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INFORMATION FOR MEMBERS

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Briefing Note

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Superconductivity

Superconductivity hit the headlines in 1986 when IBM researchers working in Switzerland broke through a barrier which had restricted development and application of this technology for 60 years. Since then, most leading industrial nations have launched research to develop, understand and apply the phenomenon.

This briefing note describes the scientific breakthrough and its potential, and examines the UK response with reference to similar efforts abroad.

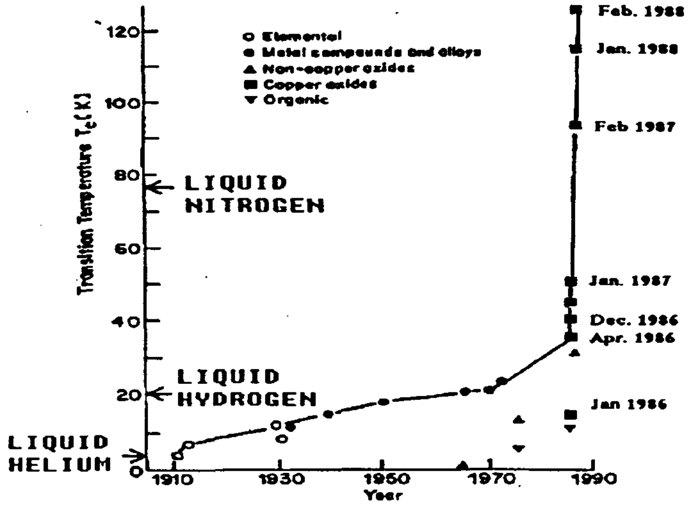

Figure 1: Superconductivity Improvements 1910-1990

WHAT USE IS SUPERCONDUCTIVITY?

When current flows in an ordinary conductor such as a copper wire, some energy is lost through the resistance which the current has to overcome. In a light bulb or an electric fire, this resistance creates light and heat which is used, but in other cases the energy is simply wasted. Superconductors, on the other hand, have no resistance, so that electrical currents flow without any power loss. In theory, a steady current will circulate in a superconducting coil for ever[1]. Superconductors also exhibit other properties (Josephson effects) which can be exploited in electronic devices.

Table 1 : Potential Applications of Superconductivity

Magnets	*Energy*
Magnetic Shields	Energy Storage
Medical imaging	Generators/ motors
Particle accelerators	Stabilising coils
Magnetic separation	
Magnetic levitation	*Electronics*
Launchers	Wiring
Rail guns	Sensors
Magnetic thrusters/drives	Computer chips

The phenomenon was discovered in 1911 and many superconducting metal alloys have been developed. These can only be used at very low temperatures, however, requiring all superconducting parts to be kept in liquid Helium (4° above absolute zero (°K) or -269°C). The expense of coolant systems has limited applications to a few costly ones - primarily high power magnets. Nevertheless, superconducting magnets have found specialised but widespread application in medical technologies (X-ray, MRI scanners etc.), particle accelerators such as at CERN, and sensitive magnetometers.

1. Perfect superconductivity is only possible for steady (DC) currents - alternating currents (AC) meet resistance even in superconductors.

Engineers have long been aware of potential applications such as loss-free electrical transmission, faster computer chips (Table 1). These are presently unattractive due to the need to operate with liquid helium.

BREAKTHROUGHS SINCE 1986

Each superconducting material loses this ability above its own "transition temperature" (T_c). The earliest material discovered had a T_c of 4°K, and research over the period 1911 to 1986 succeeded only in finding materials which kept their superconductivity up to 23°K. In 1986, however, two IBM researchers (now Nobel prizewinners) found a ceramic material with a substantially higher transition temperature. An explosion of experimental activity followed, and new materials were quickly discovered which have pushed the transition temperature to more than 130° above absolute zero (-143°C).

Although all of the substances in Figure 1 have scientific interest and may help understand the mechanism behind superconductivity, industrial applications require a combination of several properties. In addition to being superconducting at the working temperature, the material should be able to carry sufficient current and also be capable of fabrication into wires, sheets, tapes etc. There is thus a major international research effort not only to find materials with higher transition temperatures but, through materials science, also to improve the properties of existing materials to make them more amenable to industrial application.

Three main groups of new superconductors have emerged from the latest research[2]. All are brittle ceramics creating significant processing problems but considerable progress has been made with all three recently. Wires and tapes which can carry useful currents at liquid nitrogen temperature (77°K) have been made, and thin films can also be made which can carry over 1 million amps per square centimetre.

Since liquid nitrogen cooling is much easier and cheaper to maintain than liquid helium, many workers are optimistic that industrial applications will expand beyond the current limited applications in high energy magnets. Others, however, point out that the cost of refrigeration in some large scale applications is not a major factor and believe that the extra cost of these materials still outweigh the advantages. However, the first commercial applications are now in sight - for example, certain microwave circuit components and sensitive infra-red detectors are being developed in several countries, including the UK.

INTERNATIONAL RESPONSE

The response of several countries to the 1986 discoveries is summarised in Figure 2. The USA's response has been investigated by several Congressional Committees as well as the USA Office of Technology Assessment (OTA), which reached a number of conclusions which could be of interest to the UK;

- The US was seen as already falling behind the Japanese effort. Commercialisation in Europe was expected to be slower than in the USA or Japan.
- The US Government-supported research effort was too removed from the commercial market place.
- American industry appeared reluctant to invest in research (with some notable exceptions), reflecting commercial uncertainty over long-term payoffs. In contrast, Japanese companies had made substantial commitments to both research and applications-related work. A wide range of businesses are involved e.g. steel companies, glass makers, chemical producers and electronics manufacturers.
- Key needs identified included a strong emphasis on processing research and for multi-disciplinary teams. US research funds spent may not be fully effective due to a lack of appropriate graduate scientists and engineers educated in the fields involved - from materials processing to the physics of electron devices.

THE UK RESEARCH PROGRAMME

The UK research effort is comparable to that of France on a GDP basis, while the USA, the Federal Republic of

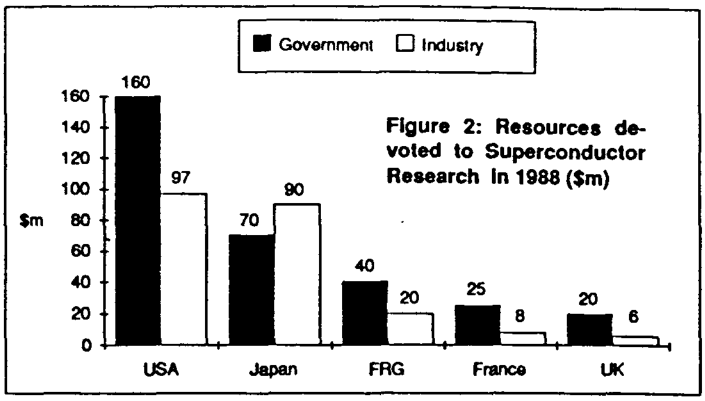

Figure 2: Resources devoted to Superconductor Research in 1988 ($m)

Germany (FRG) and Japan have proportionately larger programmes (Figure 2).

The Department of Trade and Industry (DTI), the Science and Engineering Research Council (SERC) and the Ministry of Defence (MOD) are working together on a coordinated national programme embracing industry, academe and Government laboratories. The SERC has established an inter-disciplinary research centre (IRC) at Cambridge, as well as providing support to University research groups. It is committed to spending over £3.5m per annum, while the DTI has £8m available over 3 years to fund up to 50% of allowable costs with industrial partners on pre-competitive collaborative research.

Because of the critical importance of being able to process any materials discovered, industrial participation is crucial and has been emphasised by DTI and SERC. Some companies have also developed links with universities active in the area, and the IRC has attracted almost 30% industrial support. Despite this, industrial involvement remains a constraining factor and may limit exploitation in the UK of research findings.

The UK initiatives meet a number of the criteria identified by OTA for an effective programme. However, the UK and USA appear to share the same problems in other aspects. Both are experiencinng a shortage of young scientists and engineers in the required disciplines, so that reliance has to be increasingly placed on foreign research students. Both are also finding industrial interest to be limited in contrast to Japan, where high-temperature superconductivity is seen as a vehicle for creating new businesses as well as finding new applications in existing lines of business.

FURTHER READING

Additional details and background information are available from POST, 2, Little Smith St., Westminster, SW1P 3DL, Tel (071)-222-2688.

The ***PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY*** has been set up by the Parliamentary and Scientific Committee to inform Parliamentarians on scientific and technological matters underpinning current issues.

2.YBCO - yttrium-barium-copper oxide (USA) with a Tc of 93°K.
BISCCO -bismuth-strontium-calcium-copper oxide (Japan), Tc of 107°K
TIBCCO - thallium-barium-calcium-copper oxide (USA), Tc of 125°K