

Transformation from Heat of Low Temperature Sources into Work Fundamentals for a Maximum of Efficiency

Maurizio VIGNATI
ISPESL
Via Urbana 167, 00184 Roma
Italy

Abstract

The problem of converting the heat produced by cold fusion into work, meets with a classical limit consisting in the second principle of thermodynamics, because the heat produced within electrolytic cells is released to the heavy water, and remains at a low thermal degree. However, this paper draws attention to the existence of ideal thermodynamic cycles the efficiency of which is considerably higher than the efficiency attained by the corresponding Carnot cycle between the same temperatures. In addition to this, it can be shown that combinations of these cycles can attain even higher efficiencies. Owing to the characteristics of these cycles and combinations of cycles, and being also possible to put them into practice, they could be taken into consideration for projects aiming at the transformation into work of the heat produced by cold fusion or other heat sources at low temperature.

1. Introduction

Making use of data on real fluids, it is possible to calculate the efficiency of ideal cycles with various fluids. A milestone in this field is a publication (ref.1) of the National Bureau of Standards (now National Institute of Standards and Technology), concerning the thermodynamic properties of Argon (1969). A more recent work is the publication of the thermodynamic properties of water (ref.2), (1988). And many other thermodynamic properties of different fluids have been published in books and reviews (ref. 3 - 8). Most of these papers propose a mathematical model of the fluid under study. It is possible, therefore, to make part these mathematical models of interactive programmes which allow to calculate the efficiency of ideal cycles and combinations of ideal cycles with the same fluid.

2. Ideal Conditions

Our aim is to demonstrate the existence of cycles the efficiency of which is greater than the efficiency of the Carnot cycle. In order to do this, we will assume the same assumptions generally accepted to deal with ideal cycles, that is, that every kind of energy or heat loss can be avoided by the use of ideal devices and conditions. Except the Carnot cycle, other cycles need to be conceived with a heat recuperator, so that we also assume that this device may be perfectly insulated and sized in such a way as to render the internal viscous losses negligible. Isothermic and isochoric transformations will be assumed ideal as well.

3. Theorems on Ideal Transformations and Cycles

On the basis of the assumptions made in the previous point, it is possible to demonstrate ten theorems concerning the thermodynamic behaviour of the ideal

heat recuperator when applied to cycles with real fluids in gaseous phase. It is not possible to give extensive information, here, about this very important subject. Interested readers are addressed to the references (ref. 9-10). What can be said here is that the perfect heat recuperator allows perfect compensation of the isothermic quantities of heat of an Ericsson cycle, if the quantities of heat are the same. In addition, it allows perfect compensation of the isochoric transformations of a Stirling cycle, if the quantities of heat are the same. If the quantities of heat are not the same, the entire difference of heat is absorbed by (or imparted to) one heat source only.

4. Programmes to Calculate Efficiency

Once the theorems are stated and demonstrated, it is possible to use them in numerical (computerized) calculations of the performances of ideal thermodynamic cycles. These programmes have been made for argon, making use of data available in ref.1. To facilitate more people to understand these programmes, they have been written in BASIC programming language (ref.15-16). Five programmes have been set up, named CARNOT, STIRLING, STIRREV, ERICSSON, ERXREV. They are interactive programmes, which require the user to type in a few numbers at the beginning. The user has to type in the thermodynamic characteristics of the main points of the cycle chosen. In addition to the said theorems, these programmes merely apply the rules to calculate energy and heat exchanges of the various sections of the cycles, in particular, they make use of the first principle of thermodynamics.

5. Result: The Ideal Carnot Cycle with Gaseous Argon

To check the validity of this kind of calculation, we first applied CARNOT to the Carnot cycle. The result of this verification is fully satisfactory, because it is always verified the identity between theoretical efficiency and numerically calculated efficiency.

6. Result: The Ideal Stirling Cycle with Gaseous Argon

Once the validity of the calculation method has been assured, we can extend our research to other kind of cycles. The ideal Stirling cycle can be provided with a perfect heat recuperator, or it can be missing. Making the calculations with STIRLING, we find that if the perfect heat recuperator is applied, efficiency is practically equal to the efficiency of the Carnot cycle, but a small irreversibility occurs. If the heat recuperator is missing, efficiency is lower.

7. Result: Combinations of Stirling Cycles

We can imagine to pair two adjoining and opposed Stirling cycles and provide them with a common heat recuperator. Using STIRREV, we *always* find couples of opposed Stirling cycles with overall efficiency exactly equal to the one due to the Carnot cycle. These couples are reversible as a whole.

8. Result: The Ericsson Cycle with Gaseous Argon

The same procedure can be applied to the Ericsson cycle. It can be imagined with or without a perfect heat recuperator. However, running ERICSSON we have a big surprise, because the efficiency pattern of the Ericsson cycle is very unusual: it shows peaks over and below the efficiency value of the Carnot cycle. What more counts is

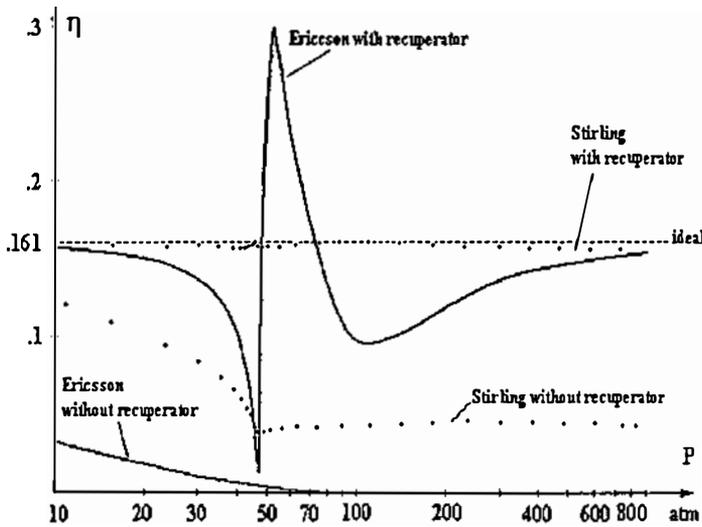


Fig.1 Efficiency of various cycles with gaseous argon

Recapitulatory diagram with the efficiency patterns of the indicated cycles, versus the highest pressure encountered along the cycles. The "hot" source is at the temperature of 180 K, while the cold source is at 151 K.

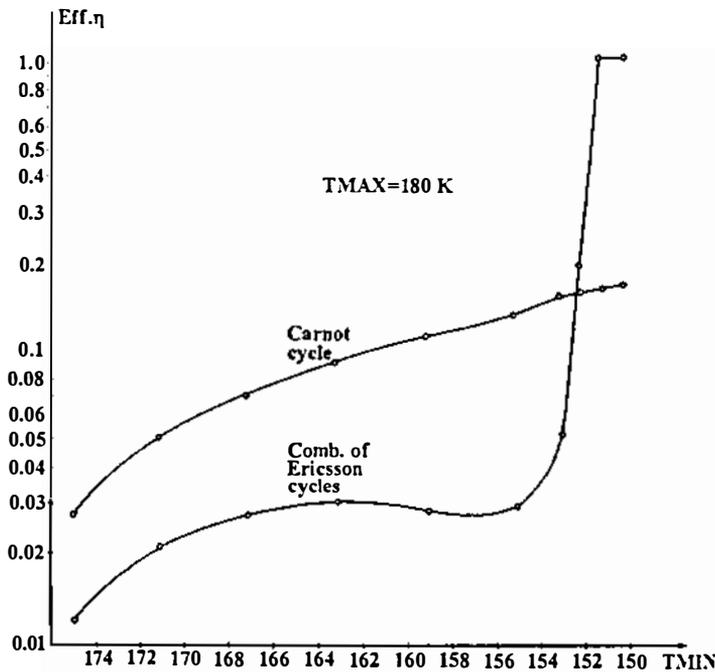


Fig.2 Efficiency of a combination of Ericsson cycles

By pairing two adjoining and opposed Ericsson cycles, it is possible to obtain conditions in which the overall efficiency η is greater than the efficiency of the equivalent Carnot cycle. This depends, mainly, on the vicinity of the temperature of the cold source to the critical temperature T_c of the gas used. The case shown is relative to argon ($T_c = 150.86$ K) with $PE = 60$ and $PK = 40$ atm. T_{MAX} is fixed to 180 K, while T_{MIN} is variable (in abscissa).

the fact that the maximum efficiency depends heavily on the proximity of the cold temperature to the critical temperature, and it depends also on the position chosen on the P-V plane. In addition, it is possible to show that the Ericsson cycle attaining maximum efficiency is reversible. Fig.1 shows the patterns of efficiency of the various cycles examined.

To prove that these results are not due to ill-conditioning of the programme ERICSSON, we can make the calculation by hand, and verify the exactness of the calculations made by ERICSSON, since we obtain the same results. It is also possible to find the same conditions of increased efficiency with many other fluids in gaseous phase employed in the Ericsson cycle, namely: He-4, N₂, Kr, Xe, NH₃, CH₄, Ethane, Propane, Isobutane, Normal Butane, Ethylene and Water. With all these elements and substances it is possible to determine Ericsson cycles with an efficiency value about twice the efficiency of the equivalent Carnot cycle.

9. Result: Combinations of Ericsson Cycles with Gaseous Argon

We can imagine to pair two adjoining and opposed Ericsson cycles and provide them with a common heat recuperator. When this is done, we *always* find couples of opposed Ericsson cycles reversible as a whole. As regards the efficiency, the overall efficiency depends,

once more, on the position chosen on the P-V plane, but it also depends on the proximity of the temperature of the cold source to the critical temperature of argon (Fig.2).

10. Conclusions

Since our reasonings concern ideal conditions, it is difficult to establish at the moment to what extent these high efficiency cycles can be put into practice. However, this study shows that it is possible to go far beyond the limit of efficiency which derives from the thermodynamic theory - theory which, we remember, obtains this limit from Kelvin and Clausius' postulates by means of demonstrations based on *reductio ad absurdum*. The numerical calculations give quite another limit of efficiency. What I showed is nothing but a possible track that could be followed by those who are interested in exploiting heat sources at low temperature. About the aspects of the matter which seem to be in contrast with the principle of the increase of entropy, there is not enough space to master the subject here. Interested readers could consult ref. 9-10. I will only say that if we stick to the operative modalities with which one states, case by case, that entropy is increased after the occurrence of an irreversible transformation, then we can say that the principle holds, notwithstanding we have discovered cycles which attain an efficiency greater than the efficiency of the corresponding Carnot cycle.

References

1. Gosman L.A., McCarty R.D., Hust J.G., *Thermodynamic Properties of Argon From The Triple Point to 300 K at Pressures to 1000 Atmospheres*, p.150, NBS-27 National Bureau of Standards, (1969).
2. Sato H., Uematsu M., Watanabe K., Saul A., Wagner W., "New International Skeleton Tables for the Thermodynamic Properties of Ordinary Water Substance" *J. Phys. Chem Ref. Data*, 17, N.4, 1439-1539 (1988).
3. Rabinovich V.A., Vasserman A.A., Nedostup V.I., Veksler L.S., *Thermophysical Properties of Neon, Argon, Krypton and Xenon*, p. 622, National Standard Reference Data Service of the USSR. Theodore B. Selover, Jr. English-Language Editor, Hemisphere Publication Co. (1988).
4. McCarty R.D., *Thermophysical Properties of Helium-4 for Temperatures from 2 to 1500 K with Pressures to 100 Mn/m²*, p. 155, NBS report 9762, (1970).
5. Jacobsen R., "Thermodynamic Properties of Nitrogen from the Freezing Line to 2000K at Pressures to 1000 MPa", *J. Phys. Chem. Ref. Data* 15, N.2, 736-909 (1986).
6. Haar L., "Thermodynamic Properties of Ammonia" *J. Phys. Chem. Ref. Data* 7, N.3 635-972 (1978).
7. Younglove B.A. "Thermophysical Properties of Fluids Methane, Ethane, Propane, Isobuthane and Normal Buthane" *J. Phys. Chem. Ref. Data* 16, N.4 577-798 (1987).
8. McCarty R.D., "Thermophysical Properties of Ethylene from the Freezing Line to 450 K at Pressures to 260 MPa", *J. Phys. Chem. Ref. Data* 15, N.2 593-734 (1986).
9. Vignati M. *Riflessioni sulla Potenza Motrice del Calore Ambientale*, p288, 1 floppy disk, Astrolabium Ed., Viale Garibaldi 4, Civitavecchia, Italy (1993).
10. Vignati M., *Crisis of a Dogma - Clausius' Theorem at the settling of accounts* p.160, 1 floppy disk, Astrolabium Ed., Viale Garibaldi 4, Civitavecchia, Italy, telefax 766 - 501648, (1995).