
Report of the Referee -- BG14421/Hirsch

This paper presents a case for a fundamental inconsistency of the time-honored conventional theory of superconductivity. If true it would constitute a major problem, not only for theory, but for numerous experimental results as well. However, the claim is not correct, in my view.

There are at least two problems with this paper. First, it is not clearly spelled out what the consequences of the claimed inconsistency would be. In other words, which experiment (or theoretical study) would detect the inconsistency unequivocally. Secondly, the calculations presented are incomplete.

To demonstrate the claimed inconsistency a seemingly simple thermodynamic process is considered: the cooling of a type I superconductor in a magnetic field. The process starts from the equilibrium state at temperature T1 and ends at temperature T2. The question posed in the paper is whether the final state is an equilibrium state. It is, of course, an equilibrium state if the change is performed adiabatically, meaning infinitely slowly. Experiments are, however, performed at finite rate of change. The author calculates the changes of energy and entropy involved in the process in the framework of phenomenological theory, including the change of the superfluid and normal component. The essential conclusion is that the normal component will undergo dissipative processes, which contribute to the entropy balance. The entropy of the final state will therefore differ from that of the equilibrium state.

To describe the cooling process at finite cooling rate in detail is not a simple matter. The thermal reservoir has to be modeled in some way, e.g. as a source of phonons in equilibrium at temperature T (dropping from T1 to T2) and a sink for any phonons emitted from the superconductor. The state of the superconductor during the cooling process is out of equilibrium, which is to say that the Bogoliubov quasiparticle distribution is not the Fermi distribution, but changes with time in a complicated way. Whatever the details will be, any increase of entropy caused by dissipation taking place in the system, will not contribute to the final entropy balance of the system, but will be absorbed by the heat reservoir. Suppose the cooling process starts at time t1 (temperature of the reservoir T1) and ends at time t2 (T2), then the system will be still out of equilibrium at time t2, but will equilibrate at temperature T2 after some microscopic relaxation time. The final state will be an equilibrium state, as enforced by the contact to the thermal reservoir.

To conclude, I am not convinced that the paper presents sufficient evidence for the existence of a fundamental thermodynamic inconsistency of the conventional theory of superconductivity. The paper should not be published in its present form.