Chemical Heritage Newsmagazine

Summer 2007, Vol. 25, No. 2

Feature

Suspended in Orbit

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Dudley A. Saville in 2004.
Courtesy of Joy Saville

In the summer of 1996, from the viewing area of Kennedy Space Center, Dudley Saville (1933–2006) watched wide-eyed as the space shuttle *Columbia* blasted off with one of his own experiments on board. Saville, then a professor of chemical engineering at Princeton University, had been passionate about flight since his days in the U.S. Air Force, but on this day he was more excited about scientific inquiry than the romance of space. The shuttle's Life and Microgravity Spacelab (LMS) carried an experiment on the electrohydrodynamic properties of suspensions that Saville had been waiting to send into orbit since 1990. If given the opportunity, Saville would almost certainly have accompanied his experiment in space, but he had to settle for the next best option: carrying out the experiment via computer from NASA's Marshall Space Flight Center in Huntsville, Alabama. Saville's project was one of dozens planned for the spacelab, on topics ranging from the human heart's performance in space to the growth of protein crystals in a gravity-free environment.

Microgravity first attracted scientific interest in the 1950s as the possibility for space flight began to look like a reality. (Scientists refer to *microgravity* rather than *weightlessness* because objects in orbit are not in a perfect state of freefall. Slight decelerations from atmospheric drag and disturbances from items outside the spacecraft's center of gravity alter an orbiting object's freefall by a force equivalent to one millionth the force of Earth's gravity, a micro-G.) The effects of gravity on Earth are such an accepted part of our lives that we may rarely think about it, but such simple, everyday actions as boiling a pot of water, mixing oil and vinegar for salad dressing, or mopping up a spill are profoundly affected by gravity. Convection, surface tension, buoyancy, sedimentation, and hydrostatic pressure are all gravity induced, and all mask the true nature of fluid processes.

Gravity can also play a detrimental role in certain manufacturing industries, such as those that manufacture crystals, value-added chemicals, metals, ceramics, and countless other products. Transforming sand into silicon crystals, separating ordinary biological materials into modern pharmaceuticals, and producing high-strength, temperature-resistant alloys from ordinary metals are all processes that are affected by gravity. These industries must operate mixers almost constantly to keep ingredients blended, and molten items like glass must be continuously spun to retain their shape in a 1 G environment (i.e., on the surface of the earth). Manufactured crystals are often not as perfectly ordered as they could be because of the effects of gravity, not an insignificant problem as even impurities at the parts-per-billion level can render a crystal useless. In contrast, a microgravity environment allows researchers to isolate and control gravity-related phenomena and permits processing techniques that are not possible in ground-based laboratories.

Improving the production of certain materials, with or without gravity, requires a keen understanding of fundamental fluid processes. By 1976, when Saville joined the Universities Space Research Association, his impressive academic credentials and expertise in fluid mechanics gave him a unique insight into the effects of gravity on fluids. Saville had graduated from the University of Nebraska with a degree in chemical engineering in 1954. He returned to graduate school after a brief stint at Union Carbide and three years of flying fighter jets, eventually receiving a Ph.D. from the University of Michigan in 1966. He then worked in industry for two years before joining the faculty of Princeton University as an assistant professor in 1968. Within three years Saville had tenure, largely on the strength of several seminal papers on the exact conditions required for an electrically controlled jet of fluid to maintain stability.

Although Saville was enthusiastic about space flight, he was at first skeptical that an orbital microgravity environment could provide a suitable place to conduct fluid physics research. Power and weight restrictions had severely limited the capability of space experiments during the Apollo program, and although *Skylab*, a short-lived space station in Earth’s orbit from 1973 to 1979, expanded these opportunities, it was nevertheless inadequate for NASA’s lofty goals. At the same time NASA was already developing its new space-shuttle program, which would open a new era of microgravity research by allowing heavier payloads, repeated missions, and longer flights. The shuttle program would effectively make more complex experiments possible, especially those related to biotechnology and materials processing. Saville soon came to share this view after beginning to serve on various NASA committees on space science. As he explained to Microgravity News in 1996: “I began to realize that in some sense, science has been trapped in a 1 G environment forever, so there are a lot of things we don’t know because we haven’t had the opportunity to do laboratory science in microgravity.”

In 1990 NASA accepted Saville's proposal to investigate the dielectric and electrohydrodynamic properties of suspensions in microgravity, and the project was later given a place on board the space shuttle as part of the spacelab mission. Saville's experiment was slated for the spacelab's Bubble, Drop and Particle Unit, which was developed by the European Space Agency to study fluid mechanics on the second International Microgravity Laboratory, which flew aboard the *Columbia* in 1994. Since the behavior of fluids is at the heart of many phenomena related to materials science and biotechnology, Saville's proposed experiment was a perfect match for the spacelab program goals. His experiment was designed to study the stability of cylindrical columns of liquid under the influence of an electric field, focusing on the series of shape changes that occur in a liquid bridge. Several kinds of oil, including castor and silicone, would be suspended in the form of a column that bridged two electrically charged plates. As the plates were moved farther apart, an electric field was applied to the plates, thereby stabilizing the column so that it would not break into droplets. Saville and his team would be looking for two transition points: first, when the shape changed from a cylinder to a vase-like amphora, and, second, when the bridge broke, creating suspended droplets. Although he had conducted similar experiments on Earth, the effects of gravity required that the two liquids be studied with a host liquid of the same density, thereby complicating the experiment. In microgravity the liquid bridge could be suspended in a low-density gas. He named his experiment "A Liquid Electrohydrodynamics Experiment" and gave it the acronym ALEX after his son by the same name.

The spacelab was launched into orbit on *Columbia* on 20 June 1996. When it touched down again 16 days and 21 hours later, it set a record as the longest-duration space-shuttle flight in the history of the program. The Spacelab itself consisted of a long module, located in the shuttle's cargo bay, which held 12 racks of equipment for various experiments. A total of 40 scientific investigations were associated with the spacelab, including 16 life science and 24 microgravity investigations. Investigators produced metallic alloys and protein crystals, studied fluid behavior, and examined how surface tension, thermal gradients, and other parameters affected materials processing and fluid behavior.

Saville operated his experiment from Earth by sending commands to the shuttle that would inject drops into liquid-filled test cells and then subject the cells to predetermined temperature changes. Cameras and sensors would record the temperature, density and position of the drops. Days before the experiment took place, however, a power-supply feed to one of ALEX's test containers shorted out, forcing Saville and several of his graduate students to catch the next flight to Huntsville and work around the clock in order to repair the short and save the experiment. In true "MacGyver" fashion the shuttle crew repaired the short by cutting a credit card–sized piece of plastic off the cover of a flight procedures manual and inserting it between the wires and metal housing that was causing the problem. The experiment went off without a hitch, and Saville declared himself "positively euphoric" about the way the experiment performed.

Although all the experiments aboard the spacelab had implications for government and commercial interests, Saville freely admitted that ALEX did not have any immediate or direct applications. Driven by his passion for knowledge and pure science, he nonetheless saw his work as relevant, remarking to a reporter, “a reliable theory has many applications. . . . Although I can’t tell you it’s going to appear in your catalytic converter or your home appliance next year, there are many applications for knowledge.” But Saville’s modesty may have led him to overstate the impracticality of his research. The theoretical findings from his experiments help investigators determine how much electrical field strength is needed to stabilize fluid cylinders, with important implications for atomizing and spraying, polymer blending, polymer membrane manufacturing, and fiber spinning. The phenomenon he explained has seen widespread use in medicine, in the production of polymers, and in electrically controlled spray painting.

Saville was truly a pioneer in the field of fluid mechanics and colloid science, and his work reveals fundamental principles governing the behavior of fluids. Along with William Russell and William Schowalter, he published *Colloidal Dispersions* (Cambridge, 1989), which became a major text in the field. In recent years Saville and his collaborator, Ilhan Aksay, also at Princeton, developed methods for controlling the behavior of colloids, bringing researchers one step closer to guided self-assembly. Saville’s peers lauded his accomplishments; in 1997 he was presented with the Alpha Sigma Chi Award for Chemical Engineering Research, and in 2003 he was elected to the prestigious National Academy of Engineering. Sadly, Saville passed away from cancer late last year, but his legacy will be preserved at CHF, which acquired his extensive personal archive in December 2006.

For Further Reading

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