# Titanium: Aerospace age material

## The titanium metal industry has seen several peaks and valleys over the last few decades

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*B-1B over the Pacific Ocean*.

Titanium metal did not exist prior to the year 1950. Some laboratory samples had been made, first by Matthew Hunter at GE in Schenectady, N.Y., and then by the Phillips Glow Works in the Netherlands. It was Dr. William J. Kroll, working alone in his private laboratory in Luxembourg who developed a process that could make pilot production quantities. He brought his samples to the U.S. twice during the 1930s to find a use for the metal and his process. No one was interested in a metal that had no market. He returned in 1940 to escape the German invasion of his country. That same year Kroll publish and presented a paper on his process and received a patent. He accepted a research position at the Niagara Falls Laboratory of Union Carbon and Carbide Corp. After World War II, Kroll was hired as a consultant to the Bureau of Mines at Albany, Ore., to use his process to produce zirconium for submarine atomic reactors.

In the late 1930s a small research project was started at the U.S. Bureau of Mines using samples from the Phillips Glow Works. The properties seemed interesting enough that they started using the Kroll's process to make quantities for further study. This work received low priority during World War II.

After the war there was considerable interest in a light-weight, strong metal for jet engines, supersonic aircraft, army ordnance, and general purpose military equipment. Titanium supplied by the Bureau of Mines was distributed to various laboratories for study. The results excited the Air Force, Army, Navy, the airframe industry, and jet engine builders.

A titanium industry was underway in 1950 with full government support. Kroll's process was to react titanium tetrachloride with magnesium at a high temperature in a sealed retort. DuPont was the first industrial firm to make product with Kroll's process. The product was called sponge and needed compacting, melting and casting before it could be made into useful metal. The National Lead Company took over the Bureau of Mines plant in Henderson Nevada to make sponge and together with the stainless steel producer, Allegheny Ludlum, formed a company called Titanium Metals Corp. of America (TMCA). It became the first integrated producer of titanium metal. Remington Arms of du Pont joined the Crucible Steel Company to form Remcru and Sharon Steel with P. R. Mallory formed Mallory Sharon. Later Republic Steel Company combined with Crane to form Cramet.

Major research programs were started to support the required metallurgy for alloy development. The Army Watertown Arsenal and the Air Force Wright-Patterson Laboratory started in-house programs and many outside contracts. Recipients of contracts were private research laboratories, industrial companies, and university research centers. Research on phase diagrams and alloy development was done under Dr. John Nielson at New York University, Dr. Robert Jaffee at Battelle Memorial Institute, and Dr. Max Hansen at Armour Research Foundation. Hansen, who was from post-war Germany, was an international expert on phase diagrams.

Production of metal was slow getting started. The stainless companies who thought titanium could be processed on their equipment soon learned it was much more difficult to melt, forge, and roll than stainless. Melting was solved by using a technique invented for molybdenum and modified for titanium by Hal Kessler at Armour Research Foundation. This process was called consumable-electrode, vacuum, arc melting. It would become standard for titanium and all metals that react with oxygen.

Shipments of mill products could not keep up with the demand of the jet engine builders and the airframe companies. Only 250 tons were shipped in 1952 and 1100 tons in 1953. Then metal in the shipments showed brittle failure further slowing production. The problem was hydrogen embrittlement, and was solved by annealing in a vacuum.

The bulk of production was in unalloyed titanium or in alloys with only moderate strength increases. Major users demanded material of greater strength. Out of research at Battelle Memorial Institute by Robert Jaffee and Armour Research Foundation by Hal Kessler, came an alloy that would become the standard of the industry: Ti-6Al-4V.

In 1956 industry increased production of sponge to 15,000 tons and metal to 5200 tons. Most of the metal was going into jet engines and the biggest user was the Pratt-Whitney Division of United Technologies. Airframe companies still had problems with sheet metal and needed better alloys for forming parts and improving strength. The Air Force with support from the Department of Defense initiated a program to assist the industry in sheet production. This program, conducted by the Materials Advisory Board of the National Research Council, assembled a panel from producers, users, research laboratories, and government agencies. This panel looked at all aspects of titanium processing. Over several years this project produced not only improved alloys and improved material quality but also a much better appreciation of the reliability of titanium as an aerospace material. An indirect benefit was

close relationships resulting from the individuals of all parts of the industry participating in the common goal.

The improved business conditions and the resulting enthusiasm within the industry continued into 1957. First quarter metal shipments were 2200 tons, which indicated an annual goal of perhaps 9000 to 10,000 tons. Titanium was on its way to becoming the aerospace metal that its promoters had hoped for. Then an earthquake shook both the aerospace industry and titanium. The Secretary of Defense, Charles Wilson, formerly of General Motors Corp., announced a decision to base the defense of the country on missiles rather than on manned aircraft. The accompanying reductions and cancellations of contracts rocked the industry.

The plunge in orders and prices caused many of the pioneers of the industry to abandon titanium. DuPont ceased production of sponge, Remington Arms and Crucible Steel closed Remcru, the Crane sponge plant was closed, and Republic Steel ceased making mill products. Mallory Sharon was sold to another sponge producer. Of the original producers, only TMCA and RMI (formerly Mallory Sharon) survived. The government supported research was phased out and many experienced engineers left for other fields.

The Federal Government that initiated and supported this industry nearly strangled it before it reached maturity. Fortunately, the remaining producers held on and eventually titanium was revived by the introduction of jet powered commercial aircraft and the all-titanium plane: the SR71. Later 100 B-1 bombers were built with titanium. The industry has seen a number of peaks and valleys, but recent production finally reached the 30,000 tons per year predicted in the early 1950s as the need by 1960.

THE B-1 BOMBER WAS NEARLY ALL TITANIUM (WIKIPEDIA)

(The complete manuscript on the history of titanium can be seen at www.metals-history.blogspot.com)