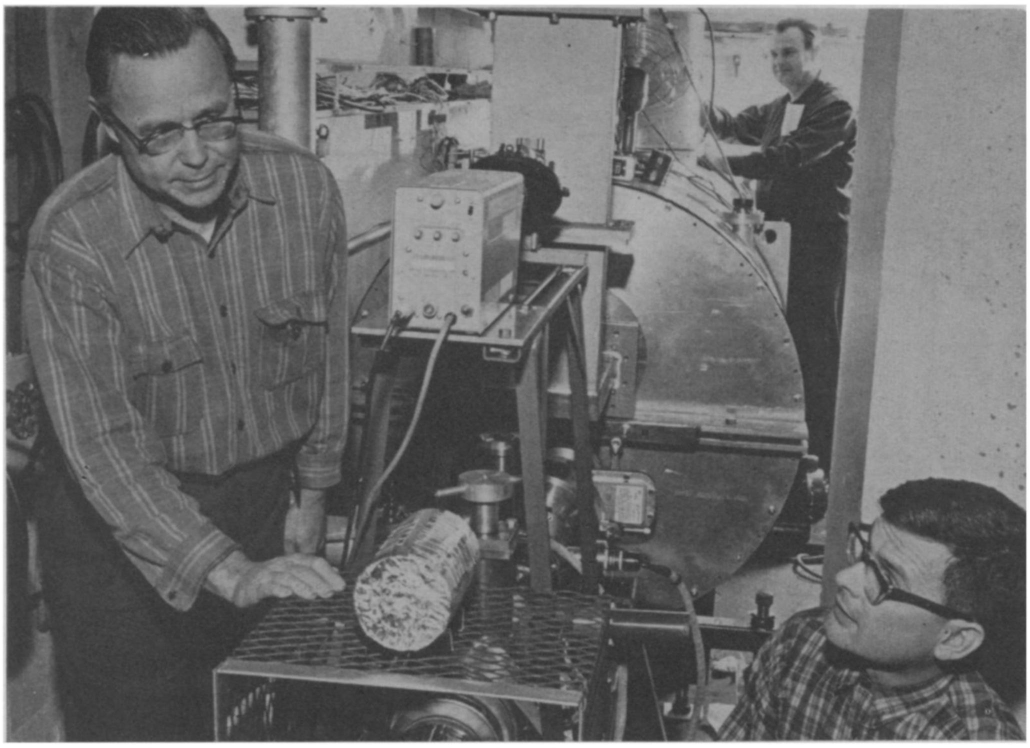

Stanford University

Profs. William Fairbank and Alan Schwettman inspect prototype accelerator.

CRYOGENICS

Superconductivity: integrate for economy

Resistance-free electric circuits promise many things; now they may be coming down from the ivory tower

by Dietrick E. Thomsen

When Prof. Heike Kammerlingh Onnes of Leiden University discovered superconductivity in 1911, he didn't believe it.

More than half a century later, superconductivity is still hard to believe, and harder to explain—no theory yet has completely and adequately accounted for the phenomenon. Worldwide, engineers are still looking for a practical way to realize the savings in power and increases in precision that superconducting circuits promise.

The engineers' dream is gradually being brought about. A centrally refrigerated laboratory now under construction at Stanford University may finally lead the way in economic application of low-temperature techniques to large systems. A superconducting particle accelerator that will be part of the laboratory is expected to show both that large-scale refrigeration to temperatures below two degrees Kelvin is practical and that superconducting techniques offer new research possibilities in particle physics, if not in other applications as well.

The rub has been that superconductivity exists only at temperatures near absolute zero (273.16 degrees below zero C.). The techniques of refrigeration have been both cumbersome and costly—possible for experiments but uneconomical for industry.

Some physicists who want to find practical uses for superconductivity have sought to get around the refrigeration problem by looking for materials that would be superconducting at higher temperatures. When Prof. Kammerlingh Onnes discovered superconductivity, he found that the materials he worked with—mostly lead and mercury—returned to a normal conducting state at temperatures of about nine or ten degrees Kelvin. Today physicists know of many more superconducting materials than Kammerlingh Onnes did, and a number of these have higher transition temperatures. Dr. Bernd Matthias of Bell Telephone Laboratories, who has been especially active in the search for higher transition temperatures, has found them up to 20 degrees Kelvin in a variety of hard metal alloys. There have been persistent suggestions that constituents of biological cells should be superconducting at room temperature, but nobody has yet been able to verify such proposals.

The other possible approach to the problem, the one being used at Stanford, is the exact opposite: to go to the lowest possible temperatures, below two degrees Kelvin, where the bizarre properties of superfluid helium might be used to set up a large-scale, economical refrigeration system.

Stanford's Prof. William Fairbank believes that the properties of superfluid helium are so uniquely useful in large-scale refrigeration that he says: "Below two degrees Kelvin is where nature wants us to do the experiments."

Superfluidity is the liquid analogue of superconductivity. As the electrons move without resistance through a superconductor, so the helium flows without friction. It will pass through holes so small that gases—including helium itself—will not diffuse through them.

Its other advantages as a refrigerant are its high specific heat—100 times that of water—which means that flowing helium can carry away large amounts of heat without changing its state—and the ability of a small amount of heat to lift it large distances without pumps.

The lifting system Prof. Fairbank plans to use consists of a pipe whose end is closed by a plug with very fine holes in it. An electric coil heater is in the pipe above the plug. When the pipe end is inserted into a reservoir of superfluid helium and the heater is turned on, the helium will be attracted to the heat and flow through the plug. But once it has been heated a little it cannot flow back. Thus as long as the heat is on, liquid helium will mount in the pipe—to distances up to 100 feet.

Prof. Fairbank reasons that a large integrated system with superfluid helium piped from a central refrigerator to stations where it is needed will render economical the practical uses of superconductivity. In such a system small superconducting elements such as oscillators, magnetometers, and computer memory elements could be used without the expense of providing them with individual refrigerators.

A scientific laboratory constructed according to such a principle could serve as a prototype for industrial uses of such an integrated refrigerating system. But the usual low-temperature experiments are done in very small volumes; what was needed to attract scientific support for such a laboratory was the promise of a large piece of equipment in which superconductivity would yield improvements over existing techniques and which required central refrigeration.

Fortunately the idea of a superconducting particle accelerator was around. If such a machine could be built, great savings in money and improvements in efficiency could be expected. And at Stanford there were experienced accelerator specialists who could help to build it. A spokesman for the Navy, which has been funding Prof. Fairbank's project, calls the coincidence of low temperature and high energy physicists at Stanford "a unique combination."

The Navy has been giving the money because it hopes to use the refrigeration system in a ship where it can be used to chill superconducting elements for sensing, control and communications apparatus.

An electron linear accelerator was chosen to be the example. Such a device consists of a series of metal waveguides in which radio frequency waves are confined. The waves accelerate electrons in much the same way that a water wave accelerates a surfboard. As the electrons pass through the device they receive a kick from each cavity of the series; to increase the final energy of the electrons one increases the number of cavities in the series. Stanford has an accelerator that is two miles long which spits electrons with 20 billion electron volts of energy.

The wave guides are customarily made of copper, and a severe power loss occurs in resistance heating of the copper. The two-mile accelerator, for example, requires several billion watts. The use of superconducting wave guides made of niobium could cut the power requirement by a million times—to a few thousand watts—saving not only on power but also in the construction of auxiliary equipment such as klystron tubes used to energize the cavities.

A superconducting accelerator could also operate continuously. At room temperature an accelerator operating continuously would melt; the two-mile one is on for one-billionth of a second and off for one-millionth—that is, it is producing accelerated particles for only one-thousandth of its time.

Continuous operation would not only give more time for experiment; it would permit different kinds of experiments. Many small and delicate interactions get lost in the explosive background generated by conventional accelerator bursts. They would be more easily seen in the steady build-up of evidence over a long period of observation that is impossible with present accelerators.

In the Stanford building where the new laboratory is being set up, a $400,000 central refrigerator has already been installed. A five-foot prototype has convinced the accelerator men that the superconducting idea works in practice, and they are now constructing—in the area above the refrigerator—the 500-foot working model. It may be some time, however, before the technique is economically competitive with large-scale, room-temperature accelerators.

But after the accelerator, the Navy envisions a helium refrigerator and piping system in the hold of a ship. Once one has the central refrigeration, such things as cryogenic computers and servomechanisms become economically feasible. Many other useful devices could be run off such a system, especially some that would sharpen the ship's sensory abilities. Superconducting magnetometers for better detection of submarines are one possibility. A Navy spokesman also cites superconducting radio oscillators, which would provide ultrasharp tuning and squeeze many more communications channels into a given waveband than room temperature receiving equipment could ever sort out.

So in spite of Defense Department cutbacks in research support (SN: 2/10, p. 136), the Navy continues to fund the low-temperature part of the Stanford work. But it has indicated a desire to be quit of the specifically high energy part, and, Prof. Fairbank says, negotiations are under way to see whether the National Science Foundation will take over that part.