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The myth of free steam

The concept of getting something free, without paying a price for it, has fascinated man for as long as he has existed. Classical and commonplace philosophers, however, throughout history, have recognized that, as it is expressed in today's commonplace terms, "there is no such thing as a free lunch." Works expressing the fallacy of something for nothing span from Aesop in 550 BC through the *Arabian Nights* tale of Aladdin and Shakespeare's works to Browning's *Pied Piper* in the nineteenth century. There are countless examples.

Unfortunately, leaders in business, government, and even some decision-making members of the engineering community tend to be misled by the something for nothing concept as it is related to energy conversion systems. Understandably, we must continually seek more effective methods of converting our limited energy resources to the needed forms in the needed quantities required by society. However, in striving for our goals, we must be most careful to avoid the attractive pitfall of thinking that we can get something for nothing, that we can get something free.

Energy effectiveness improved

One of the methods of providing for the energy needs of society currently being considered (in fact, it has been employed for more than half a century) is the integrated conversion plant or cogeneration cycle. This type conversion plant conceptually utilizes an energy conversion cascading system, wherein the energy rejected from a second law process is beneficially used in a lower grade form in a thermal process, thus satisfying two needs. With the combination of the proper form of prime movers and in cases where the shaft and thermal loads are adequately coincident and of the proper magnitudes, such plants can and have been beneficial both from the standpoint of monetary savings and *energy effectiveness (Ee)*. To force adequate coincidence in the loads, the designers of buildings and systems have the opportunity to some extent of controlling the magnitude of the loads and, as a last resort, of providing thermal storage.

However, the whole system concept enters the area of misuse when, to raise the thermal efficiency of the second law process, attempts are made to *build* the thermal load in the normal valleys. This concept of "building the load" often creates a false need for thermal energy under the mistaken notion that the heat energy (generally steam) is free!

Consider economics and *Ee*

Let us consider the economics and *Ee* of a system, considering three simple examples. The conditions are:

- Cost of purchased electricity is 2¢ per kW-hr.
- Heat rate of the utility is 11,377 Btu per kW-hr ($Ee = 0.30$).
- Higher heating value of coal is 11,000 Btu per lb.
- Coal cost for on-site generation is $28 per ton ($1.27 per MMBtu).
- Seasonal boiler efficiency (on-site) is 75 percent.

Case 1

Power is to generated on-site with a steam Rankine cycle, throttle conditions, 400 psig and 750 F; exhaust, 2 in. Hg; 1000 Btu per lb (admittedly low, but adequate for these examples) and 70 percent isentropic efficiency are assumed for the turbine. The heat required to generate 1 kW and the cost is shown in Fig. 43-1. The fuel cost is 1.80¢ per kW-hr and the

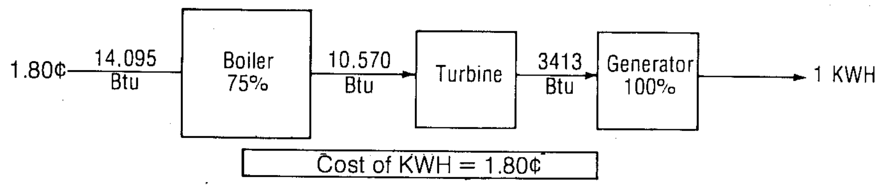

Fig. 43-1. Case 1.

Ee is 24 percent, compared to 2¢ per kW-hr and 30 percent for the utility company.

Case 2

The same energy community has a need for 30,587 Btu thermal energy coincident with the need for 1 kW electrical energy. The conditions and assumptions are the same as in Case 1, except that the turbine will exhaust at 100 psig. The turbine heat rate per kW-hr rises to 34,000 Btu (part (a) of Fig. 43-2) and the plant input fuel requirement is 45,333 Btu, at a cost of 5.75¢. The value of the cascaded heat is represented by the alternative method of generating it with a simplex steam boiler cycle (part (b) of Fig. 43-2), with an indicated value of 5.18¢. The difference, then, is the true cost of the fuel for the kW-hr at 0.57¢. In this case, the *Ee* for the combined plant is 75 percent. With utility electricity and on-site steam, the *Ee* would be 65 percent.

In Case 2, it is quite likely that the appropriate savings of 1.5¢ per kW-hr could amortize the cost of the generating plant and cover such costs as management, operations, maintenance, and so on. However, in the vast majority of energy communities, the need for the hypothetical 30,587 Btu of thermal energy is seasonal in nature, and some balance between the favorable Case 2 and the highly marginal Case 1 is strived for by utilizing variable extraction at the 100 psi level. It is at this point, the striving for the advantages of Case 2, that the pitfall in the logic is found, i.e., *building the steam load.*

Case 3

Case 3 is the same as Case 2, except that the community has a requirement for 1.5 ton-hr of cooling coincident with the 1 kW electricity. This is provided as shown in part (a) of Fig. 43-3, with all conditions the same as Case 2, except that the 30,587 Btu is generating the 1.5 ton-hr through an absorption cycle. An obvious alternative to the absorption cycle would be to purchase electricity from the utility and produce the 1.5 ton-hr through a compression cycle consuming 1.5 kW-hr (COP of 3.5) at a cost of 3¢. Subtracting this credit from the 5.75¢ fuel cost produces a net cost for the

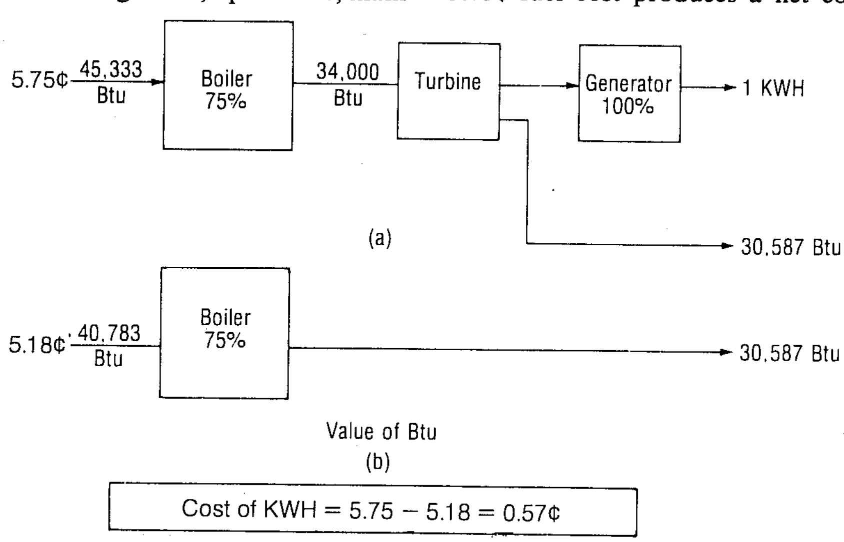

Fig. 43-2. Case 2.

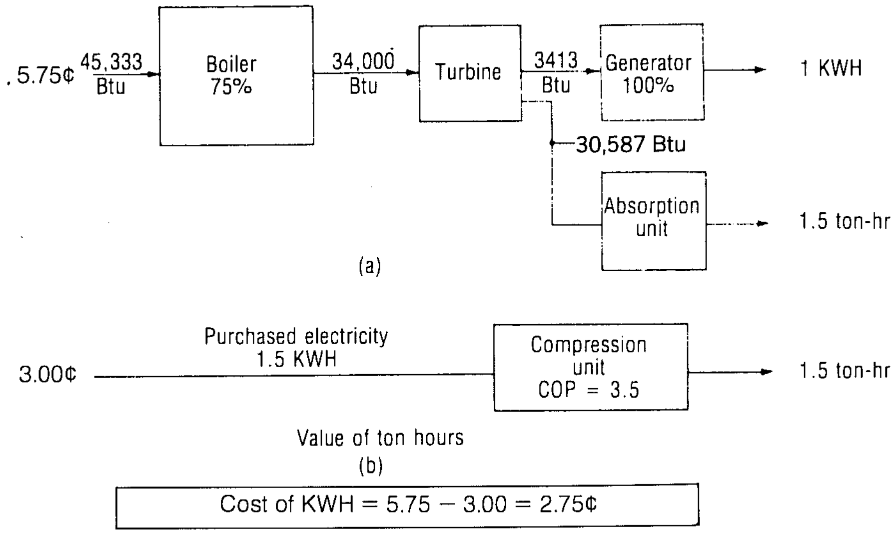

Fig. 43-3. Case 3.

generating kW-hr of 2.75¢. The energy effectiveness for this combined cycle, based on a standard COP of 3.5, is 19 percent, and the total cost is 5.75¢. If the value option were employed—utility power for compression cooling and on-site power for site electricity—the cost would be 4.8¢ and the *Ee* would be 27 percent.

The purpose of this simplified example is to illustrate that so-called free steam is, in fact, not free if the load must be created to provide a use. The decision making relating to combined plants must be based on in-depth analysis of all the dynamic operating conditions relating to the true connected loads and *not* to the loads that are created within the conversion plant itself to increase the so-called efficiency of one specific module or subsystem.

For an economics relationship for this type of conversion system, see Chapter 41.