflashover temperature estimates than it is for flashover prediction.

I first became familiar with the MQH correlation shortly after it was published in 1981. This was at the end of my first year of graduate studies in Fire Protection Engineering and Combustion Science at the University of California, Berkeley. At that time, Professor Brady Williamson and Fred Fisher, the fire research lab manager at the university's Richmond Field Station had a research grant from NBS (now NIST) to develop a room fire test method based on the principal of oxygen consumption calorimetry [3]. At the time, practical implementation of oxygen consumption calorimetry at this scale was just being established. This was the seminal work leading to the development of many current standard room fire test methods, including NFPA 265, NFPA 286 and ISO 9705. Professor Quintiere was the Chief of the Fire Research Division at NBS during this period.

As an aside, Professor Quintiere and a number of colleagues and students, including Tom Cleary [4] at NIST, and Scott Dillon [5], Jerry Haynes and Brian Rhodes [6] at UMD to name a few, would subsequently use the results of ISO 9705 tests with different lining materials to develop and calibrate flame spread prediction models. But Professor Quintiere's monumental work on material flammability properties and flame spread should be the topic of another commentary.

As part of this early 1980s research program at Berkeley, we conducted dozens (if not hundreds) of fire tests using what is now the standard gas-fired burner with heat release rates ranging from 40 to 160 kW. For all of these tests, the square burner was positioned directly in contact with one of the rear corners of the standard 2.4 m x 3.6 m x 2.4 m high room with a 0.8 m wide by 2.0 m high doorway in an end wall. During all these tests, the room was instrumented with thermocouples located 0.1 m below the ceiling surface at the quarter-points and the center of the room, as well 0.1 m below the center of the doorway opening. Thus, we had lots of temperature data to evaluate the MQH correlation for this room and corner burner configuration.

Another development during this early 1980s time frame was the first availability of personal computers bundled with software. I obtained an Osborne computer that came bundled with the WordStar word processing program, the SuperCalc spreadsheet program and a couple of BASIC compilers. One of the first things I did was to program the MQH correlation into SuperCalc and gave the template the name TEMPEST for TEMPerature ESTimation. As many of our mutual students will recall, this was the first of the many "FREDsheets" I continued to develop at UMD.

Unfortunately, when I compared the temperatures we were measuring in the room corner fire test with the MQH correlation, I found the measured temperatures to be much higher than the temperatures predicted by the MQH correlation. Without giving it too much more thought at the time, I set this problem aside. At this point, the MQH correlation was not well known and only a few fire protection engineers were performing fire dynamics calculations in professional practice.

It was a few years later, while still a graduate student working with the room fire test method, that I revisited this issue both experimentally and analytically. Experimentally, we conducted a few fire tests with the burner moved from the corner to the center of the room, against a side wall and against the rear wall. Temperatures were measured 0.1 m below the ceiling at the same quarter-points, center-point and doorway, as before. Analytically, I realized that the rate of air entrainment is restricted when a burner is placed against a boundary and used the concept of reflection suggested by Zukoski [7] to modify the entrainment rate for burners located in a corner or against a wall. However, the change in entrainment rate alone did not account for the observed changes in temperatures for these burner locations because as the entrainment rate reduces, the smoke layer interface moves up, resulting in a reduced entrainment rate but over a longer vertical distance. The details of this analysis are documented in Reference [8] in 1987. This analysis suggests that fires along walls produce hot gas layer temperature increases approximately 30% higher than predicted by the MQH for wall fires and approximately 70% higher than predicted by the MQH correlation for corner fires. These became known as the Mowrer-Williamson modification factors to the MQH correlation.

In 2003, Professor Quintiere worked with colleagues at FireSERT University of Ulster to revisit the MQH correlation to describe center and corner pool fires [9]. It was gratifying that one conclusion of this study was to lend support to the Mowrer-Williamson modification factor for corner fires. However, it is also important to recognize that this 2003 study also identified additional factors that need further investigation for further evaluating and refining the MQH correlation.

One of my thoughts over the years regarding the original MQH correlation is that it was based on available room fire test data acquired largely during the 1970s. Many of these fire tests used wood or plastic cribs, or gas burners, located on the floor in the center of the room as the fire source, so there is a bias in the data. When we tried to apply the MQH correlation to corner fires in the standard fire test room, our analysis showed that reduced entrainment rates for fires along boundaries resulted in higher hot gas layer temperatures, as would be expected with less air flow.

It is also expected that elevated fires would also result in reduced entrainment rates and, therefore, would similarly be expected to result in higher hot gas layer temperatures than predicted by the MQH correlation. It is suggested that a fitting tribute to Professor Quintiere (as well as the other deceased members of the MQH team) would be for a student take on a project to evaluate the effect of elevated fires on MQH temperature predictions.

As a closing comment, I think this is one of many good examples of the lasting impact Professor Quintiere has had on the fire safety science community. The MQH correlation was developed more than 45 years ago based on sound dimensional analysis arguments and has largely stood the test of time. It is perhaps the most-used equation for estimating fire hazard throughout the international fire safety profession. But even with its widespread application, Professor Quintiere, in his inimitable way, continued to evaluate and attempt to improve on this seminal work. He never stopped probing!

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A unified analysis for fire plumes

J.G. Quintiere and B.S. Grove, *Symposium (International) on Combustion* (Vol. 27, No. 2, pp. 2757-2766), 1998.

Abstract

A unified analysis based on an integral approach is presented for fire plumes involving finite axisymmetric and rectangular sources. The analysis, using Gaussian profiles, obtains the best fits to experimental data found in the literature. Phenomenological constants in the theory are found to give consistent results in that coefficients expected to be numerically similar by theory are found similar among the various data sets. Thorough reviews of the literature data for line and rectangular sources are presented and yield consensus correlations, accordingly. The effect of flame radiation is explicitly included by a radiation fraction that proves to be a significant variable, previously overlooked in experiments. Effective entrainment coefficients for the far-field non-combusting plume are found to be 0.09 to 0.10, and for the flame region about 0.22 for the axisymmetric and rectangle cases as long as D/L . 0.1. For D/L , 0.1, the infinite line gives nearly double the flame entrainment. Generalized results are presented for entrainment rate and flame height in terms of single algebraic equations that span a wide range of Q* or energy release rate values. For low Q* fires, the effect of diameter and line width are important and expressed by the theory but not enough to address dependence involving Grashof and possibly Froude number effects near the origin. Laminar results are also addressed.

Commentary by Dr. Sara McAllister, Rocky Mountain Research Center

This paper is certainly a one-stop shop for all things fire plumes. The Combustion Symposium format means that the material is very dense. Impressively dense. It includes integral solutions for axisymmetric, line, and rectangular fires, compares these solutions to data from the literature, and provides fitted constants for the solutions to the data. It includes entrainment rates and axial temperature and velocity profiles in both the near and far fields, as well as flame heights. All this in 10 pages with a commentary. Once we managed to digest the material, this work has been extremely valuable to our group because it actually addresses line fires, and does so with equal weight to axisymmetric fires. Line fires were in fact the given motivation: "This work was motivated by the need to synthesize the literature results for line plumes." Line fires are an often-overlooked configuration that are critical to wildland fire. The typical fuels consumed in a wildland fire are fine fuels like blades of grass or fallen pine needles. Because they are so small, they burn out quickly, resulting in a finite flame zone depth (distance from the point of ignition to the end of flaming combustion). Once the fire has spread sufficiently from the ignition point, the classic approach is thus to treat the problem as an infinitely long line fire. Of course, axisymmetric plumes have their application in wildland fire as well, such as considering an individual torching tree or when considering the large-scale plume-atmosphere interaction. Laying out the axisymmetric next to the line fire solutions in the tables makes it easy to see the important differences between these two cases. Given all the information that's packed into this paper, it's no surprise that the well-worn hard copy never seems to get buried too deeply on my desk.

Scaling applications in fire research

J.G. Quintiere, *Fire Safety Journal*, 15(1), pp.3-29, 1989.

Abstract

The principles for scaling fire phenomena are examined from the dimensionless groups derived from the governing differential equations. A review of the literature shows examples of where correlations have been successfully developed for a wide range of fire phenomena in terms of the significant dimensionless groups. Scaling techniques based on Froude modeling, pressure modeling and analog modeling are described and illustrated. The use of small geometric models ranging from fire plumes to enclosure fires are illustrated by many examples.

A unified analysis for fire plumes

J.G. Quintiere and B.S. Grove, *Symposium (International) on Combustion* (Vol. 27, No. 2, pp. 2757-2766), 1998.

Abstract

A unified analysis based on an integral approach is presented for fire plumes involving finite axisymmetric and rectangular sources. The analysis, using Gaussian profiles, obtains the best fits to experimental data found in the literature. Phenomenological constants in the theory are found to give consistent results in that coefficients expected to be numerically similar by theory are found similar among the various data sets. Thorough reviews of the literature data for line and rectangular sources are presented and yield consensus correlations, accordingly. The effect of flame radiation is explicitly included by a radiation fraction that proves to be a significant variable, previously overlooked in experiments. Effective entrainment coefficients for the far-field non-combusting plume are found to be 0.09 to 0.10, and for the flame region about 0.22 for the axisymmetric and rectangle cases as long as D/L . 0.1. For D/L , 0.1, the infinite line gives nearly double the flame entrainment. Generalized results are presented for entrainment rate and flame height in terms of single algebraic equations that span a wide range of Q* or energy release rate values. For low Q* fires, the effect of diameter and line width are important and expressed by the theory but not enough to address dependence involving Grashof and possibly Froude number effects near the origin. Laminar results are also addressed.

Commentary by Professor José L. Torero, University College, UK

Understanding the impact of someone's work requires to look at a sequence of studies that many times cover long periods of time. Only as knowledge acquisition progresses the fundamental objectives are met, and clarity of outcomes is achieved. This is very much the case with the work of Prof. Quintiere. The impact of his work is centered around fundamental explanations to complex fire problems that use simple mathematical tools to extract the key governing principles. The objectives might be clearly set early on, but the outcomes many times take a decade to achieve. The two papers presented here describe two stages in the progression of understanding and are a perfect example of the tenacity of Prof. Quintiere when pursuing the "unified solution." These papers are only two moments in time, and there are many other relevant papers before, in between and after these two papers. Nevertheless, the first paper crystalizes a general objective while the second paper presents a "unified solution" to one of the problems identified in the first paper. The hope is that through a commentary that focuses on two papers, and example will be constructed that illustrates the vision and impact of Prof. Quintiere.

In “Scaling Applications in Fire Research” a clear objective is defined: “The complexities of fire preclude complete mathematical solutions to its problems. Consequently, a deliberate strategy of scale modeling, based on the governing laws of physics, is both an essential and practical means of obtaining general results. The use of dimensional analysis leading to the significant dimensionless parameters is a well-known technique for generalizing experimental results and for establishing the 'laws of scaling' for a system.” This paper is to borrow from classical disciplines such as heat transfer a method that enables to extract the fundamental laws governing fires from experimental results conducted at a scale smaller than that of a real fire event. While precision will be inevitably lost, the insight obtained will enable predictions of real scale fire behavior: “The study of a fire phenomena at a scale suitable for laboratory observation can also give insight on the mechanisms and behavior of the system, even if it does not give exact quantitative results.”

The starting point of many of Prof. Quintiere’s papers will inevitably be Philip Thomas, this paper is no exception [1]. Philip Thomas and Jim Quintiere had an extraordinary personal and intellectual connection based on mutual admiration and respect. Their philosophies, when it came to describing fire problems, were very similar and complementary, hence they will often cross-reference each other. In a seminal paper on scaling applications Thomas acknowledges that it is Quintiere in “Scaling Applications in Fire Research” who “has extended the discussion of the application of dimensional analysis to fire problems” [2]. Following an exhaustive, and deep analysis of the literature, the introduction ends, with yet another of Prof. Quintiere’s trademarks, the delivery of adequate proof and demonstration as the art of handling a complex problem where many aspects of it remain misunderstood: “scaling in fires is an art which requires attention to ignored phenomena and adequate proof and demonstration that the scaling technique is proper.”

The paper then extracts from the conservation equations, and their boundary conditions, fourteen non-dimensional parameters that explain all modelling strategies used by prior studies. Assumptions and simplifications are justified on the basis of these scaling parameters and new dimensionless groups substitute classical parameters as part of these simplifications. Among the key outcomes is the formalization of the power laws that govern fire plumes. Length scales, velocities and the rules that govern self-similar temperatures and velocity profiles in fire plumes are all described as a function of the key dimensionless parameters. Many of these representations will appear in subsequent studies in forms that are now very familiar (ex. [3]) to all those working in fire research and practice, and that extend its application into many fire problems including CFD formulations. In a subsequent paper [4], Prof. Quintiere will benchmark CFD computations using these same scaling laws.

The paper will also conduct a similar analysis of ceiling jets, burning rates, flame spread, growing and fully developed enclosure fires. In all these cases a set of driving parameters is identified. These parameters will influence the relevant literature for decades, with many publications using the same non-dimensional parameters to characterize these different phenomena. The fundamental value centers on the use of the same principles to describe all the different phenomena. While others might have reached similar scaling laws for specific problems, this paper represents the first publication where the different processes are treated as sub-cases of the same universal laws.

Ten years later, these universal laws, that branched into many different processes, had produced tangible results that enabled the synthetization of much of the existing data into simple descriptive correlations that could be used by practicing engineers for design and fire investigations. “A unified analysis for fire plumes” is an exceptional example of a simple method, based on the scaling laws obtained in the 1989 paper, that allowed to unify different fuel geometries from the axis-symmetric pool fire to the one-dimensional line fire.

Like most of his papers with his MSc students at the University of Maryland, Prof. Quintiere invested himself deeply in the work, way beyond what it will be normally expected from a supervisor. This paper is a very good example of his attitude towards research. His investment was such, and I am sure Brian Grove will not mind me saying so, that his students many times did not fully understand the depth and importance of the papers that carried their names. I do have to admit, that this was also the case for me when we worked together on ignition.

"A unified analysis for fire plumes" opens by saying "This study will demonstrate how a theory can unify experimental correlations for fire plumes—dissecting them into two regions: the "near-field" combustion zone and the "far field," having a point source character." Correlation of the fundamental laws with extensive experimental data provides a unified approach towards representing the data and allows to identify the roles of length scale, "fire power – " and radiative losses, finally delivering, as indicated in the conclusions: "a unified analysis that correctly expresses the behavior of finite axisymmetric and rectangular fire plumes." Independent of the evolution of modern analysis and prediction tools, the fundamental physical processes and the scaling laws describing them as identified in these two papers, will remain as the means to represent data and predictions.

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Commentary by Brian S. Grove, ATF

As a master's student at UMD I had the privilege of working with Prof. Quintiere as my adviser on my thesis "Correlations for Infinite Line Fires" found in the NIST publication "Correlations for Fire Plumes" [1]. The paper "A Unified Analysis for Fire Plumes" is based in part on this thesis.

The work was funded by NIST in recognition of the lack of attention applied to fire phenomena from non-axisymmetric fuel sources to include "line fires". Dr. Sara McAllister's commentary in this publication would have made Prof. Quintiere smile as he always cited the advancing front of a forest fire as the paragon of a line fire. Additionally, the only published comment to the paper concerned crosswinds for altitudes of interest (0-1000 m) for stratification and plume rise indicating the communities' acknowledgment of the utility of these correlations to large fires outdoors.

Our work was broken into two parts. Prof. Quintiere worked on the theory and developed the equations. I conducted literature searches and assimilated data from wide ranging fire power sources (Q*) onto charts with dimensionless variables. These sources ranged from a heated resistance wire to fires nearing transition from buoyancy to momentum dominated. The equations were then fit to this data yielding empirical constants and complete correlations.

Throughout this process I spent many hours in Jim's office watching him develop our equations from first principles. A notepad of handwritten theories and equations in immaculate penmanship grew in size with each of our sessions. Not only did he produce equations from first principles he also worked without a calculator, grinding out basic math in his head with an ease that only comes from repetition. In his commentary in this publication Dr. José Torero wrote, "His investment was such, and I am sure Brian Grove will not mind me saying so, that his students many times did not fully understand the depth and importance of the papers that carried their names". Dr. Torero is correct on both counts.

I think the most important skill I learned from Prof. Quintiere was his ability to analyze a problem and find simplified solutions that were good enough for the resolution demanded of the answer. This is epitomized when later in life during my career at ATF Jim was frustrated that we weren't bringing our equipment online fast enough. "No one will ever get convicted over a few kilowatts", he said.

I had the privilege of presenting our paper at the International Symposium on Combustion in Boulder, CO. I remember being very nervous as I was preparing to present a subject on which I had a surface knowledge to a group of highly intelligent scientists and engineers. During my presentation one individual stopped me on three separate occasions and asked me questions that I did not completely understand. After the third question Prof. Quintiere stood up and turned to the man and said, "It's physics." I never had another question after that.

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Numerical simulation of axi-symmetric fire plumes: accuracy and limitations

T. Ma and J. G. Quintiere, *Fire Safety Journal* Vol. 38, pp. 467–492.

Commentary by Professor Arnaud Trouvé, University of Maryland

The paper by Ma & Quintiere presents an early evaluation of the performance of the computational model called Fire Dynamics Simulator (FDS). FDS is a free, open-access, open-source, fire model developed by the National Institute of Standards and Technology (NIST); FDS was first released in 2000 and has since then become the leading fire simulation software used by fire engineers and fire researchers around the world. FDS is a general heat transfer model, i.e., a combination of a Computational Fluid Dynamics (CFD) solver that simulates heat transfer processes through gas flow, a radiation solver that simulates heat transfer processes (across gas, solid and liquid matter) through propagation of radiant energy, and a solid-phase solver that simulates heat transfer processes through heat conduction and thermal radiation inside inert or thermally degrading solids. The paper by Ma & Quintiere focuses on the CFD component of the FDS fire model.

The paper presents a theoretical and computational discussion of the main features of fire plumes in canonical open pool fire configurations. The evaluation of the performance of FDS is made through comparisons between simulation results and established correlations taken from the fluid mechanics and fire research literature. These comparisons describe the variations in temperature, vertical flow velocity and vertical mass flow rate as a function of vertical distance above the burner surface. Such correlations are now considered standard material in courses and textbooks on fire dynamics (many of them written or co-written by Professor Jim Quintiere); they provide insight into the buoyancy-driven mechanics of the flow and also provide methods to calculate the production of smoke in pool fires. The paper includes a detailed presentation of fire plume theory and in particular a discussion of the dominant role of a non-dimensional scaling parameter called *Q*-star (Eq. (12)). *Q*-star, used by the fire research community, is the equivalent of the flame Froude number used by the combustion science community: "large" values of *Q*-star (i.e., values between 0.2 and 10) correspond to most laboratory-scale pool fires; "small values" of *Q*-star (i.e., values below 0.2) correspond to large diameter industrial-scale pool fires.

The paper also includes a careful evaluation of the grid resolution required in simulations of pool fires. This is one of the main contributions (and in my view, the main lasting contribution) of the study by Ma & Quintiere, in particular because the fire research literature does not provide clear guidelines on the selection of grid resolution in simulations of fires. On one hand, computational cost increases strongly with higher numbers of computational cells (i.e., with increased levels of spatial resolution); on the other hand, accuracy decreases significantly with lower numbers of computational cells (i.e., with decreased levels of spatial resolution). The question then becomes to determine the best trade-off between these conflictual requirements in computational cost and accuracy. Ma & Quintiere provide a response to this question through a criterion, presented in Eq. (35), that compares the grid cell size to a characteristic length scale of the pool fire problem called *z*-star (*z*-star is defined in Eq. (19) and is also known as *D*-star in the FDS documentation). The criterion proposed by Ma & Quintiere formulates an idea that was novel at the time of their study and that is now an established rule for best practice when selecting grid resolution in CFD applied to fires: (1) compare the grid cell size, noted Δx, to the characteristic physical length scale(s) of the problem; and (2) provide approximately 10 grid cells across that (or those) characteristic physical length scale(s). The validity of the criterion proposed by Ma & Quintiere is evaluated in Section 5 of the paper by performing a gridconvergence study that shows that numerical results are quasi-independent of choices made in grid resolution provided that the criterion presented in Eq. (35) is satisfied.

Note that the criterion proposed by Ma & Quintiere is often misunderstood: many CFD practitioners use the same criterion for problems that do not correspond to pool fires and miss the point that the criterion should be adapted to new configurations of interest rather than directly applied without analysis. The selection of the grid resolution is a crucial design step in a computational project that requires a thought process and some insights into the dominant features of the fire scenario to be simulated. In my view, one of the reasons why the criterion proposed by Ma & Quintiere is often misunderstood is because it is not written in the most intelligible way: the criterion would gain in clarity if instead of using an abstract length scale, *z*-star (or *D*-star), it would acknowledge the presence of two relevant length scales in the pool fire problem, the vertical flame height, L_f, and the horizontal dimension of the burner surface, D, and would then require suitable resolution of both length scales, $(L_f/\Delta x) \geq 10$ and $(D/\Delta x) \geq 10$. In this more general framework, it is the CFD practitioner's responsibility to identify the new relevant length scales, L_f, D, etc, in their configuration of interest. This more general framework has also the advantage of drawing the attention of the CFD practitioners to the possible presence of several length scales, rather than just one. In fact, the study by Ma & Quintiere shows the importance of the two length scales that control the main features of pool fires: at "large" values of *Q*-star, the flame height is larger than the horizontal dimension of the burner surface, $(L_f/D) \geq 1$, and the grid resolution requirement is controlled by D; in contrast, at "small values" of *Q*-star, $(L_f/D) < 1$ and the grid resolution requirement is controlled by L_f. While this change in the geometry of the problem is well understood by Ma & Quintiere, Figure 4 (left figure) suggests that in their series of simulations, the cases with the lowest values of *Q*-star (0.1 and 0.2) are significantly under-resolved (the criterion $(L_f/\Delta x) \geq 10$ is not satisfied).

Overall, the study concludes that FDS performs well for *Q*-star values above 0.2 and the early validation study by Ma & Quintiere confirms the potential of FDS as a tool for both engineering-level and research-level computational projects, a conclusion that since then, has been confirmed many times.

In conclusion, the paper by Ma & Quintiere is a brilliant contribution to the goal of establishing the performance of the FDS fire model. The study is grounded on a deep understanding of fire plume theory and applies the power of scaling analysis and engineering correlations to the validation of FDS. To some extent, this is a study that uses the engineering tools of the past - scaling analysis and correlations based on integral models - to establishing the emerging power of the engineering tools of the future - CFD in general and FDS in particular.

Another sign of the emerging power of FDS is that the analysis was conducted by Dr. Tingguang Ma, at the time a Master of Science (MS) student at the University of Maryland. Whereas until the 1990s, CFD software products were generally considered advanced engineering tools that could only be operated by an expert workforce (usually PhD graduates), FDS brought simplicity and user-friendliness to fire modeling projects, with the ambition to make the simulation software accessible to the wider fire engineering community; the profound changes in the educational profile of CFD practitioners spearheaded by FDS can be seen in the present study through the leading role played by an MS student.

Finally, it is also telling to see Professor Jim Quintiere, one of the main architects of scaling analysis applied to fire science and one of the leading experts in the zone modeling approach that was the dominant fire modeling approach in the 1980s-1990s, embrace the new CFD approach to fire modeling, even though the adoption of CFD would ultimately correspond to the waning of the approaches that he had previously championed. This is a sign of the constant curiosity, open-minded attitude, technical versatility, confidence in the future, and visionary thinking that were some of the traits of Professor Jim Quintiere.

L to R: Kunio Kawagoe, Weicheng Fan, Toshisuke Hirano, Jim Quintiere, Geoff Cox.

Memories of Prof. Quintiere

Commentary by Tensei Mizukami, Building Research Institute, Japan

I joined Dr. Q's laboratory in Univ. of Maryland in 2005 as a visiting researcher. Pock (Dr. Utiskul, US Coast Guard) was Ph.D candidate at the time. And I had simulated his compartment fire experiments by BRI2, 2-layer smoke zone model developed by Prof. Tanaka. Dr. Q organized Wednesday meeting with Prof. Trouve, Marshall and their students; Nicolas, Hu, Vivien, Ken and me. It was great pleasure to discuss with them about compartment fire. And I was so proud when Dr. Q was happy for the good calculation results saying "We have a good team!"

The lab was very international, and there were also Yi, Darlene, Ming, Monique, Sean and Peter. Dr.Q always took care of the students, and sometime took us to swing dance party at Glen Echo Park. I was very bad and back away from partner at the beginning. But gradually, I get to know that I cannot establish trust unless devoting myself. And it was the same for research in his lab. He was a good dancer as well as a research partner having a broad mind.

On my 25th birthday in 2006, he also invited me to tango dance. However, my friends planned a sukiyaki party for me. He joined us instead and told me that he was in rehabilitation on his 25th birthday and writing a thesis in the summer house near the beach. I got to know he was 65 years old at the time, but couldn't believe it since there was always a sparkling light behind his eyes, like the boy in front of ice cream. (He also told me that he lived upstairs of ice cream shop in his childhood, and he still loved it.)


He also invited us to his house. His bookshelf has a wide variety. The garden was full of flowers and fruits. There was a beautiful harmony of wisdom and nature, as if he were playing the piano. After returning to Japan, I start building my house by myself in a forest, following Dr.Q's example. He used to say that the advantage of smoke zone model against CFD model is its simplicity. And it reminds me of Mies van del Rohe aphorism, "Less is more". So, I stick with natural materials and traditional techniques, which allows me to hold the whole house in my hand. I kept in touch with him by Christmas card showing how much progress I have made in this year. He always sent me a reply back with his photo at the Mummers parade. And finally, I could tell him it's completed in 2023 after 15 years journey. I am sorry that he couldn't come to the housewarming party; I wish he saw the same harmony in it as his house. This is just one of small case, but your passion and mind are handed over all over the world.


The Big Man, Jim Quintiere

Commentary by Alexander Snegirev, Ghent University, Belgium

"Have you already read my new book?" This question was asked after a good English beer arrived at our table in a pub near the venue of the third ISFEH conference, held in 2000 at Windermere Lake in the UK. At that time, I was working at the Fire Research Centre of the University of Central Lancashire, and this conversation stands out in my memory as the first one when Jim not only inquired about my work but also wanted to know how his books were being used in teaching. Of course, they were used intensively – thanks to their clarity, conciseness, and scientific elegance.

Conference dinner in St. Petersburg, 25 April 2019

Until 2018, the frequency of our meetings was limited to fire and combustion conferences that I could attend. On several occasions, Jim mentioned that he had received my paper for review, and this was a unique opportunity to immediately discuss his comments face-to-face. I had the privilege of presenting my work in informal seminars at UMD in 2016 and 2018. During my first visit to College Park, Jim took me to the Airspace Museum and asked the same question about the new edition of his another book. He radiated aristocratic confidence, personal and professional curiosity, critical thinking, encouragement, and a fine sense of humor – all perfectly balanced. These qualities made him a brilliant collaborator and an inspirational mentor. Hence my enthusiasm lit by his invitation for me to join the research program that culminated in BRE (Burning Rate Emulator) orbital experiment performed onboard the International Space Station. Jim passionately pursued the idea to emulate combustion of condensed fuels by taking full control over the fuel gasification rate.

While working with the same experimental database, we appeared to focus on its different aspects. Jim was particularly interested in exploring the existence of steady diffusion flames above a flat fuel surface in microgravity [1, 2], whereas I concentrated on flame dynamics once the flame became unstable [3]. This divergence began when simulations revealed the potential uncertainty of the conclusions based on the short-duration drop tower tests. Indeed, the flames appearing steady during first 4-5 seconds (the duration of microgravity in the drop tower) were predicted to become heavily unstable just a few seconds later. Yes, we shared a reasonable skepticism towards blind CFD simulations. It took about two years before the orbital tests confirmed that many of tested flames did indeed become unstable – exhibiting fascinating dynamics prior to complete extinction which was notably similar to that in the predictions.

Jim and his colleagues at UMD published several important papers in Combustion and Flame to elaborate the theoretical background generalizing the experimental database [1, 2]. Around that time, I proposed an alternative formulation to delineate the boundary between the distinct combustion modes and presented it to Jim. He challenged every statement of that formulation. Thanks to the evolution of communication technologies during the COVID era, we were able to have many detailed discussions online. His conclusion was: "We are converging"; the paper on radiative extinction of microgravity diffusion flames was then submitted to and published in Combustion and Flame [4]. This was a thrilling experience, which I am deeply grateful for.

In 2019, the ISFEH conference was organized and held in St.-Petersburg. Jim was eagerly involved (please see the pictures taken during this event), and his contribution was remarkable. He delivered a compelling plenary talk on scale modeling of fires, and, on top of that, presented his ongoing research on thermal runaway in battery fires. I highlight this diversity to underscore the encyclopedic breadth of his expertise which is so vividly reflected in this compilation of his research and in the memories shared about him. He was truly a big man in every sense.

The most recent message from him in my mailbox was received just few weeks before the sad news. It referred to the ESFSS conference in Barcelona which he could not attend in person. Jim wrote to me and his former PhD student, Parham Dehghani: "… I am slowing down but fine. I am so happy to see you both at a fire conference. Jim Q".

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Jim Quintiere at the 9th International Seminar on Fire and Explosion Hazards, St.-Petersburg, 2019

The gift of firepower

Commentary by Jonathan Perricone, former Graduate Student.

I was first introduced to JQ as a student in his undergraduate Fire Dynamics course. I had seen and heard him speak often from afar in the Fire Protection Engineering hallway/classroom/office area of the Engineering Building's first floor. It was obvious from afar that he was uniquely confident, intelligent and engaging. As a young student excited to learn, I felt drawn into the group of other students, professors, consultants, researchers, practitioners and firefighters always seeking his advice.

As a student in the Fire Dynamics classroom, I was instantly impressed with JQ's ability to effortlessly pull equations out of thin air while explaining a new or different perspective. Looking back on those lectures, I realize that he was approaching problem solving like storytelling. We were all on a journey to find solutions, but along the way there was still so much to notice and learn if we could find the right tools to help. JQ used his rare ability for simplification to give us those tools. In this way, he empowered contemporary and future audiences to engage with seemingly intractable problems like the collapse of the World Trade Center.

Towards the end of my semester in Fire Dynamics, I was fortunate enough to be approached by JQ with an opportunity to pursue a Master's Degree in Fire Protection Engineering under a grant from the National Science Foundation. The plan was to study scale modeling of wood crib fires in compartments as part of a parallel effort with structural engineer Dr. Peter Chang and his graduate student Ming Wang. I was fascinated by the idea that the heat load of an entire floor level of an office tower could be studied using bench-scale, solid, ordered piles of wood sticks burning inside a small insulated box. Working with fellow grad student Peter Veloo, we quickly realized the importance of patience in repeatedly assembling these precisely cut, glued and dried piles or "cribs" of different sizes. But all of that attention to detail paid off in the form of very repeatable and predictable transient growth, steady-state and decay curves for burning rate, free from the confines of any surrounding compartment. This was our baseline. We had demonstrated a potential for using solid fuels in models instead of gas burners.

Building compartments with different insulating materials at three different scales with all of the necessary instrumentation was our next challenge. We also quickly realized the potential for the plumes from those small flashover events to overwhelm the exhaust hood in our little lab on the first floor of the Potomac Building. So, JQ put in a call to a couple of former students at the ATF lab in Beltsville. We rented a U-Haul and moved our setup from the Potomac Building to the ATF for the largest of our experiments. On the way, JQ went a little too fast over a speed bump and there was a loud crash in the back. As we rushed to repair the compartment, I remember him reassuring me that he would do whatever he could to help. I also remember feeling confident and determined to succeed. This was JQ's greatest gift to me. Setbacks and challenges are an inevitable part of professional life. He role modeled an approach to problems both big and small with great resolve. I'm sure there were times when he was overwhelmed by challenging problems, but he never let that shake his confidence in his own ability to keep moving and making a difference in fire research.

I think of JQ often now as so much of the professional world is held captive by fear of scarcity. When I do, I remember the abundance of tools he created for me to take on any problem at any scale. With that, the fear becomes fuel for the fire within.

L to R: Jim Milke, Robert Gagnon, Steven Spivak, Jack Watts, John Rockett, Jim Quintiere, George Dieter, Vince Brannigan, Marino diMarzo, Jose Torero and Harry Hickey.