ESSAY

The cost of living: tracing the supply chain for superconductors in MRI machines

Gone are the days when medical museums collected and displayed the contents of vintage physician's bags. We now deal with objects such as 20-tonne magnetic resonance imaging (MRI) machines. In 2005, the Canada Science and Technology Museum acquired a decommissioned Philips Gyroscan S15 ACS MRI machine from the Montreal Neurological Institute in Montréal, Quebec.[1] This was an important acquisition because of the institute's leading role in the development and use of medical imaging, and the rare opportunity to collect and preserve an entire MRI system. Researching and cataloguing such a constellation of components is not trivial, and in this case has been complicated by a lack of records and that the machine included several parts deriving from between 1985 to 1993. My preliminary efforts, however, produced a surprising glimpse inside the elaborate and revealing manufacturing world of modern medical technology.


David Pantalony

The Philips Gyroscan S15 ACS was installed at the Montreal Neurological Institute in 1993.

In researching the main magnet from 1993 (1.5 T Oxford Unistat, serial no. 44480 07.93), I was led into an exchange with staff at the Montreal Neurological Institute, employees at the makers of the main magnet at Oxford Instruments in Oxford, England (now owned by Siemens) and employees at Philips Medical Systems in the Netherlands. Amidst these discussions, I uncovered one intriguing technical feature of our particular magnet — its use of 36.9 km of niobium–titanium (Nb–Ti) wire for the large superconducting coil. This detail inspired me to follow the supply chain of this exotic material.

Superconducting wire is the core of magnetic resonance imaging. Electrical current passes through the Nb–Ti wire that is immersed in ultracold liquid helium, creating an incredibly strong magnetic field. The patient is then placed in this field, whereby hydrogen nuclei in the water of the patient's body reorient their tiny magnetic fields to be parallel to the applied magnetic field — like iron filings in the presence of a bar magnet. These nuclear magnetic fields are then manipulated using short bursts of radio waves to induce a current in specialized antennae. Thousands of these signals are then compiled and computed into detailed MRI images of soft (i.e., water-containing) tissues of the patient.

The key ingredient in the wire is the rare metallic element, niobium (no. 41 on the periodic table). In the 1960s, scientists discovered that niobium alloys demonstrated remarkable superconducting properties; Oxford Instruments was the first company to commercialize superconducting magnets.[2] Over the next 45 years, the Nb–Ti combination became the standard alloy of the growing superconducting industry, being used in diverse technologies ranging from MRI machines to particle accelerators to the Maglev levitating train in Japan. Even though the largest use of niobium has been for strengthening steel alloys in automobiles, airplane parts and other common products such as razor blades, its use in superconducting technologies has been substantial and influential. Europe's Large Hadron Collider, for example, has used over 500 tons of Nb–Ti wire for its giant magnets.

Where does all this niobium actually come from? Unfortunately, Oxford Instruments does not have purchase records to trace the complete supply chain for the niobium used in our magnet from 1993, but reports from the time provide a glimpse into the supply chain.[3,4,5]

In 1993, most of the world's supply of niobium (around 85%) came from a mine in Araxá, Brazil, owned by

David Pantalony

This Philips 1.5 T Unistat magnet and tank, made by Oxford Instruments in 1993, is now in storage at the Canada Science and Technology Museum.

Companhia Brasileira de Metalurgia e Mineração, still the largest supplier today. A smaller percentage (less than 10%) and the next largest supply, came from a mine near Chicoutimi, Quebec.

The next step was the extensive processing, refinement and production of high-grade Nb–Ti products such as 500-mm wire. In the early 1990s, one of the world's top producers of superconducting alloy was Teledyne Wah Chang in Huntsville, Alabama (now ATI Wah Chang), with additional competition from H.C. Starck (Germany) and Cabot Corporation (USA).

These Nb–Ti products then proceeded to one of two companies, Oxford Superconducting Technology in New Jersey, or Vacuumschmelze in Germany, which produced the highly purified and engineered composite filamentary Nb–Ti wire. The next stop was Oxford Instruments in the United Kingdom, where workers wound the specialized wire into a superconducting magnet assembly.

As I ventured further into the niobium story in the 1980s and early 1990s, I discovered that each node of the supply chain opened up with its own fascinating context and controversies. National security was one issue. American intelligence experts, for example, considered the Brazilian mine to be a security concern. A report in 1990 stated: "The fact that such a high percentage of columbium [an older name for niobium] supplies to the United States have their origins in one small isolated area of Brazil must pose problems of vulnerability. In the total mineral portfolio of the United States, this is the most extreme case of concentration …"[6] Because of this issue, international suppliers sought niobium in places such as the Democratic Republic of the Congo, which became a significant producer in the 1990s. Due to the Congolese civil war, however, most of this illicit "blood mineral" trade, which fuelled war chests on all sides, was (and still is) impossible to trace.[7] (John LeCarre's 2006 novel, *The Mission Song*, centres around the "blood mineral" issues in the Congo.)

Health has been another issue with radiation hazards posing problems for the miners and local populations. Niobium coincides with abundant radioactive isotopes in nature. In Brazil, a recent study documented that niobium miners have been exposed to concentrated levels of toxins and radiation in their work.[8] There has also been a connection made between increased amounts of radon produced during niobium mining and increased cancer incidence.[9]

Substantial environmental issues are associated with processing and refining niobium.[10] In the 1980s and early 1990s, Teledyne Wah Chang in Albany, Oregon (the location of the company's first niobium production site) was at the centre of a controversy involving radioactive sludge created from its rare metal refining and processing. There have been no studies of the long-term impact on the health of the local population, but the environmental concerns forced the company to improve their treatment of waste and move operations to a location more favourable to superalloy production. In 1984, in the midst of a ballot measure (no. 9) in Oregon targeting and restricting Teledyne Wah Chang's sludge disposal techniques, the company created a new niobium production facility in Huntsville, Alabama. The issues related to Teledyne's radioactive sludge went to the Oregon Supreme Court.[11]

Teledyne Wah Chang was also in the news for ignoring radioactive waste in its former tungsten plant.[12] These past controversies pose a challenge for historians who must weigh them against Wah Chang's singularly impressive contributions to particle physics, medical physics and a recently announced experimental verification of relativity.[13]

Environmental and health issues have surfaced in Oka, Quebec where a major niobium source has re-emerged. I use the term "re-emerge" because the Oka mine was in fact one of the first major sources of niobium in the 1950s when it was called "columbium" and praised as the "jet engine metal" and one of the "miracle minerals spawned by the atomic age."[14] Today, the Oka mine has become a source of environmental and First Nations' disputes as a Canadian company, Niocan Inc., seeks to reopen the mine to meet growing world demand for this rare, nonrenewable resource. One issue of contention is the inordinate amount of water needed for operations, as well as the associated radioactive byproducts such as radon which could pose dangers to local residents, farms, water sources and miners.[15] Some of the highest concentrations of residential radon in Canada have been found in the Oka region attributed to tailings from the former niobium mine (some homes in Oka have measured 10 000 Bq/m^3 [becquerels per cubic metre are a standard measure of radiation] compared with Health Canada guidelines of 200 Bq/m^3).[16] Radon exposure has consistently been linked to increased lung cancers, and a Health Canada report has stated that it is the second leading cause of lung cancer next to smoking.[16]

In light of the issues raised above, it becomes clear that the sleek and seemingly neutral presentation of MRI machines in the hospital setting mask the enormously complex material, manufacturing and social dimensions of these systems. These broader issues begin to surface once we place the machines themselves on the examination table. There is much debate these days about the value and potential overuse of medical imaging in medicine and the dangers of certain procedures such as computed tomography scans,[17] but little discussion about our growing demand for these images and the real people, places and conditions associated with their production. Investigating the supply chain for medical technology is a powerful tool for exploring unexpected connections between our medical system and the larger, global economy we inhabit.

David Pantalony PhD
Curator
Physical Sciences and Medicine
Canada Science and Technology Museum
Ottawa, Ont.

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