Examples of Power From Waste Heat for Gas Fields

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Abstract

This paper describes the design of three unique thermoelectric generators developed to supply electric power in natural gas fields. The unique feature of these generators is that they do not contain their own heat source but all convert the waste heat produced by equipment already used in the gas field as the thermal power source for the generators.

The first generator described uses the difference in temperature between the hot and cold legs of the glycol natural gas dehydrator cycle to produce power for cathodic protection of the well. The second system uses waste heat from the pilot light of the gas dehydrator boiler to produce power for electronic instruments. The third system used waste heat from the gas dehydrator boiler stack to provide power for instruments, communications, and other uses around the well site.

The description of these generators includes both photographs of the prototype units and performance curves from each of the generators. Each generator has unique features and advantages which are discussed in the paper.

Introduction

Oil and natural gas fields require electricity for several reasons. Among these are cathodic protection of the well casings and pipes, telemetry power, and lighting. If this power is not supplied by a connection to the grid, then it must be supplied from the field. The usual methods are to either provide small i.c. engine generator set, solar panels, or self-contained thermoelectric generator which is fueled with either propane or natural gas from the well.

For the low-power requirements motor generator sets are expensive to operate and maintain, so that either solar or self-contained thermoelectric generators have been the solutions of choice. Solar panels have their advantages and disadvantages for these applications. However, they are not the subject of this paper.

One of the disadvantages of the stand-alone thermoelectric generator is that it can represent an additional combustion source within the field, and therefore it represents a potential safety hazard. Also since it burns potential sale gas it represents a further energy depletion. In addition, a stand-alone thermoelectric generator can be expensive.

The alternative is to tap the sources of waste heat already available within the gas field. One widely used existing source is the natural gas dehydrator system in which a liquid descant such as triethylene glycol is employed to remove moisture from natural gas.

Gas extracted from a well is composed of a gaseous phase as well as distillate and water. Well-head gas and processing equipment is often situated at remote, relatively inaccessible locations and must be reliably continuously operable without attention by operating or maintenance personnel under variable and sometimes extreme climatic conditions. The well-head gas then must be transported, under pressure, great distances. Since well-head gas is usually at high pressure, the moisture, if not removed, tends to condense as the pressure is reduced upon entering the pipeline. This can lead to pipeline corrosion as well as the formation of water or ice within the distribution system subjecting the well producer to both expensive repair costs and loss of contracted sales gas.

A typical solution to the moisture problem is to pass the gas through a dehydrator to remove most of the water vapor an reduce the dew-point of the gas stream to a desired level for further handling or transportation of the gas. Gas dehydration is accomplished by passing the gas stream through an enclosure, including a pressure tower or vessel containing series of stacked liquid desiccant membranes, where gas is brought into intimate contact with a stream of triethylene glycol. Water from the gas and is absorbed in the triethylene glycol at 15 to 30°C. The absorbed water is subsequently removed from the triethylene glycol by circulating and heating the glycol/water solution to 175 to 200°C at atmospheric pressure.

A gas-fired boiler, such as the one shown in Figure 1, provides the source of heat to warm the glycol/water solution to separate and vaporize the water. The re-concentrated hot glycol is then cooled by means of well gas heat exchanger mechanisms and is returned to the contactor enclosure for absorption of moisture from further quantities of gas. The system is continuous in operation with the glycol circulation rate of 0.75 to 38 l/min depending on the capacity of the gas field.

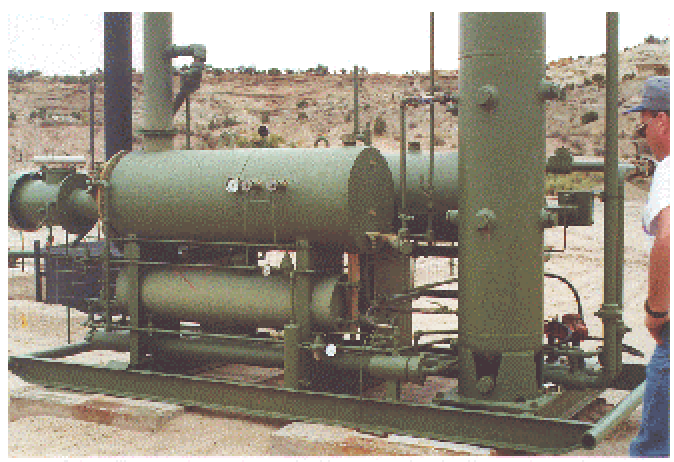

Figure 1: Gas-Fired Dehydrator Boiler in Field

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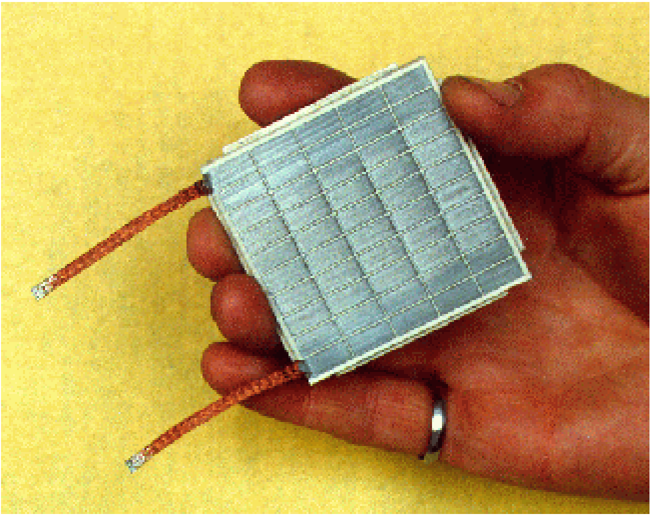

Figure 3: HZ–14 Module

The dehydrator system represents a potential source of energy recovery for conversion into electricity. This paper describes three different applications of the thermoelectric conversion which are currently being built that use the waste heat in the gas dehydrator system as the energy source.

Glycol Generator

The first application described is a generator which uses the hot (dry) and cold (wet) glycol streams as a source of energy. The generator, shown in Figure 2, consists of a single high temperature heat exchanger of rectangular cross-section, eight HZ-14 thermoelectric modules, two cold side heat exchangers, and spring-loaded clamping system to hold the cold side heat exchangers and thermoelectric modules in good thermal contact against the central hot heat exchanger. The prototype generator shown in Figure 2 is made entirely from mild steel, however, aluminum is being considered in future production models.

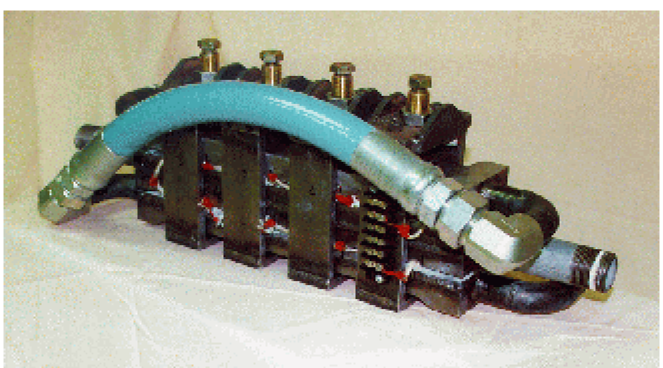

Figure 2: Glycol Generator

Hot triethylene glycol from the dehydrator boiler enters the hot heat exchanger through a straight section of pipe. It then flows by gravity through evenly spaced parallel rectangular passages in the center, giving up its heat to the thermoelectric modules. At the outlet end cooler glycol is collected and allowed to drain into the holding tank below the boiler.

Four HZ-14 modules, such as shown in Figure 3, are positioned on each side of the hot heat exchanger. Each is electrically insulated from the metallic heat exchanger by a 0.25 mm thick piece of aluminum oxide. Heat transfer grease is used on both sides of each insulator to minimize thermal contact resistance.

Cold glycol/water solution from the dehydrator column is pumped into one cold side heat exchanger by a double-acting circulation pump normally associated with the dehydrator system. The glycol flows through one cold heat exchanger and is then returned via flexible hose to flow through the second cold heat exchanger. From there, the glycol passes to a hot bubble tower located above the boiler where it is heated and the water is vaporized before the dry glycol returns to the boiler.

Figure 4 shows the installation of the glycol generator on a small dehydrator boiler. The generator is covered with a sheet metal jacket for weather protection during normal operation. With the installation of the glycol

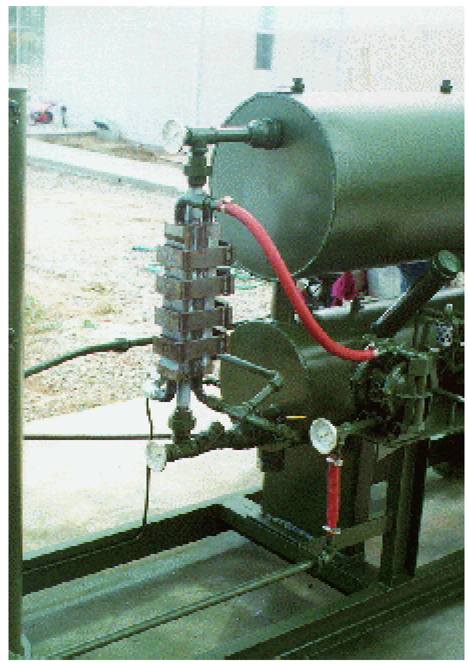

Figure 4: Glycol Generator Installed

generator none of the dehydrator operating parameters are altered but are actually enhanced.

While the eight HZ-14 modules are capable of producing in excess of 100 watts under their rated conditions, they only produce about 60 watts in this application because of the lower temperatures associated with the dehydrator glycol system. However, this low temperature system provides the potential for a long operating life with little degradation of the thermoelectric modules.

Figure 5 is a plot of output power from the glycol generator as a function of flow rate for three hot glycol temperatures and a cold glycol temperature of 15.5°C. One can see how quickly the output power falls for glycol flows of less than 4 liter per minute. One can also see the affect of temperature difference on power output.

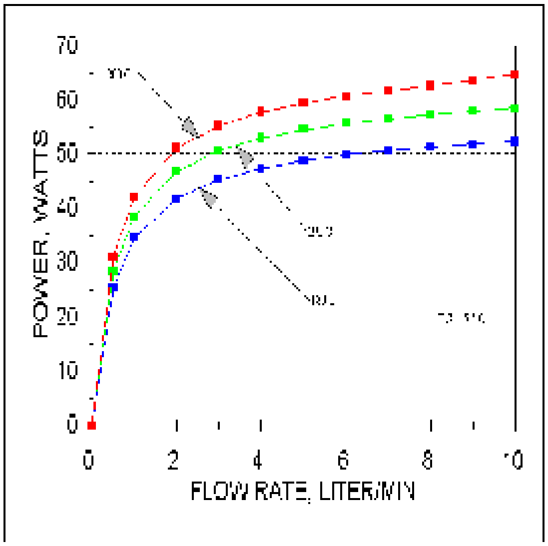

Figure 5: Glycol Generator Power Output vs Flow Rate for Various Hot Glycol Temperatures

The electric interface requirement for this generator depends on its use. If it is to be used solely for cathodic protection it would be connected to a DC/DC (buck) voltage converter and a constant current controller. If it is to be used to charge batteries or to provide power for transmission of wellhead data from a remote sit, it would probably be interfaced with a constant voltage DC/DC boost converter.

The generator has no controls of its own. It depends totally on the existing controls of the dehydrator system. This should lead to low cost and reliable power solution without requiring additional combustion sources in the gas field.

This generator is currently being field tested on a gas well in Colorado where it is being used as the power source in a cathodic well protection system.

Pilot Generator

Another clear source of available energy is the pilot light for the dehydrator heating system boiler. Heating systems such as these consist of an elongated burner housing containing a main gas burner unit, which is operable intermittently on demand when heat is required, and a pilot gas burner unit which provides a continuous flame to ignite the main burner unit. The pilot burner has a thermal output of 29 kilowatts. This relatively high thermal output is dictated because of some of the special requirements of boiler operation.

Only a small fraction of the energy in the pilot has to be converted to provide a minimum 10 watts at 14.5 V necessary to maintain a typical remote telemetry system. One design challenge to overcome is how to get the thermal power out of the pilot when it is being fired by the pilot burner alone without being thermally overwhelmed when the much larger main burner is ignited. Another challenge is the restricted space available within the existing burner housing.

After some experimentation, it was found that the energy required to support a single HZ-14 module could be provided from the housing that encloses the pilot burner tip. The tip temperature remains essentially constant independent of main burner operation. Air flow to the pilot burner is sufficient to cool the cold side heat sink.

A machined copper hot side heat exchanger mounted perpendicular to and encompassing the pilot tip is used to conduct heat to the hot side of the thermoelectric module. The cold side of the module is mounted in the burner inlet airstream on an aluminum heatsink. The heatsink is machined to fit within the existing burner housing without excessively blocking air flow to the either the pilot or the main burner. The module power leads are connected to insulated conductions which penetrate the burner wall so that the burner flame arrestor system is not compromised. A drawing of the pilot generator is shown in Figures 6 and 7.

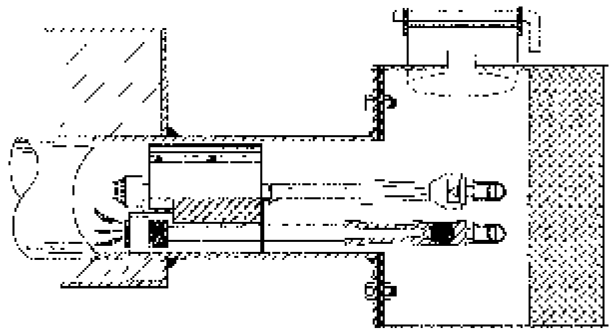

Figure 6. Drawing of Pilot Generator and Burner

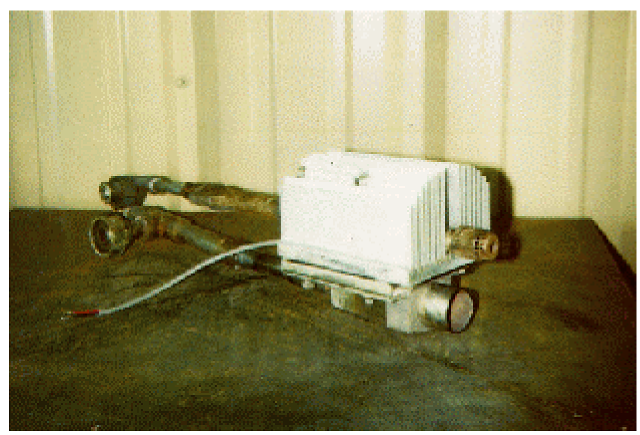

Figure 7: Components of Pilot Generator

The pilot generator will produce a maximum power of 14 watts and 1.65 volts at matched load. This system can be coupled with a DC/DC boost voltage converter and used to charge a battery and provide over 200 watt-hr per day of energy for various uses within the gas field, such as wireless data transmission from the wells. The burner housing described is typical of many types used in oil and gas fields. The pilot generator design can be adapted to most of these systems.

Stack Generator

The boiler emissions stack is also a considerable source of available energy to convert into electricity. The

stack generator is shown in the drawing of Figure 8. This generator consists of two HZ-14 modules, a hot heat exchanger and a
cold heat exchanger.

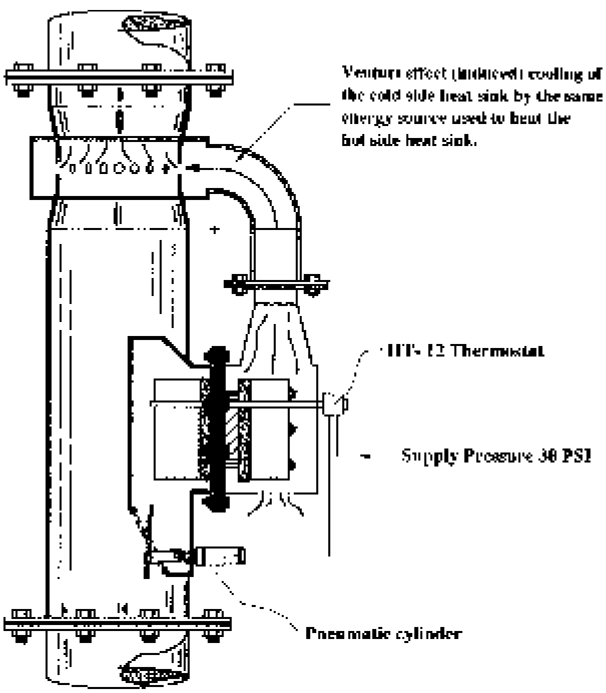

Figure 8: Drawing of Stack Generator

The generator obtains its energy from the hot combustion gasses leaving the dehydrator boiler. The energy at this point can be from 66 kilowatt to 293 kilowatt. The temperature of the stack gas can vary over a wide range depending on boiler rating and whether only the pilot is burning or both the pilot and main burner are in operation. To handle this wide difference in gas temperature, a thermostat-actuated gas diverging valve is mounted upstream of the generator hot side compartment to divert combustion gas into and through the hot side compartment transferring heat through the hot side heat exchanger to the hot side of the thermoelectric modules when only the pilot burner is operating and around the hot side compartment when both burners are in operation.

A unique feature of this generator is that it uses induced air flow to cool the cold side heat sink. This is accomplished by connecting an air duct between the cold heat exchanger and a venturi section located within the stack above the generator as shown in Figure 8. The lower pressure in the stack at the throat of the venturi provides adequate suction of the air flow from the cold side heat sink compartment to cool the heat sink without consuming any energy. Eliminating the fan also eliminates possible gas ignition source.

The stack generator shown is capable of producing 28 watts of power at 3.3 volts. Again, this power can be used in several ways to provide electricity in the oil and gas field. It is obvious that a stack generator could be designed and built to provide much higher output power if there were a special need.

Conclusion

We have shown here three different examples of converting waste heat to electricity in the oil and gas field using thermoelectrics. These methods of producing useable electric energy do not add additional combustion sources within the field and therefore do not compromise field safety in any way.

We believe that such systems can be provided power at a lower cost than some of the stand-alone generators currently being used in the production fields. Both the acquisition cost and the maintenance cost can be lower than stand-alone systems as well as being hidden within the equipment assuring tamper-proof operation. The generators could be installed by original equipment manufacturing firms further reducing application and installation costs..

This technique of reusable energy can be readily extended to other operations where there are sources of thermal energy which are currently being wasted. The power obtained can be made available for an unlimited number of uses without any increase in energy usage. Another example of exploiting reusable energy in an unrelated field was the thermoelectric generator for the Diesel engine[1] which was presented at the 1994 ICT conference.

References

(1) Bass, J.C., N.B. Elsner, and F.A. Leavitt, "Performance of the 1 kW Thermoelectric Generator for Diesel Engines", Proceedings of the XIII ICT, 1994, Kansas City, MO, American Institute of Physics.