Thermodynamic Aspects of Gravithermels

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In spite of their many shortcomings, the concepts of thermodynamics still enjoy referee status for problems concerning heat or other forms of energy. It is sometimes fortunate that the laws of thermodynamics are based on experience rather than pure reason. Thus, when we pose the question, "Is it possible to discover any alloy the temperature of which can be affected by gravity waves?" thermodynamics replies with a resounding affirmative, but only after we have subjected specific systems to its scrutiny. It is comforting to realize that such alloys are neither startling nor unprecedented. Thermodynamics anticipates their discovery, sanctions their use by reference to systems currently accepted in our philosophy, and even tells us the properties we ought to seek in order to discover the most efficient alloys.

It might be economical to digress briefly to establish the word "gravithermels" which I shall henceforth employ to designate alloys which may be heated or cooled by gravity waves. The coining of this word follows modern practice which produced such words as "thermistor" and "electrad." It might also be useful, although not necessary, to broaden the definition of "alloys" to include non-metallic systems. I make this suggestion because it removes a needless restriction on the practical application of the ideas which follow, although my discussion is entirely general, and my conclusions are independent of the chemical nature of the materials involved.

It was stated previously that thermodynamics is based on experience, which includes planned experiences, experiments. A favorite toy of the classical physicist was a wire, suspended at one end, and hanging under gravity tension with or without the aid of an appended inert mass. (The appended mass is used merely because it permits simplification of the mathematical treatment of the system.) It would seem that this same system would constitute the simplest form of gravithermel, and by making a few, not unreasonable assumptions it is possible to consider it within the framework of thermodynamics. It should be emphasized that these assumptions, should they be contrary to fact, will not affect the qualitative conclusions presented, but may present a challenge to their quantitative significance. The resulting facility of thought and calculation far outweighs the advantages of quantitative demonstration. We must assume that our stretched wire is not extended beyond its elastic limit, and that gravity waves produce only infinitesimal changes in the thermodynamic coordinates of the wire. Accelerated motion, such as occurs during free falling in a gravitational field, would not be included in the following calculation.

Experiment has indicated that the thermodynamic equation of state of this stretched wire is a function of three coordinates, the temperature T, length L and tension D.

Solving this unknown function for T,

$$T = \Phi(L, D)$$

and by a theorem of partial differential equations,

$$dT = \left(\frac{\partial T}{\partial L}\right)_D dL + \left(\frac{\partial T}{\partial D}\right)_L dD$$

multiplying through by $\frac{1}{L}\frac{(\partial L)}{(\partial T)_D}$,

$$dT\,\frac{1}{L}\left(\frac{\partial L}{\partial T}\right)_D = \frac{dL}{L} + \left(\frac{\partial T}{\partial D}\right)_L dD \cdot \frac{1}{L}\left(\frac{\partial L}{\partial T}\right)_D$$

Replacing $\frac{1}{L}\left(\frac{\partial L}{\partial T}\right)_D$ (which is the coefficient of linear expansion) by α, and transposing,

$$\frac{dT}{dD} = \frac{dL}{L\alpha\, dD} + \left(\frac{\partial T}{\partial D}\right)_L$$

$\frac{dT}{dD}$ is a measure of the variation of temperature with variation of gravity tension (gravity waves), and it is thus seen that any substance formed into a wire and stressed within the limits of Hooke's law is a gravithermel, provided that its coefficient of linear expansion is not zero.

Furthermore, while a wire was chosen as the least complicated system for consideration, it is readily shown that a parallel derivation may be made for a block of alloy under compression, or for a liquid or gas enclosed in a cylinder by a weighted piston. For these situations the equation of state is a function of temperature T, volume V, and pressure P, which latter may be arranged as a function of gravity tension. The equation then becomes:

$$dT = \left(\frac{\partial T}{\partial V}\right)_P dV + \left(\frac{\partial T}{\partial P}\right)_V dP$$

and one multiplies through by the coefficient of volume expansion $\frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p$.

The derivation is otherwise identical with that presented for the stretched wire.

It must be admitted that other thermal phenomena are superimposed upon these infinitesimals and that the others may be more important, yet we have conclusively established that nearly all elastic materials may function as gravithermels.

Unfortunately, all of the gravithermels now known exhibit extremely small temperature changes, but the final equation shown for the stretched wire points to properties which may be chosen to increase the effectiveness of the alloy as a gravithermel. This alloy should be a "soft" elastic (large $\frac{dL}{L}$ ratio) and should have a very small coefficient of linear expansion. The partial differential $\left(\frac{\partial T}{\partial D}\right)_L$, the rate of change of temperature with tension at constant length, has no physical significance but is undoubtedly a short range constant, and is a property of the individual alloy. It is probably a function of α and $\frac{dL}{L}$.

The present status of metallurgy permits tailoring alloys to suit these specifications.

My discussion to this point has been concerned only with changes of state, and has not needed a consideration of the means by which the thermodynamic coordinates have been varied. It is, however, of interest to see how the energy is obtained to produce temperature variations. Returning to our stretched wire, we can visualize that its compression and rarefaction with variations in gravity tension may be either adiabatic or isothermal.

The frequency of the gravity waves and the rate of heat transfer through the wire and to its surroundings determine which condition will prevail. It is expected that the process will be adiabatic.

Under isothermal conditions the work performed by gravity during one wave is $-DdL$, and the heat transferred equals

$$-T\int\left(\frac{\partial L}{\partial T}\right)_D dD.$$

Since the coefficient of linear expansion is $\frac{1}{L}\left(\frac{\partial L}{\partial T}\right)_D$, the heat transferred equals $-T\int L\alpha dD$. Adiabatic effects, however, are of

greater interest for the present discussion. By making the adiabatic change reversible,

$$TdS = C_D dT - T\left(\frac{\partial L}{\partial T}\right)_D dD = 0$$

since under such conditions the system is isentropic. The equa- may be simplified to:

$$dT = \frac{T}{C_D}\left(\frac{\partial L}{\partial T}\right)_D dD = \frac{TL\alpha}{C_D} dD.$$

From this, we gain the additional information that our desired alloy should have a low heat capacity, and the system should be maintained at the highest practicable initial temperature. As was shown previously, the same argument may be easily extended to systems other than wires, and may even include liquids or gases.

Thus, we see that in trying to justify what we believed to be a remote possibility, we find instead that such alloys daily surround us. The magnitude of the effect they produce is small, yet we now know how to enhance that effect. The problem is no longer one of discovering radically new alloys, but reduces to the more congenial task of improving those we now possess.

This essay is "on the possibilities of discovering some alloy the temperature of which can be affected by gravity waves."

My title is "Thermodynamic Aspects of Gravithermels"

Summary: By the methods of thermodynamics it is demonstrated that substances which vary in temperature under the influence of gravity waves are already known. The question thus reduces to one of degree rather than kind, and thermodynamics points the way to production of alloys which may be orders of magnitude more efficient than any previously discovered.