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Cogeneration of Ethanol from I.C. Engine Powerplants: An Economical and Convenient Method to Supply Process Energy for Ethanol Production

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Cogeneration of Ethanol from I.C. Engine Powerplants:

An economical and convenient method to supply process energy for ethanol production.

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Abstract

I.C. engine power plants have significant and suitable waste heat for the production of ethanol. Such power plants are often located in conjunction with cattle and grain producing areas, two of the important ingredients for ethanol production. Cogeneration of ethanol from I.C. engines will afford significant production of ethanol without requiring more fuel than is currently used.

1. INTRODUCTION

Ethanol has been shown to be a useful fuel for spark ignition engines. It can be used directly, or it can be used as an extender to gasoline in Gasohol blends.

Ethanol can be produced in a variety of ways: from coal, from petroleum, or from biomass resources. As a way of reducing dependence upon imported oil, it has been proposed that the ability of the United States to grow abundant food be partially used to provide feedstocks for the fermentation of ethanol. It is argued then that by this method some of our liquid fuel requirements can be made from renewable resources.

However, while the feedstocks themselves, such as corn, wheat or sugarcane may be renewable, the process energy used is often from nonrenewable resources. The three most commonly proposed fuel sources for ethanol process energy requirements have been natural gas, diesel fuel, and coal. Diesel fuel is especially problematic because it is presently in limited supply. Since most farm equipment utilizes diesel engines, the production of alcohol can possibly put more strain on diesel fuel, especially since ethanol is not as readily usable in diesel engines as it is in spark ignition engines.

2. I.C. ENGINE COGENERATION

One way to get around the process energy problem is to cogenerate ethanol with existing power plants. Generally, cogeneration brings to mind large rankine, coal-fired, steam systems. However, the development of condensing turbines has greatly reduced that kind of cogeneration opportunity. Also the centralized "energy centers" concept currently being applied to new construction, means that power plants will be more geographically centralized than before. This means that fewer steam system locations will be available for cogeneration.

In Kansas, one useful way to cogenerate ethanol is to use internal combustion power plant engines. These engines are often owned by local municipalities and provide electrical power to small towns or districts. They are usually of the dual-fuel variety and principally use natural gas. They range in electrical output but do not usually exceed 10 megawatts peak electrical ratings. This type of engine provides an excellent source of process heat for ethanol production. Furthermore, their very nature of being used in rural areas, puts them in excellent proximity to grain and cattle, two of the chief ingredients to the economics of ethanol production. Local municipal ownership is also a plus when it comes to lessening administrative barriers and securing low cost cogeneration rates.

Generally speaking, an I.C. engine is only about 33% thermally efficient in the production of electricity. That leaves 67% waste energy of which about 50% could be recovered for process heat. This means that roughly the same amount of energy can be obtained for cogeneration that is produced as electricity.

In I.C. engines, waste heat can come from four sources: the engine cooling jackets, the aftercoolers, the lubrication system, and the exhaust gas. Roughly speaking, the relative amounts of available cogeneratable energy from these sources are show in table 1.

Table 1. Approximate I.C. Engine Distribution of Available Cogeneration Energy

Heat Source	% of Cogeneration energy	Maximum temperature
Engine cooling jacket	20%	165-170° F
Aftercoolers	15%	105-115° F
Lubrication system	10%	140-150° F
Exhaust gas	55%	900-950° F (Supercharged)
		550-650° F (Forced Air)

3. ETHANOL PRODUCTION VIA COGENERATION

The waste heat can be recovered for ethanol process energy in the following way. Water can be passed through heat exchangers with the aftercoolers, lubrication system, and the engine cooling jacket. After this water has been preheated, it can be heated to dry steam conditions of up to 850° F through a heat exchanger with the exhaust gas. This steam is then put into the distillation columns of the ethanol recovery portion of the system.

To facilitate "cooking", the process stage where starch grains are ruptured for effective enzyme action, dry steam above atmospheric pressure at about 340° F can be bled off from the exhaust gas heat exchanger. Since warm water facilitates the first process stage of "soaking" the milled corn, warm water can be bled from the aftercooler heat exchanger. While other bleed offs can also be used, it is assumed that efficient heat recovery within the ethanol process system makes that measure unncessary.

In some cases it may be advantageous to dry the wet stillage into dried distillers grains (DDG). The wet stillage would first be concentrated using screens, filters or centrifuges, and then the resulting damp bulk would be dried. The heat for drying can be obtained by using an air to exhaust gas heat exchanger placed downstream from the steam producing heat exchanger. However, it should be kept in mind that the exhaust gas temperature should not be lowered below 400° F. This is to avoid condensation and subsequent corrossion in the stack.

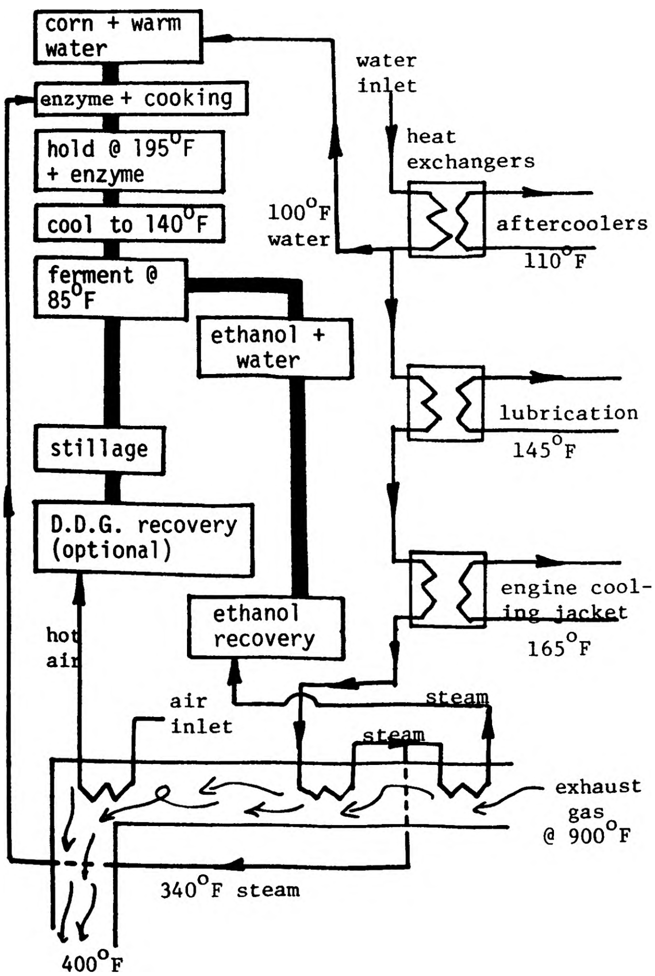
In figure 1 is shown a schematic of a hypothetical ethanol cogeneration system. The internal waste heat recovery system of the ethanol production equipment is not shown in order to simplify the schematic. It should be noted, however, that in a well-engineered system, a signficant portion of the energy used in the ethanol distillation equipment can be recovered and used in the lower temperature hydrolysis processes.

In present ethanol production systems, the amount of process energy required per gallon of anhydrous ethanol* ranges from as high as 185,700 BTU to a low of 72,584 BTU using good heat recovery techniques within the production system.** These figures include drying the by-product. Table 2 indicates the distribution of energy

* 1 gallon ethanol = 84,400 BTU HHV

** Net Energy Analysis of Alcohol Fuels, Jenkins, McClure, and Reddy, API Pub. 4312, Nov. 1979.

Figure 1. Schematic of Ethanol Cogeneration With I.C. Engine Waste Heat Recovery



requirements of a hypothetic ethanol production system utilizing extensive heat recovery techniques. While no such plant presently exists, the various components of necessary technology to accomplish extensive heat recovery are well known and can be integrated into a single system. Table 3 indicates the distribution of energy requirements of an ethanol production system utilizing moderate heat recovery techniques.

Table 2. Ethanol Process Energy Requirements Utilizing Extensive Heat Recovery Techniques

Function	Energy Required per Gallon of Anhydrous Ethanol	Energy Required as a Percent of Total
Hydrolysis, cooking and fermentation	12,000 BTU	20%
Distillation	27,000 BTU	46%
Stillage drying	20,300 BTU	34%
TOTAL	59,300 BTU	100%

Table 3. Ethanol Process Energy Requirements Utilizing Moderate Heat Recovery Techniques

Function	Energy Required per Gallon of Anhydrous Ethanol	Energy Requirements as a Percent of Total
Hydrolysis, cooking and fermentation	12,000 BTU	14%
Distillation	32,000 BTU	38%
Stillage drying	40,502 BTU	48%
TOTAL	84,500 BTU	100%

For estimation purposes, it is assumed that if the by-product is used wet, about 44,000 BTU of process energy is required. If the by-product is dried, an additional 21,000 to 41,000 BTU of process energy would be needed. Table 4 indicates the amount of potential alcohol production from a 1,000 kilowatt rated I.C. engine at various load factors, based upon 330 full-time operating days per year. Table 4 can be reasonably scaled up or down linearly to estimate other engine sizes.

Table 4. Potential Ethanol Production from I.C. Engines

Engine Rating Peak Electrical Output	Ethanol Produc. Load Factor	(Gal./Yr) Wet By-product	Dried DDG
1,000 KWe	100%	614,340	318,000-415,900
1,000 KWe	75%	460,800	238,500-312,000
1,000 KWe	50%	307,170	159,000-207,950
1,000 KWe	25%	153,580	79,500-103,980

From the figures indicated in table 4, the potential ethanol production from the waste heat of a power plant sized I.C. engine is significant, even if the by-product were dried.

Additionally, cogeneration of ethanol in some cases could affect cost savings in new power plant installations. For example, if four engines of equal size were to be installed, it would be general practice to install two or four cooling towers to handle the lubrication aftercooler, and engine jacket cooling requirements. It could be feasible to substitute an ethanol production plant for some of the cooling tower requirements, and thereby lower the overall capital costs of the power plant.

4. SUMMARY

Cogeneration of ethanol from I.C. engine waste heat offers the potential of producing significant amounts of ethanol without using any more fuel than is currently used. I.C. engine power plants are often located in areas adjacent to grain and livestock, two of the important factors for ethanol production. Cogeneration of ethanol in this fashion may be one of the most convenient and economical ways to produce fuel alcohol from grain.

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ABOUT THE AUTHOR

Randall Noon is an Assistant Director of the Kansas Energy Office, responsible for energy research and resource development in Kansas. Mr. Noon is professionally licensed in both the United States and Canada, and holds B.S. and M.S. degrees in mechanical engineering from the University of Missouri. Besides ethanol, Mr. Noon has investigated the application of municipal power plant cogeneration for crop drying, wood drying and cold storage.