

*Serial and Parallel Power Equipment with
High-Temperature Superconducting Elements.*

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Summary

One of the prospective, practical applications of high-temperature superconductors is the fault-current limitation in electrical energy networks. The development and testing of experimental HTSC serial current limiters have been reported in the literature. A Hungarian electric power company has proposed the development of a parallel equipment for arc suppressing both in the industrial and customers' networks.

On the basis of the company's proposal the authors have outlined the scheme of a compound circuit that can be applied both for current limitation and arc suppressing. In this paper the design principles and methods of the shunt equipment are presented. These principles involve the electrical, mechanical and cryogenic aspects with the special view on the electrical and mechanical connection between the HTSC material and the current lead.

Preliminary experiments and tests have been carried out to demonstrate the validity of the design principles developed. The results of the experiments and of the technological investigations are presented.

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Introduction

A new project for the investigation of the possible application of high-temperature superconductors in electrical switch gear has been initiated and financed by a Hungarian power engineering company, *EPOS-PVI, Rt.* The organisational and functional structure of the project is shown in Figure 1.

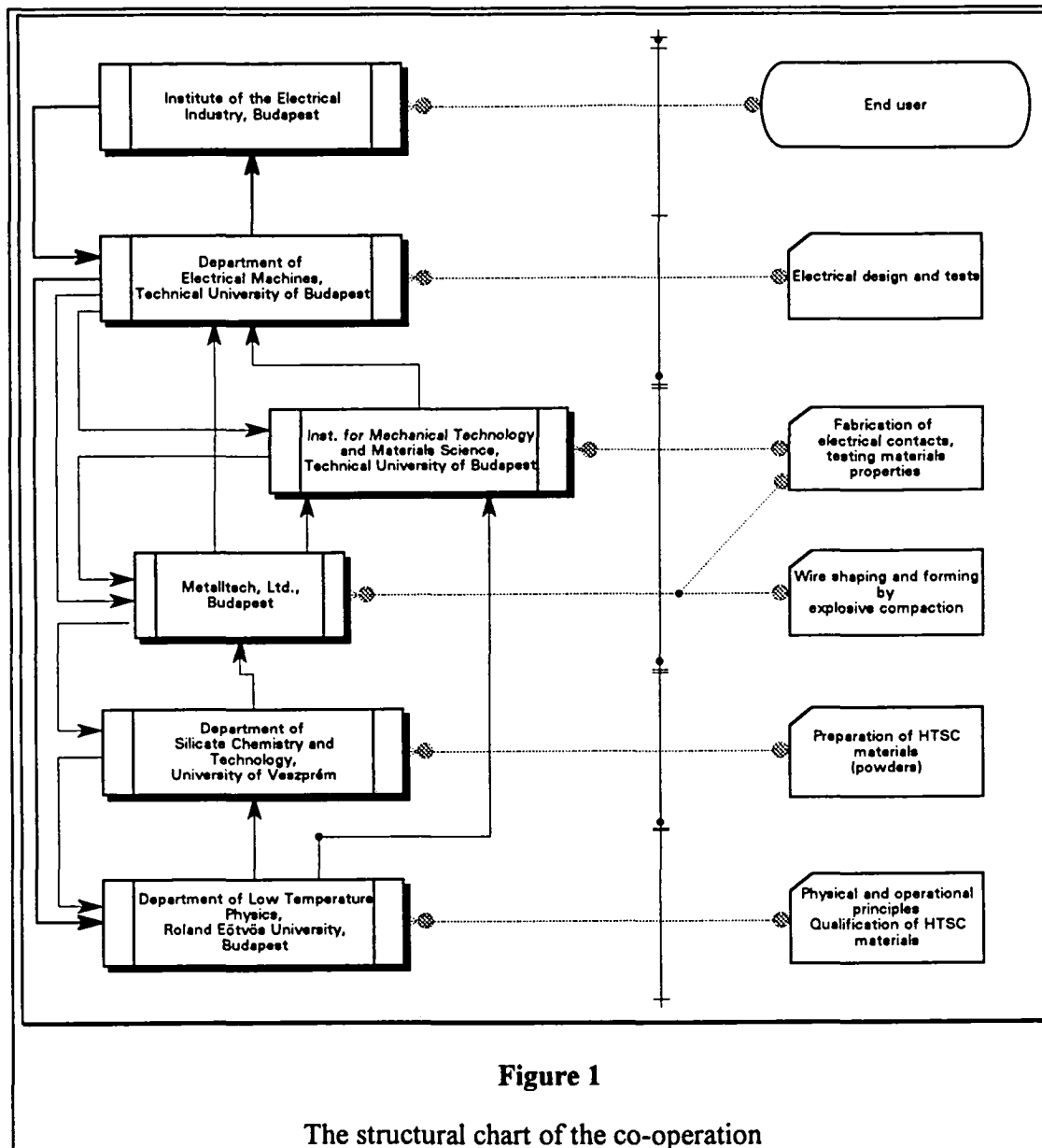


Figure 1

The structural chart of the co-operation

This project is in close connection with the one carried out at the Department of Electrical Machines, Technical University of Budapest, supported by the *Hungarian Academy of Sciences (National Fund for Science and Research)*. The aim of this project is the development of a model of an HTSC electrical machine. In this frame a

numerical method and a software have been developed for the calculation of the magnetic field of superconductors [2], [3].

The work carried out in the frame of the Hungarian co-operation has attained an attention and interest from abroad. The national co-operation is planned to be elevated onto an international level.

Design principles

The device containing the HTSC element is connected parallel with the section of the network to be protected. The arrangement of the device for a single-phase network is shown on *Figure 2* [6].

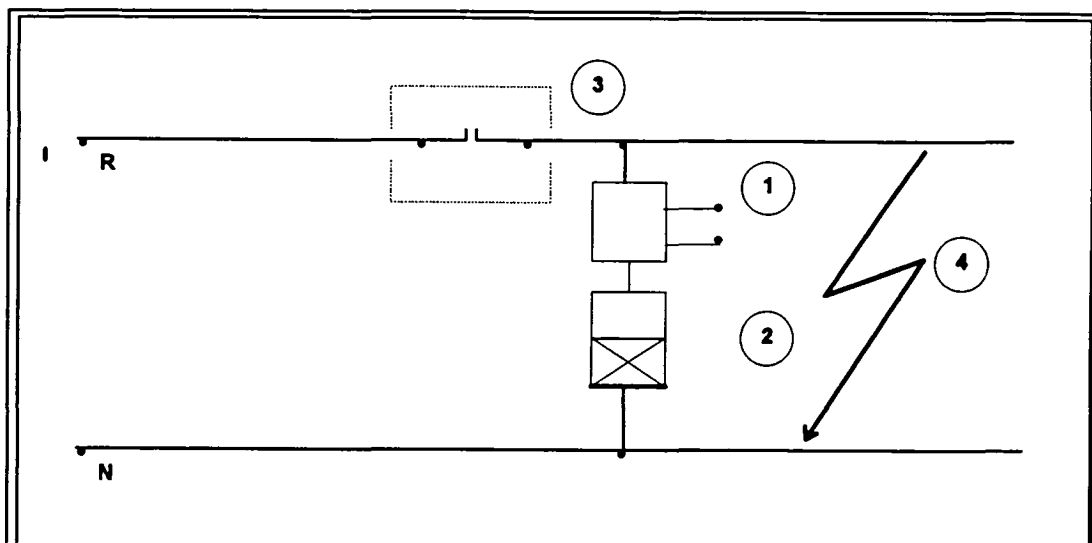
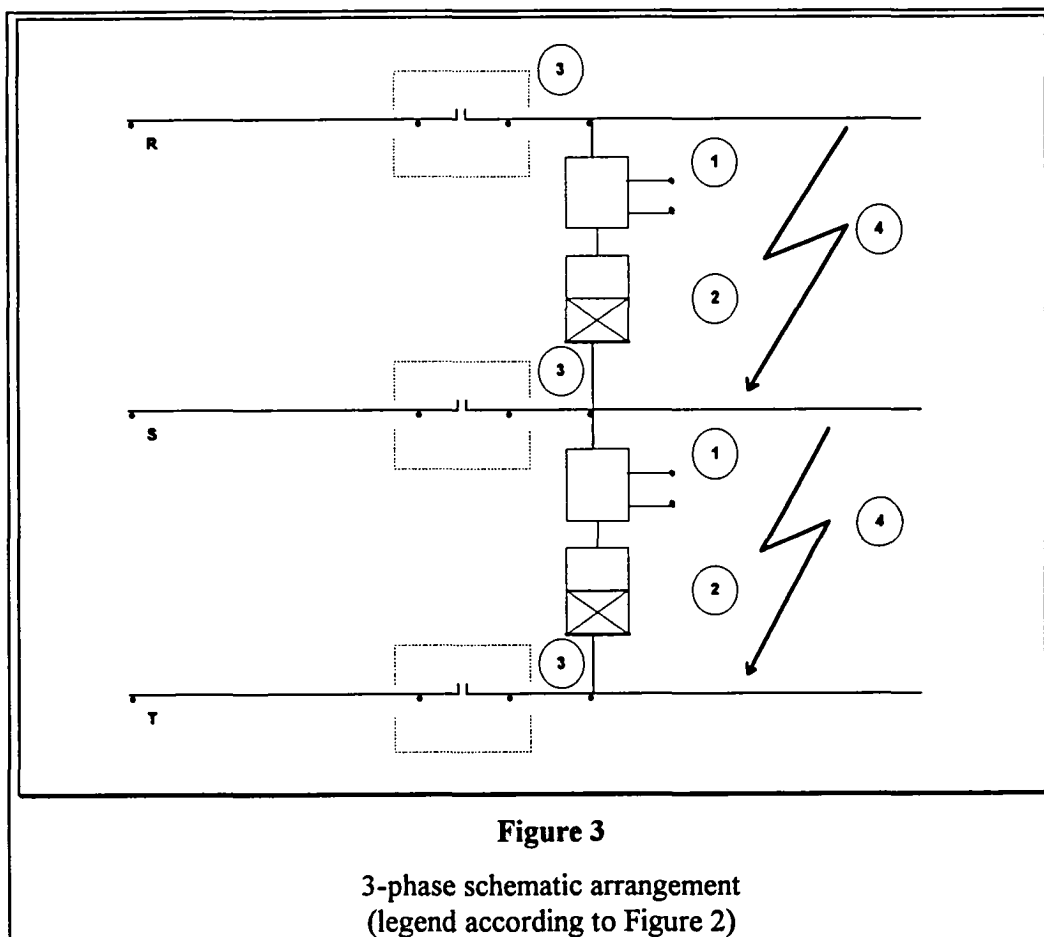


Figure 2

1-phase schematic arrangement

- 1 controlling element
- 2 HTSC-element
- 3 classical switch-gear
- 4 electric arc (short circuit)

According to *Figure 2*, the device containing the HTSC element is connected parallel with the section of the network to be protected between the phase- and the neutral conductor. If, for example, an arc develops in the section of the network to be protected, then the protection system supplied with optical and electrical sensors detects the arc and gives a signal to the controlling element of the device containing the HTSC element. Due to the operation of the controlling element the HTSC element



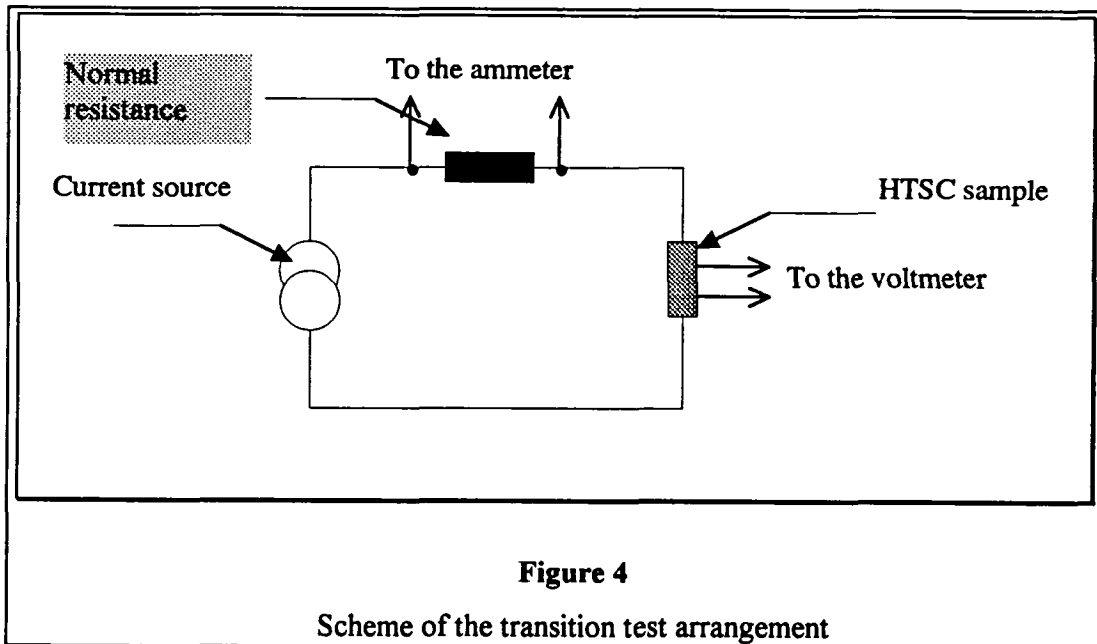
carries a given current. If the value of this current exceeds the critical current characteristic of the selected superconductor then the HTSC material goes from its superconducting state into its normal state. The HTSC material in its normal state behaves as a current limiter and, thus, decreases the current load of the traditional circuit breakers.

In the case of a three-phase network the device may be connected, for example according to *Figure 3*, between the line conductors.

Modelling of the superconducting-normal transition

One of the fundamental parameters of both of the operation and of the design of the switching device containing an HTSC element is the switching time, that is the time of the transition from the superconducting to the normal state (and back). Similarly it is essential to know the ratio of resistivities of the superconducting and the normal states.

For the investigation of the conditions, as the first step, a small sample of the device has been constructed since HTSC materials, at least at present, are characterised by relatively low critical current densities [4], [5]. The arrangement for the transition tests is shown in *Figure 4*.



The HTSC sample has been fed from a current source giving an output current of triangular form. For a better evaluation the frequency of the current has been set to 10 Hz. The voltage proportional to the current and sampled with the frequency of 30 kHz has been registered and processed by a computerised measuring system.

To avoid the distortion of the results by the voltage drop on the current feed we have formed separate pairs of contacts for the current feed and the voltage signal.

For the evaluation of the switching speed we have used the results of measurements shown in *Figure 5*.

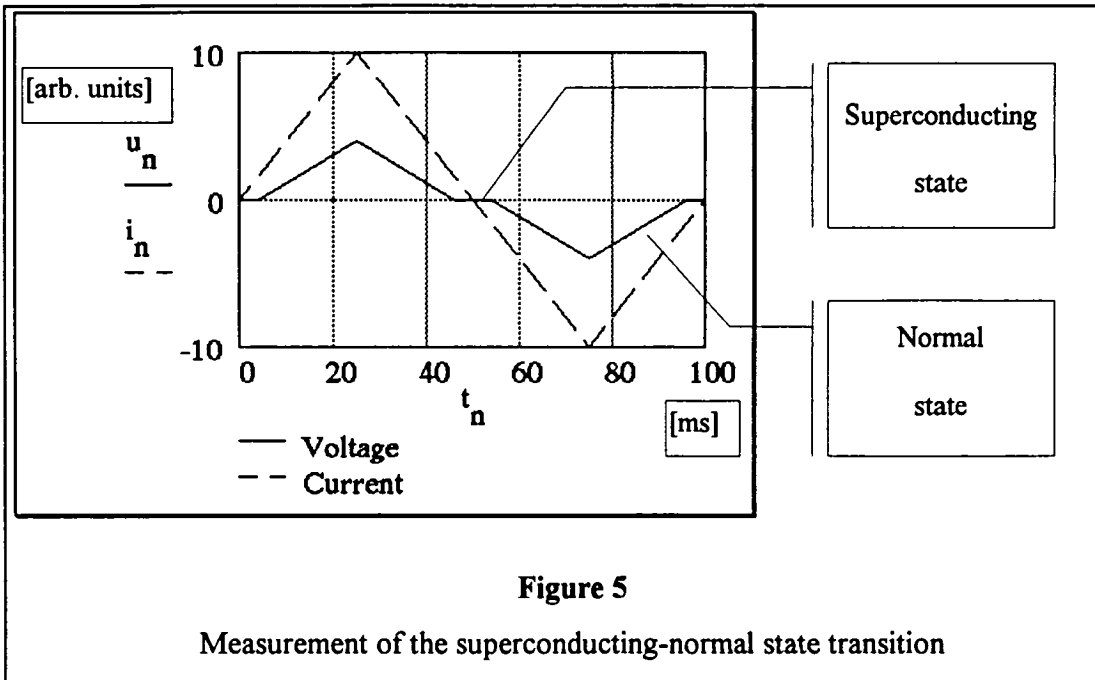


Figure 5

Measurement of the superconducting-normal state transition

It is clearly seen in the figure that in the moment when the current flowing through the sample has exceeded the critical value then a voltage drop has appeared momentarily indicating that the HTSC element has gone from its superconducting state into its normal state. Similarly, when the current has decreased below the critical value then the material has returned to its superconducting state.

According to the commonly accepted convention the sample is considered to be in its superconducting state if the voltage drop per unit length (in centimetres) is not more than $1 \mu\text{V}$ independently of the dimensions of the sample and of the current flowing through the sample. Consequently the ratio of the resistivities of the normal and the superconducting states of the sample may be considered to be practically infinite since the voltage drop on the sample in its superconducting state is practically zero.

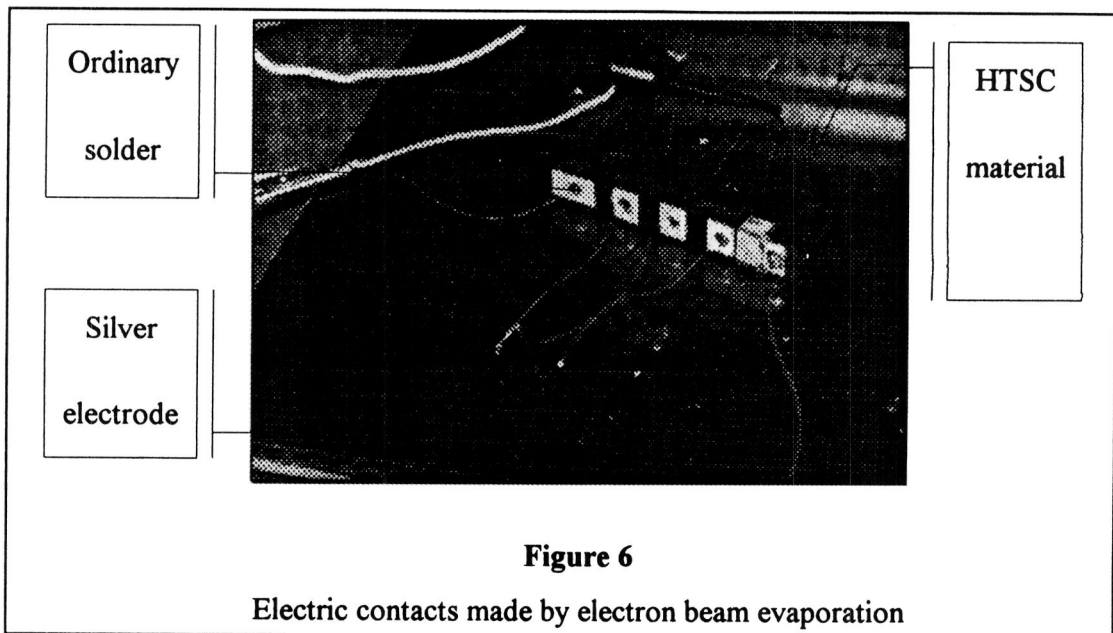
The switching time of the sample both in the superconducting \Rightarrow normal state and the normal \Rightarrow superconducting state has been orders of magnitude less than 1 ms. This time period is critical for the arc suppressing.

Fabrication of HTSC material-metal contacts

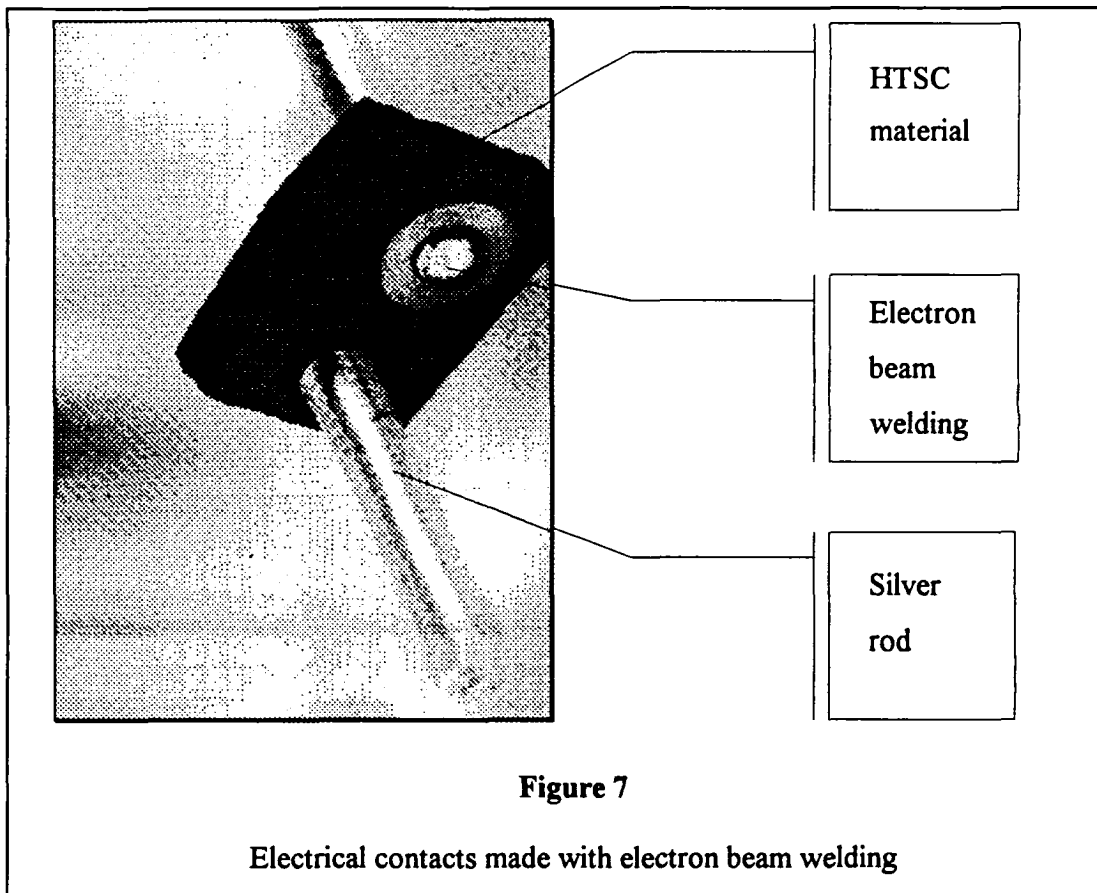
One of the crucial points of the application of the HTSC materials in current limiters or circuit breakers is the possibility of fabrication contacts with satisfactory mechanical properties and contact resistivities [7].

In the frame of the project various welding and soldering methods are planned to be investigated. The first successful results in this respect have been achieved by electron beam evaporation and welding.

Figure 6 shows silver contacts evaporated by an electron beam on the surface of an YBaCuO rod.



Silver rods of $\varnothing 3$ mm jointed to an YBaCuO plate by electron beam welding is shown in *Figure 7*.



According to our investigations the welded contacts allow current loads that are orders of magnitude higher than what has been achieved by other technologies referred in the literature. The electron beam welding seems to be a suitable method of fabricating contacts of considerable cross section between HTSC materials and metals.

It is worth to be noted that we have made promising experiments in wire forming and contact making by the method of explosive powder compaction as well [1].

Conclusions

The design principles of a device containing an HTSC element and suitable to arc suppressing has been developed. A sample switch for the modelling of the superconducting \Rightarrow normal and the normal \Rightarrow superconducting transitions has been constructed and tested. Preliminary experiments regarding the technologies of contact making have shown promising results.

References

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