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In Celebration

## Professor Issam Mudawar on his 60th birthday



This article is in celebration of the 60th birthday of Dr. Issam Mudawar, his achievements as a distinguished scholar in mechanical engineering, and his outstanding contributions in the field of heat and mass transfer. He is a well-known expert for his research in thermal engineering and highly respected among colleagues, friends, and students all over the world. As a Professor of Mechanical Engineering at Purdue University, his primary research interests include two-phase flow and heat transfer, materials processing, electronic cooling, thermal management of aerospace systems, and nuclear reactor safety.

Professor Mudawar was born in Beirut, Lebanon, in 1955. During his pre-college years, he excelled in mathematics and physics, which were paralleled by a strong passion for oil painting, sculpture and study of art history. While his initial plans were to study art and architecture, he ultimately settled for mechanical engineering. He pursued undergraduate studies at the American University of Beirut, where he discovered the broad and exciting opportunities mechanical engineering offers. In 1978, he immigrated to the United States, where he pursued his graduate studies at the Massachusetts Institute of Technology (M.I.T.). He credits his years at M.I.T. for paving a lifelong career dedicated to the study of two-phase flow and heat transfer, having worked closely with some of the world's greatest pioneers in the field. He joined the Purdue University School of Mechanical Engineering as assistant professor in 1984 and was promoted to associate professor in 1989 and full professor in 1993. He currently serves as Chairman of the Heat Transfer Area at Purdue University.

Since joining Purdue, Professor Mudawar founded both the Boiling and Two-Phase Flow Laboratory (PU-BTPFL) and the International Electronic Cooling Alliance (PU-IECA). He also served as co-principal investigator for both the Rolls-Royce Purdue University Center in High Mach Propulsion and the Hydrogen Storage Laboratory. He has supervised over 65 Ph.D. and M.S. students as well as Visiting Scholars. He has written 4 handbooks, 199 archival journal papers, 126 of which were published in the *International Journal of Heat and Mass Transfer*, 9 book chapters, and a large number of conference papers and topical reports.

Professor Mudawar is internationally recognized for his theoretical and experimental research on phase change mechanisms and applications in energy, electronics thermal management, space, and intelligent materials processing. His theoretical research encompasses virtually every aspect of phase change. Examples include theory of initiation of nucleate boiling, critical heat flux (CHF), Leidenfrost point, contact angle, turbulence in the vicinity of moving wavy interfaces, pool boiling, film condensation, heating, evaporation and boiling, flow boiling in straight and curved channels, boiling in rotating systems, droplet impact dynamics, sprays, jets, surface enhancement, nano-fluids, and carbon nanotubes. He is credited for authoring the first comprehensive methodology for analysis of boiling in micro-channels, which has recently evolved into universal predictive techniques for adiabatic, evaporating and condensing flows. He has developed customized experimental methods for these studies, including simultaneous use of laser Doppler velocimetry (LDV) and interface tracking probes, micro-particle image velocimetry (micro-PIV), photomicrography, high speed video imaging, and specialized microfabrication techniques and carbon nanotube surface coating.

Professor Mudawar's energy research encompasses numerous energy systems and applications, including magnetohydrodynamic energy conversion, liquid-cooled industrial gas turbine engines, high efficiency gas turbine power cycles, vertical evaporators, rotating evaporators, vertical condensers, desalination, particle accelerators, metal hydride hydrogen fuel cell storage systems, energy efficiency improvement and reduced water utilization in metal processing, and nuclear power generation. Published in 1999, his three-volume handbook "Critical Heat Flux (CHF) for Water in Tubes" is used by nuclear reactor manufacturers to predict upper safety limits for reactor operation.

Launched in 1984, Professor Mudawar's electronics cooling research center quickly became the nation's first laboratory dedicated to the study of very-high-flux and phase change thermal management of electronics using such schemes as thermosyphons, semi-passive falling film cooling, channel-flow boiling, micro-channel boiling, micro-channel condensation, jet impingement, spray cooling, and vapor compression. He has played a pioneering international role in the development of thermal solutions for supercomputers, servers, laptops, chip testing, hybrid vehicle power electronics, avionics, and X-ray medical devices.

Professor Mudawar has played a critical role in NASA's shift from present mostly single-phase liquid-cooled thermal management and control systems for space missions to two-phase thermal management. These efforts are aimed at capitalizing upon the orders-of-magnitude enhancement that is possible with boiling and condensing flows compared to their single-phase liquid counterparts. His research team performed extensive microgravity flow boiling experiments in parabolic flight and developed the first theoretical model for flow boiling CHF in microgravity. He is presently partnering with the NASA Glenn Research Center on the design of a flow boiling and condensation facility for the International Space Station (ISS), and on the implementation of phase change processes in space power generation and both cabin and avionics temperature control.

Since the late 1980s, Professor Mudawar has pursued several studies aimed at developing an intelligent heat-treating technology for complex-shaped metal alloy parts that would eliminate altogether the trial-and-error approach prevalent in the industry today. Using cooling and metallurgical transformation models, he developed a CAD-based pilot facility where the most critical phase of heat treating, the quench, is optimized by configuring water cooling sprays in response to the part's size and shape. This technology was shown to greatly increase part strength and hardness, enhance corrosion resistance, reduce residual stresses, warping, and cracking, greatly increase productivity, and virtually eliminate scrap. Another important aspect of this technology is the development of new non-contact temperature measurement techniques and algorithms.

Professor Mudawar's research contributions and innovations have been highly acknowledged worldwide. He earned the title of Fellow of the American Society of Mechanical Engineers (ASME) in 1997, and is a senior member of the American Institute of Aeronautics and Astronautics (AIAA), and member of both the American Society for Metals (ASM) and American Society for Gravitational and Space Research (ASGSR). One of his key research accomplishments is the attainment of the world's highest phase-change cooling heat flux for uniformly heated tubes, over 27,000 W/cm<sup>2</sup>. In 1995 and 1996, "Business Week" featured his breakthroughs under "Developments to Watch" in three separate issues during a single 10-month period. He has received numerous awards, including best paper awards at the 1988 National Heat Transfer Conference, 1992 ASME/JSME Joint Conference on Electronic Packaging, and ITherm 2008. He also received the ASME Journal of Electronic Packaging Outstanding

Paper Award for 1995, in addition to numerous awards and recognitions from ASME, AIAA, JSME, ASM, U.S. Navy, and Rolls-Royce. In 2013, he received the ASGSR Founder's Award, the ASME Heat Transfer Memorial Award in Science Category, and the 75th Anniversary Medal of the ASME Heat Transfer Division. Many of his publications have been recognized for top international citation rankings, including the International Journal of Heat and Mass Transfer top two most cited papers for 2005–2008.

At Purdue, Professor Mudawar is widely known for his strong passion for teaching, evidenced by several awards he received for dedicated teaching, curriculum development, instructional heat transfer laboratory development, introducing prototyping initiative in design courses, and dedicated service to minority students and organizations. They include best teacher in mechanical engineering for 1987, 1992, 1996, and 2004, most outstanding teaching at Purdue University for 1997, and Purdue Chapter of the National Society of Black Engineers professor of the year award for 1985 and 1987. He is a Founding Fellow of the Purdue University Teaching Academy and Inaugural Member of the Purdue University Book of Great Teachers. While the absolute effects are not quantifiable, it is quite certain that many engineering careers and lives have been shaped and enhanced by Professor Mudawar's love and dedication to education and research in the field of mechanical engineering. Professor Mudawar tirelessly pours out his energies into his graduate students with patience and dedication, helping them to improve their technical and leadership abilities. As a result, many of his students have gone on to be strong contributors in academia and industry.

On behalf of his many students, friends, and colleagues, from all around the world, we are pleased to wish him a very happy birthday and all the best in the company of his wife Jane and daughter Alexine. We are grateful for his exemplary contributions in the field of heat and mass transfer and look forward to his continued achievements. May he have many more years of happiness and success ahead.

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