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A SCHEME TO PROVIDE LOW HEAT CONDUCTION IN SUPPORT MEMBERS OF SUPERCONDUCTING DEVICES AND OTHER APPLICATIONS

F. Hornstra

Fermi National Accelerator Laboratory

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Introduction

A problem confronted in building thermally insulating support systems is that a compromise is often made between desired mechanical properties and the required thermal resistance. This practice makes it difficult to obtain substantial reductions in heat flow without seriously compromising the mechanical support system. A scheme is suggested which essentially avoids the above compromise.

The Concept

In a vacuum, unwetted contact surfaces provide notoriously poor heat flow. If the continuity of any heat path in a support system is interrupted by a number of contact surfaces or junctions, heat flow may be reduced substantially.

In a compressive support system, a series of insulating spacers can be stacked in the heat path to provide a number of thermal blocking junctions. In a tension support system, ceramic covered, or oxidized, chain links should be substituted for rods or wires. In both cases, rather than the thermal resistivity of the support materials, the number and nature of the contact junctions characterize the heat flow. As a result, the basic geometry of the support system can be chosen to satisfy mechanical requirements.

Analysis: A. Compression Support System

Consider the simple compression support system of Figure 1. The heat flow through the system is simply given by the total temperature difference across the support multiplied by the thermal

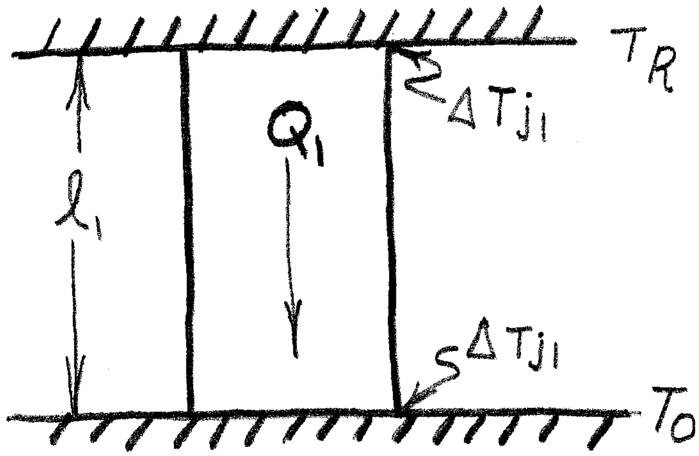

Figure 1

Compression Support System of
Cross Sectional Area A_1

conductivity and the cross sectional area and divided by the length as follows:

$$Q_1 = [T_R - T_O - 2\Delta T_{j1}] \frac{K_1 A_1}{\ell_1}$$

where;

T_R = one temperature

T_O = another temperature

ΔT_{j1} = the junction temperature difference (assumed equal for both junctions)

K_1 = the thermal conductivity of the support material

A_1 = the cross sectional area of the support material.

In Figure 2 the cross sectional area of the support has been reduced. The heat flow is as follows:

$$Q_2 = [T_R - T_O - 2\Delta T_{j2}] \frac{K_2 A_2}{\ell_1}$$

$$A_2 < A_1.$$

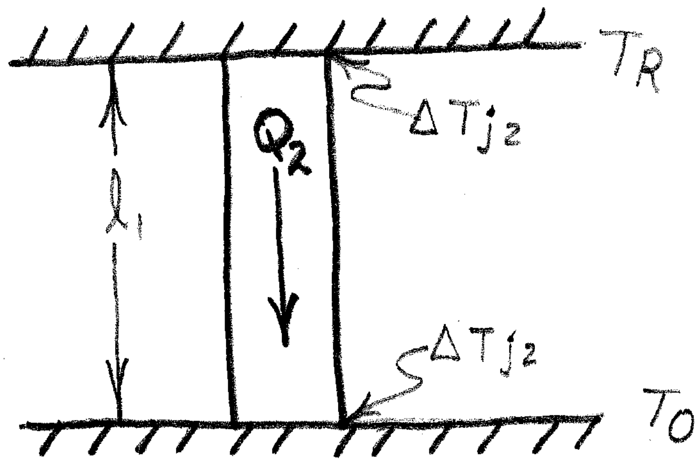

Figure 2
Compression Support System of Cross Sectional Area A_2

The decrease in heat flow may not be as great as expected because greater contact pressure may produce junction temperature differences ΔT_{j2} less than junction temperature difference ΔT_{j1} in Figure 1. Under the best circumstances, one can expect an even trade between cross sectional area (strength) and thermal insulation. Clearly, an order of magnitude reduction in heat loss will prove difficult if one must rely on linear trade-offs.

In Figure 3, the heat path is interrupted by a series of thermally blocking junctions formed at the interface of relatively rigid materials. The following equation shows that the heat flow is reduced as the number of junctions is increased as follows:

$$Q_3 = \left[T_R - T_O - 2\Delta T_{j3} - 2\Delta T_{jcs} - n\Delta T_{cc}\right] \frac{K_1 A_1}{\ell_1}$$

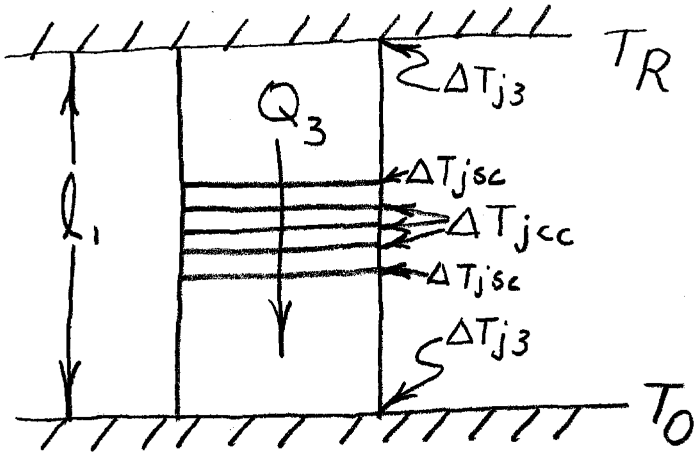

Figure 3

Compressive Support System of Cross Sectional Area A with a Series of Thermally Blocking Junctions

where in addition to the definitions set forth above,

ΔT_{jsc} = the temperature difference across the support - ceramic junction

ΔT_{jcc} = the temperature difference across the ceramic - ceramic junctions

n = the number of ceramic - ceramic junctions.

ΔT_{sc} is distinguished from ΔT_{jcc} as the former may be less if the support is of an amorphous material (such as G-10) which may conform to the contact surface of the ceramic, thereby forming a more perfect thermal contact. The assumption that ΔT_{jcc} is the same for each ceramic - ceramic junction is not a good one. Not only are unwetted contacts notoriously poor thermal contacts, they exhibit notoriously poor reproducibility; however, as n, the number of ceramic junctions, increases, less variation from support to support should be observed.

The important point in the last equation is that Q_3 can be substantially less than Q_1 by making the number of junctions large. As a result the support system may be designed to satisfy the basic mechanical requirements.

<u>Analysis</u>: B. Suspension or Tension System

The same analogy as that above may be applied to a suspension system. In Figure 4, the support member of cross sectional area A_4 is in tension.

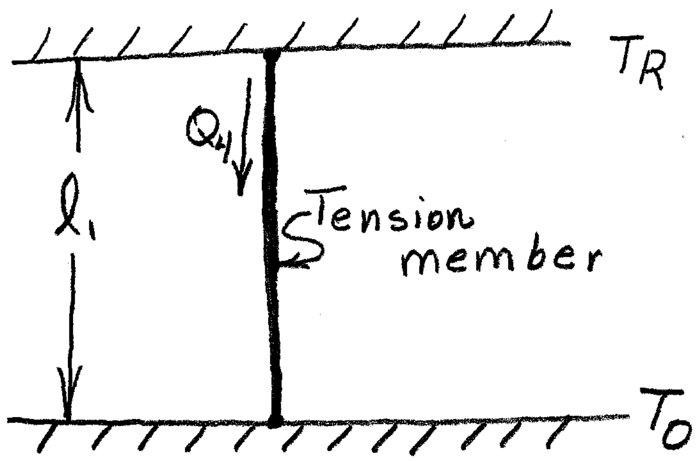

Figure 4
Tension Support System of Cross Sectional Area A_4

The heat flow is again the temperature difference multiplied by the thermal conductivity and the cross sectional area as follows:

$$Q_2 = [T_R - T_O] \frac{k_4 A_4}{\ell_1}$$

In Figure 5, the continuous support member is replaced by a chain. A thermally blocking junction is formed at each interlink to greatly reduce the heat flow. In fact, at each interlink, two thermally blocking junctions can be formed if a properly formed ceramic spacer is inserted. The total length of the heat path is also thereby increased at no sacrifice in strength of the suspension system.

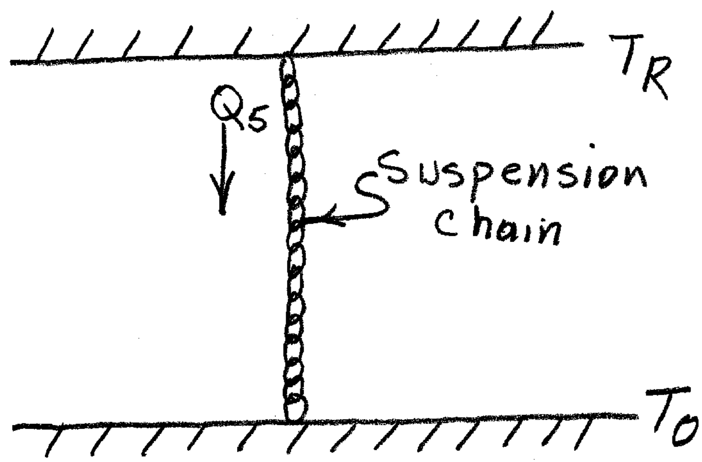

Figure 5
Suspension System Formed by Links

$$Q_5 << Q_4$$

<u>Application to the Energy Doubler</u>

Consider the present geometry of the Energy Doubler magnet suspension system, as depicted in Figure 6.

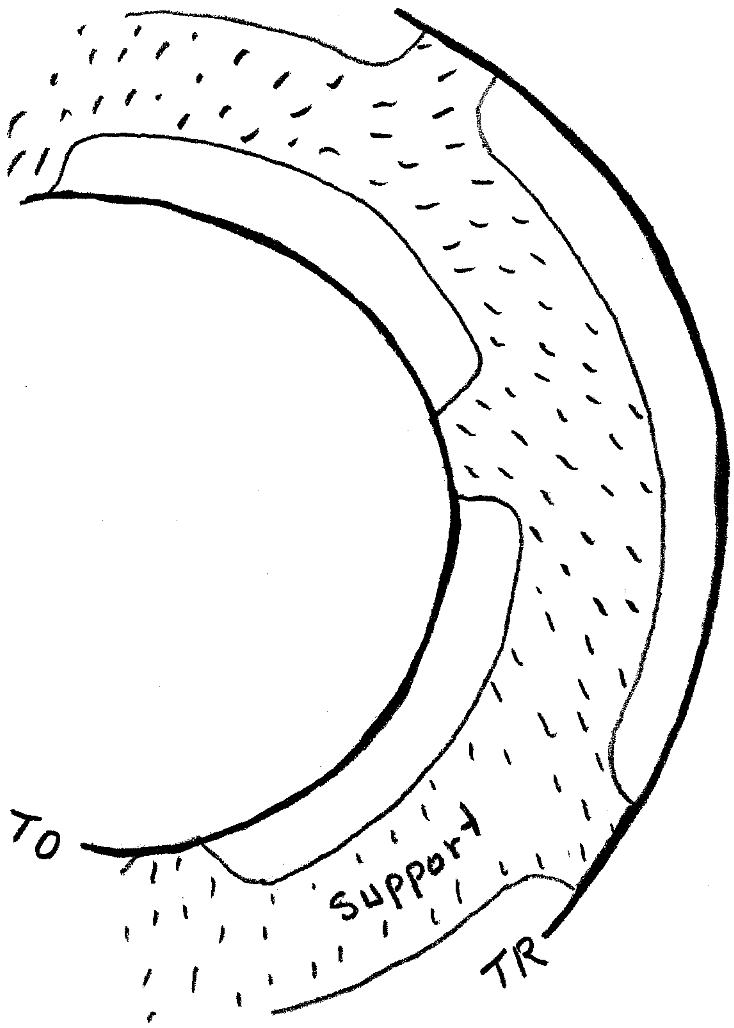

Figure 6

Present Geometry of the Energy Doubler
Magnet Support System

A significant reduction in heat conduction can be realized by simply making a ring of G-10 and replace the support stubs with ceramic spacers as depicted in Figure 7.

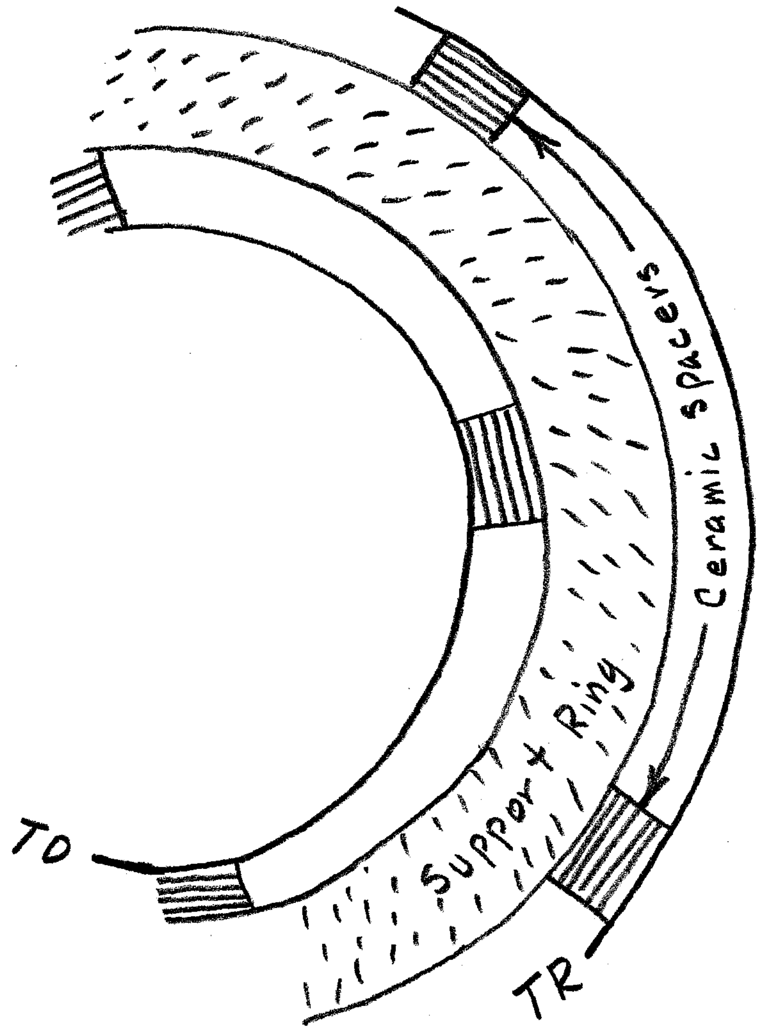

Figure 7

Suggested Configuration of the Energy Doubler
Magnet Support with Ceramic
Spacers Replacing Support Stubs

Here is a good example of where the G-10 ring may be sized and supported to satisfy the mechanical requirements while excellent thermal insulation may be obtained by the ceramic spacers.

Conclusion

The general concept presented here can be applied to any support system. The bulk of the support material and geometry may be chosen to satisfy the mechanical requirements of the system. The heat flow through the system can be blocked by judiciously placed antithermal junctions. The heat flow will be limited by the nature and the number of these junctions rather than the thermal conductivity of the support material. As a result, the support can possess good thermal insulating qualities and simultaneously, good mechanical qualities.

Acknowledgements

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