The Story of Nitinol

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In January 1958 William J. Buehler, a metallurgist at the Naval Ordnance Laboratory (NOL) had completed research on a series of iron-aluminum alloys. Buehler, born in Detroit, Michigan on October 25, 1923, had received his Bachelor of Science degree in chemical engineering (1944) and his Master of Science degree in metallurgical engineering (1948) from Michigan State University at East Lansing.

The "between-projects boredom" began to set in for Buehler after completing the iron-aluminum alloy project:

> It was at this point that lady luck played a key role. I found within the U.S. Naval Ordnance Laboratory an ongoing materials project which had the goal of developing metallic materials for the nose cone of the U.S. Navy Polaris reentry vehicle. The in-house project was under the direction of Mr. Jerry Persh, an aerodynamicist. I was able to attach myself to this project, and my initial task was to provide physical and mechanical property data on existing metals and alloys for computer-assisted boundary layer calculations. These calculations were to simulate the heating, etc. of a reentry body through the earth's atmosphere. My informational role in this project very quickly became somewhat boring, and I almost immediately began to think in terms of possibly tailoring newly developed alloys that might better satisfy the drastic thermal requirements of the reentry body.
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> My first wife and I separated, and I spent a tremendous amount of time working in the laboratory…you might say it's a good feature that came out of a disastrous situation. I had lots of time at that point…in the state of Maryland the law required a three-year waiting period of separation before formal divorce could be handled. During that three-year period I literally worked day and night. Many days I would get up at 4 o'clock in the morning, go to the lab, and not go home until 11 o'clock at night. Between working at the laboratory and playing, I really didn't do anything other than eat or sleep.[1]

Buehler selected approximately sixty…alloys [to] study. This number was then reduced, for various logical reasons, to twelve alloy systems. One of the systems, [a] nickel-titanium alloy, immediately exhibited considerably more [fatigue-, impact-, and heat-resistance] than the other eleven alloys. In 1953 Dr. Harold Margolin of New York University and his associates had carried out some studies on phase changes of nickel-titanium alloys but had sensed no uniqueness among them.

[1] Buehler, W. J., personal communication, 14 August 1991.

In 1959 Buehler…named [this nickel-titanium alloy] NITINOL (**Ni**ckel **Ti**tanium **N**aval **O**rdnance **L**aboratory). That same year he made an observation about [NITINOL] that hinted at the extraordinary, but still undiscovered, property of Nitinol.

> I distinctly remember my very exciting discovery of the acoustic damping change with temperature change near room temperature. This unusual event unfolded when my…assistant…and I were melting a number of [Nitinol] bars in the arc-melting furnace. On the day in question (circa 1959), six arc-cast bars were made. While cooling on the…table, the first bars arc-cast into bar form had cooled to near room temperature, while the last bars to be cast were still too hot…to be handled with bare hands. Between the cool (first bar) and the very warm bar (last bar) were four…bars possessing a broad spectrum of temperatures…My "hands-on" approach caused me to take the cooler bars to the shop grinder to manually grind away any surface irregularities that might produce a subsequent scaly or bad….surface. In going from the table to the bench grinder, I purposely dropped the cool (near room temperature) bar on the concrete laboratory floor [a quick test to determine roughly the damping capacity of an alloy]. It produced a very dull "thud," very much like what one would expect from a similar size and shape lead bar.
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> My immediate concern was that the arc-casting process may have in some way produced a multitude of micro cracks within the bar—thus producing the unexpected damping phenomena. With this possibly discouraging development in mind, I decided to drop the others on the concrete floor. To my amazement, the warmer bars rang with bell-like quality.
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> Following this I literally ran with one of the warmer bars (that rang) to the closest source of cold water—the drinking fountain—and chilled the warm bar. After thorough cooling the bar was again dropped on the floor. To my continued amazement it now exhibited the leaden-like acoustic response. To confirm this unique change, the cooled bars were heated through in boiling water—they now rang brilliantly when dropped upon the concrete floor.
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> Subsequent discussions with my melter assistant revealed that he had in no way mixed or altered the alloy compositions during repeated melting. This immediately alerted me to the fact that the marked acoustic damping change was related to a major atomic structural change, related only to minor temperature variation.
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> Following the startling acoustic damping discovery, other seemingly related unique changes were observed. More interestingly, these changes also occurred in about the same temperature range as the acoustic damping change.[1]

In the early 1960s Buehler prepared a long, thin (0.010-inch thick) strip of Nitinol to use in demonstrations of the material's unique fatigue-resistant properties. He bent the strip into short folds longitudinally, forming a sort of metallic accordion. The strip was then compressed and stretched (as an accordion) repeatedly and rapidly at room temperature without breaking. In 1961 a laboratory management meeting was scheduled to review ongoing projects. Unable to attend, Buehler sent… his assistant to the meeting to present [their] work. As one of their "props" for the review, [the assistant] took the accordion folded fatigue-resistant strip. During the presentation, it was passed around the conference table and flexed repeatedly by all present. One of the Associate Technical Directors, Dr. David S. Muzzey, who was a pipe smoker, applied heat from his pipe lighter to the compressed strip. To everyone's amazement, the Nitinol stretched out longitudinally. The mechanical memory discovery, while not made in Buehler's metallurgical laboratory, was the missing piece of the puzzle… [and] became the ultimate payoff for Nitinol.

In 1962 Dr. Frederick E. Wang joined Buehler's group at the Naval Ordnance Laboratory, his expertise in crystal physics being vitally needed. Wang, born on August 1, 1932 in Su-Tou, Formosa (now Taiwan), emigrated to the United States and did his undergraduate work in chemistry and physics at the University of Tennessee at Knoxville. After receiving his doctorate in physical chemistry from Syracuse University in 1960, he worked as a postdoctoral associate for future (1976) Nobel chemistry laureate William Nunn Lipscomb, Jr. at Harvard University, until he left to join Buehler at NOL. The commercial applications of Nitinol that were to come would not have been possible without Wang's discovery of how the shape memory property of Nitinol works.