Development of a Self-Powered Pellet Stove

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Abstract

The pellet stove is a device that burns compressed sawdust pellets, which are a renewable energy resource. Pellet stoves provide heat with much less pollution than is experienced with other wood burning stoves. To accomplish low pollution combustion, the pellet stove employs a forced draft fan which provides excess combustion air to the burn chamber and an auger feed to dispense pellets at a controlled rate as well as a sophisticated electronic control system to achieve the proper air/fuel ratio.

The electric power requirements of the pellet stove limits their acceptance because many pellet stoves are employed in remote and rural areas with either unavailable or unreliable power. This paper describes a program funded jointly by the Renewable Energy Resources Division of the U.S. Department of Energy and the State of California under the CalTIP (California Technology Investment Partnership) Program which is currently underway to develop a self-powered pellet stove using thermoelectric technology. This paper describes this program to date.

Background

Most pellet stoves currently available on the market use alternating currently that is normally available in most homes. As a result, these power demands are high, usually in the area of 100 Watts or more because low cost has been the goal rather than high efficiency. However, the Thelin Company of Grass Valley, California, currently manufactures a pellet stove under the "Pellex" label which is designed specifically to operate either from alternating current or, in an emergency loss of power, from a 12 Volt lead-acid battery for up to four hours. As a result, the Pellex stove has been designed to operate efficiently on direct current and, therefore, uses much less electric power (28 Watts) than many other stoves.

There are two separate air circuits within the Pellex stove. The combusting air enters through a pipe at the rear of the stove into an area below the combustion chamber, flows through the burn pot where the pellets are located, upward through the combustion chamber, downward through two rectangular passages in the rear wall of the combustion chamber into a forced draft fan, and exits through the exhaust pipe at the rear of the stove. The room air enters the bottom of the stove through a propeller fan mounted on the bottom end of the forced draft fan motor. A small amount of room air exits through the electronics' area. The remaining air passes upwards either through two pairs of inch-diameter tubes which are located inside the rectangular passages in the rear of the combustion chamber or in the space between the combustion chamber and the pellet bin, rejoins and flows over the top of the combustion chamber and out of the upper part of the front of the stove.

Development Program

The program to make a self-powered pellet stove was based on the initial use of the Pellex stove as the test bed. This stove, shown in Figure 1, was to be converted to use thermoelectric modules to produce the power required to operate the stove and recharge the start-up battery. As a result of this initial development, a new design will be developed, built, and tested using the information obtained during this part of the program.

Figure 1: Pellex Pellet Stove Prior to Modifications

The use of the Pellex stove had both advantages and disadvantages. The advantage was that much of the electric and electronic design had already been completed with attention being given to low power direct current operation. The disadvantage was that the air flow configuration within the stove was fixed for a specific type of operation and could not be easily changed to accommodate the requirements of an air-cooled thermoelectric system.

The original self-powered design concept was based on the use of two HZ-14 modules. Each of these modules would be mounted in the rectangular passage in the upper rear wall of the combustion chamber in the flow path of the gas leaving the combustion chamber. The modules and air-cooled heat sinks were located in the space between the combustion chamber and the pellet bin. To accomplish this, two square holes were cut in the rear wall of the combustion chamber through which the hot side heat exchanger was inserted, the front wall of the pellet bin was moved back two inches, and the four tubes that conducted warm room air from a fan at the bottom of the stove to the upper front of the stove were offset at the upper end to provide space of the insertion and removal of the two module/heat exchanger assemblies.

In the self-powered design, air from the propeller fan in the bottom of the stove is augmented by the warmed cooling air exiting the cold side heat exchangers in the self-powered configuration to provide warm room air.

Several thermoelectric module heat sink cooling air configurations were tied to determine which worked the best. The first approach mounted the cooling fans on the sides of the stove and sheet metal air ducts over the cold side heat exchangers to direct the cooling air flow over the heat exchange surface and into the space below the pellet bin. Another configuration mounted the fans directly on the cold side heat exchanger ducting, as shown in Figure 2. The air flow in both systems was perpendicular to the pin fins on the heat exchangers.

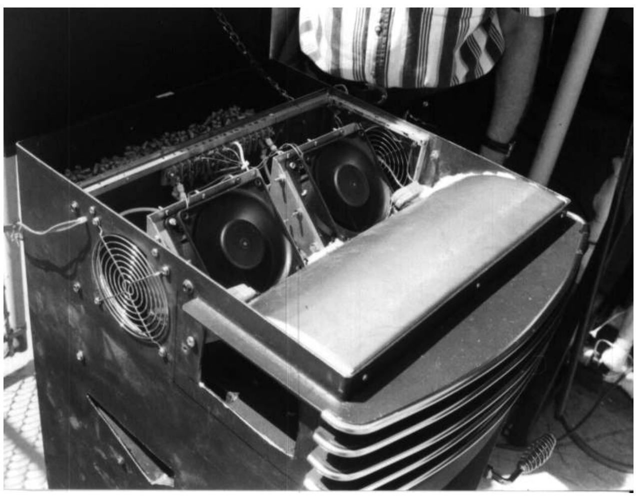

Figure 2: Modified Pellex Stove with Fans Installed on Heat Sinks

In all cases, the power output from the thermoelectric modules was too low to support self-powering. A decision was made to replace the HZ-14 modules with the higher powered HZ-20 modules shown in Figure 3. The higher thermal output of the HZ-20 module meant that better cold side heat transfer would be required. It was necessary, therefore, to improve the heat exchanger heat transfer while maintaining the same or less volume because of the space limitations within the development stove. This change was accomplished by increasing the cooling fan power and changing from cross flow through the heat exchanger to impingement flow, i.e., the incoming cooling air flowing parallel to the heat exchanger pins. The impingement flow was accomplished by bringing the cooling air in through the back of the stove to fans mounted directly on the heat exchangers.

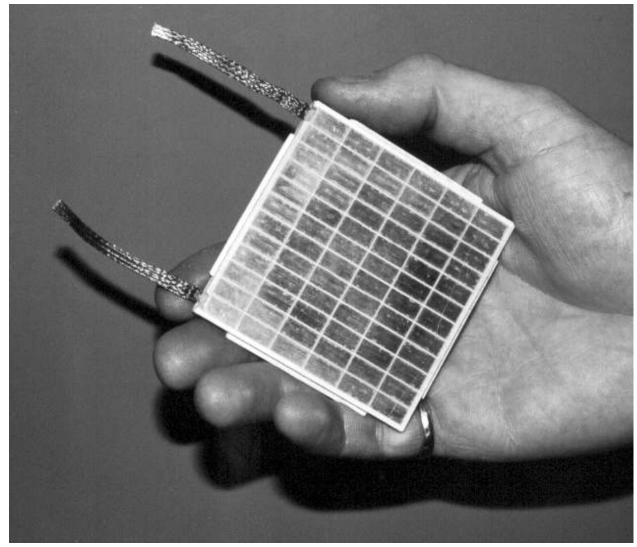

Figure 3: HZ-20 Module Used in Self-Powered Pellet Stove

The change in the cold side air flow configuration led to improvements in performance, but we were not able to achieve self-powering throughout the heating cycle until a more efficient, compact small pin heat exchanger was installed. The heat exchanger volume was reduced from 6" x 6" x 2.5" to 4" x 4" x 2". The small heat exchanger was more effective because it had much smaller diameter pins on a small pitch to diameter ratio than the original cold side heat exchanger and, therefore, more heat exchange surface. A photograph of one of the modules and heat exchanger assemblies is shown in Figure 4.

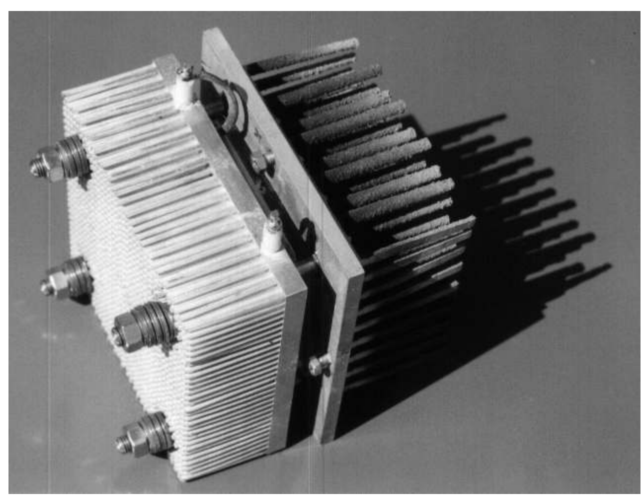

Figure 4: Hot Heat Exchanger, Module, and Heat Sink Assembly

The new heat exchanger arrangement simplified the oven stove air flow circuit. Other performance improvements were accomplished by replacing the propeller fan on the bottom of the forced draft fan motor with a separate low power vane-axial fan similar to the ones used for the heat sinks because most of the room air was now being supplied by the thermoelectric module heat sink fans.

We are still working to lower the stove's power requirements by carefully looking at the efficiency of each component. In addition, the DC/DC convertor that was originally used to increase the thermoelectric module's output voltage from 6.6V to 13.8V required to recharge the battery has been modified also.

The lessons learned during this prototype development of the self-powered stove have been implemented in an all new stove design. The prototype model of the new stove, called "Pellex II," will be finished in September 2000 and will be ready for testing. A rendering of the "Pellex II" is shown in Figure 5. The production version of the new design of a self-powered pellet stove should be available in the first quarter of the year 2001.

Figure 5: Pellex II

Conclusion

The self-powered pellet stove is feasible and practical. Attention to detail, in particular heat transfer and fluid flow, is very important to the success of such a device. Attention must also be given to the use of the most efficient electrical and electronic components that are consistent with a good stove pricing schedule in order to obtain a wide market acceptance.

We believe that both the self-powered pellet stove and the self-powered boiler, which was presented previously [1], will lead to a large number of self-powered home appliance applications. We are looking forward to working on these new and, as yet, unknown applications.

Acknowledgment

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Reference

1. Daniel T. Allen, W.C. Mallon, "Further Development of Self-Powered Boilers," Proceedings 18^{th} ICT, Baltimore, 29 August - 2 September, 1999.