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ENERGY CONVERSION EFFICIENCY VERSUS ENERGY UTILIZATION EFFECTIVENESS

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Abstract

This paper provides a brief outline of thermodynamics of energy conversion and efficiency concepts to establish a basis for the following argument that energy conversion is essentially a technical problem to be solved within the constraints of available technological know-how, whereas energy use effectiveness is largely a management problem which requires a somewhat different approach. An attempt is made to show that significant economic contributions can be made by improved management of energy use within the existing technological boundaries.

1. INTRODUCTION

Basic to any form of activity, including life itself, is a suitable supply of energy. The common denominator for the digestive process of an amoeba and placing a weather satellite in earth orbit or every process in between is the energy requirement. Specifically, the location and effective utilization of key resources, transforming them into an energy supply suited to the demands of the process more clearly defines this common denominator of the need for energy.

An equally basic fundamental has been the strong correlation between the development of an inexpensive, abundant energy supply and the rising standard of living in the United States. The development and utilization of vast and hence, cheap reserves of energy resources and their subsequent transformation into ample supplies of energy suited to industrial, commercial, and residential processes follows a growth closely paralleling the rise in average, per capita Gross National Product. (1) Furthermore, it is no accident that the world's leading producer and consumer of energy also possessed a per capita GNP that remained unsurpassed for many decades.

The sudden, albeit predicted, shift to an energy supply that is neither inexpensive nor abundant poses serious questions. Can the U.S. living standard continue to rise if our rate of energy use must slow down or even level off? Will the soaring cost of energy, so long a minimal budget item, stifle capital investments, construction, and expansion? Of ultimate concern, however, is the dilemma of survival itself. How can we survive the short-run expenses and shortages while awaiting the realization of the long-term solutions? This paper will attempt to show that improved energy auditing techniques coupled with effective energy management methods can lead directly to significant increases in energy use effectiveness, thereby controlling the short-run expenses and minimizing the adverse effects of supply shortages.

The principal concepts of energy conversion thermodynamics will be explored to serve as both a brief review and as a basis for illustration of energy management possibilities which will be presented later. Also, since energy conversion processes must obey the laws of thermodynamics, a thorough comprehension of the implications of those laws will aid in establishing the limits of current energy resource conversion technology.

2. THE ROLE OF THERMODYNAMICS

The First Law of Thermodynamics is of great importance in all energy transformations since it predicts the perfection of the processes which cause the transformations. In other words, it is extremely valuable because of the necessity of producing the maximum amount of useful work and of conserving this work once it is produced. One statement of this postulate is: When a closed system is altered adiabatically, the work is the same for all possible paths which connect two given equilibrium states. (2) Stated another way, the value of the work carried out, on, or by a closed adiabatic system is dependent solely upon the end states of the process. This postulate is made regardless of the type of work interaction involved in the process, the type of process, and the nature of the closed system.

Not only is the First Law applicable to simple adiabatic processes such as those which involve a paddlewheel or electrical work in a closed system, but it may also be applied to systems which experience electromagnetic, surface tension, shear, and gravitational field effects. In an expanded formulation, closed systems undergoing heat interactions as well as work interactions are brought within its scope. Finally, the First Law can be extended to open systems as well, where mass transfer is permitted across the system boundaries.

The first law places no restrictions on the direction of the heat and the work. A cycle in which a given amount of heat is transferred from the system and an equal amount of work is done on the system satisfies the first law just as well as does a cycle in which the heat and work directions are reversed. However, experience shows that this does not necessarily work, and this type of experimental evidence forms the basis of the second law of thermodynamics.

The second law says that no engine, actual or ideal, can completely and continuously transform all of the heat added to its working substance into work. (3) Several other forms of the second law are given in statements by Clausius, Kelvin, and Reeve, but all are related to the above and all indicate the "road block" which exists when attempting the complete conversion of heat into work in any heat engine. (4)

The implicative concepts of the second law are difficult to combine into a simple, all-inclusive statement. In general, however, the second law states that heat is a low-grade form of energy; that is, it cannot be completely converted to some other forms. The temperature at which heat is added is a measure of the possible degree of its conversion into work. Heat tends to gravitate to a lower temperature plane, resulting in a decreased possibility of its transformation into work. Heat can never, of its own accord, flow to a higher level of temperature. Finally, the maximum proportion of heat may be converted into work when the unused heat is rejected at the lowest naturally available temperature. Thus, it is impossible to construct a heat pump that operates without an input of work and it is impossible to build a heat engine with a thermal efficiency of 100 percent.

The French engineer, Sadi Carnot, was among the first to appreciate the limitation that "heat cannot perform work except when it passes from a higher to a lower temperature level." (5) He pointed out that the amount of heat thus converted into work was proportional to the difference between the temperatures at which heat was supplied and rejected. Since the purpose of any heat engine is to convert into work as much as possible of the heat supplied to the working substance, it would be to our advantage for several reasons to know this theoretical maximum amount.

This concept of limitation is expressed as the thermal efficiency of a heat engine and may be defined as the net work done by an engine divided by the heat supplied to its working substance by the hot body. If the thermal efficiency idea is applied to a power cycle in which every process is reversible therefore making the cycle reversible also, then the highest efficiency it can achieve is the Carnot Efficiency. The reversible cycle consisting of the following processes is called a Carnot Cycle: (1) an isothermal process in which heat is transferred from the high temperature reservoir to the working fluid, (2) an adiabatic process in which the temperature of the working fluid is decreased to the low temperature, (3) an isothermal process where heat transfer to low temperature reservoir occurs, (4) an adiabatic increase of the temperature of the working fluid to the high temperature. Such an engine represents the theoretically most efficient engine and serves as the ultimate development goal for cyclic engines. (6)

In actual practice the Carnot Cycle is difficult to approximate. Thus, a vapor cycle which is much easier to use as a model for performance is the Rankine cycle. In fact, it is merely a modification of the Carnot Cycle using steam as its working fluid. Obviously, the Rankine cycle will have a lower efficiency than a Carnot cycle with the same maximum and minimum temperatures. Nevertheless, because of the practical problems of the Carnot cycle, the Rankine cycle finds wide application in the electrical utility industry. The steam power plants operate on essentially this same basic cycle, whether the input energy is from the combustion of fossil fuels or from the fission process in a nuclear reactor.

3. ENERGY USE CONSIDERATIONS

The thermal efficiency of a modern fossil fuel plant is around 40 percent and that of a nuclear plant around 30 percent. Carnot cycle efficiency at about $1000^{\circ}F$ is around 60 percent assuming that the condenser operates at about $100^{\circ}F$. Thus in a steam power plant about 55 percent of the energy released by the combustion of fossil fuels is dissipated by the condenser by circulating cold water through pipes in the condenser chamber. Common sources of cooling water include the oceans, rivers, lakes, ponds and cooling towers. Thus, proportionately more energy is returned to heat the oceans, lakes, rivers or the atmosphere than that which is used to generate power when one unit of fossil fuel is burned in the combustion chamber of a modern boiler. It is interesting to note therefore that the waste heat is really the main product of such a power plant and the power generated is only a by-product. This point dramatizes the previous nature of every unit of energy available to do useful work for us. Similarly it should be noted that an automobile engine with a compression ratio of eight, operating on an ideal gas power cycle called the Otto cycle will have an ideal thermal efficiency of about 56 percent. The actual performance levels are of course much lower when the mechanical inefficiencies are also considered.

Thus we are led to the realization that useful work obtained from the combustion of precious fossil fuels is only a small fraction of the total energy released and that this is inevitable as expressed by the laws of thermodynamics. Therefore, technological and natural limitations combine to prevent significant improvements in energy efficiency and hence, our available energy supply.

Here one may consider the solution to lie in discovering new sources of energy and developing the requisite technologies to exploit them for the use of mankind. This is certainly a worthy objective. However, no one can predict when and at what cost these new means will become available. This does not mean that such research should not be continued with increased vigor. Obviously, it should. The point is that we need to act now to conserve what we have in terms of our energy resources by improving the effectiveness of their use.

4. ENERGY MANAGEMENT

The techniques of energy management range over a wide spectrum, from strict Federal regulations to simply shutting off a device when not in use. However, before effective energy management methods can be productive, a full understanding of exactly how the supply of energy is used must be gained. This is done through what is now commonly referred to as the energy audits. The U.S. Department of Commerce in cooperation with the Federal Energy Administration have developed a program guide for industry and commerce on energy conservation. It describes and clearly illustrates the steps necessary in implementing a successful energy conservation program. According to the guide the following steps are to be taken by a company: (7)

(1) Obtain top management commitment and set company goals
(2) Survey energy uses
(3) Take action to save energy
(4) Monitor programs and develop continuing effort

In addition, the program guide provides examples of energy-saving ideas with calculations of possible savings from their implementation. A listing of data and useful conversion factors pertinent to energy conservation, a set of financial evaluation procedures, sources of assistance in energy problems and many other useful information is also included. Many other documents are obtainable on the subject of energy conservation through FEA sources. State agencies such as Missouri Energy Agency, UMR-MEC have also begun to provide leadership in disseminating much needed information among interested parties. (8) (9)

In 1975 Johns-Manville Corporation conducted energy surveys for the Federal Energy Administration (FEA) in bakeries and meat packing industries. The overall program is described in three categories--measurement, method improvement, and communications. The energy audits were conducted in these highly energy intensive industries as typical examples of what can be accomplished in conservation of energy. It was shown that average savings of 12-40 percent in energy consumption as measured in BTUs with a corresponding dollar savings of 10-23 percent were obtainable in the meat packing industry without significant investment of capital. Similar analyses showed that 13-27 percent energy savings in BTUs and 9-18 percent savings in dollars were possible in the baking industry through better energy management. (10) Our own preliminary audits in small Missouri industries also indicate that 5-20 percent savings are attainable with minimum investment of capital.

The preliminary conclusions indicate that not until very recently has any one of the aforementioned agencies, industries and institutions considered energy management an important topic. Also, in spite of the achievements to date much work needs to be done in developing better and more widely applicable units and methods of measurement in energy conservation effort, as well as disseminating available information to areas of need and educating people involved in every phase of energy conservations.

5. CONCLUSION

In summary, this paper was intended to provide a brief outline of thermodynamics of energy conversion and efficiency concepts to establish a basis for the following argument that energy conversion is essentially a technical problem to be solved within the constraints of available technological know-how, whereas energy use effectiveness is largely a management problem which requires a somewhat different approach. The argument is supported by examples to demonstrate the need for better management of available energy resources. An attempt is made to show that significant economic contributions can be made by improved management of energy use within the existing technological boundaries.

6. REFERENCES

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7. BIOGRAPHIES

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