RECOMMENDATION NUMBER: 382

OERI NUMBER: 009925

TITLE: SYSTEM FOR RECOVERY OF WASTE HOT WATER HEAT ENERGY

INVENTOR: DR. CARMINE F. VASILE

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Gaithersburg, Maryland 20899

December 16, 1986

Mr. A. Jack Vitullo
Director, Inventions & Innovative Programs-CE-12
Conservation and Renewable Energy
Department of Energy
Forrestal Building, 5E-052
Washington, DC 20585

Dear Mr. Vitullo:

We wish to call your attention to an invention entitled "System for Recovery of Waste Hot Water Heat Energy" submitted to us by Dr. Carmine F. Vasile for evaluation under Section 14 of the Federal Nonnuclear Energy Research and Development Act of 1974. Our evaluation has been completed and we recommend Dr. Vasile's invention as technically valid and worthy of consideration for appropriate Government support. The enclosed evaluation report is provided in support of our recommendation.

The invention is a counter-flow heat exchanger intended for recovering heat from waste water to preheat incoming cold water in residence.

Second-stage analyses were conducted by Messrs. Harvey C. Stenger and Milton Pravda; their reports are included under Tab B. The final technical review by Mr. J. S. Dhillon of the OERI staff is given in Tab A. Material submitted by the inventor is given in Tab C.

The concept and the design are theoretically sound. However eventual practicality is still in question. Support should focus on validating cost-effectiveness and energy-saving estimates, and confirming commercial feasibility in general.

If you have any questions or would like additional information, you may contact Mr. Dhillon who has been assigned as staff coordinator for the invention. A copy of our letter of notification to Dr. Vasile is enclosed.

Sincerely,

Original signed by
George P. Lewett

George P. Lewett
Chief, Office of Energy-Related Inventions

Enclosures

UNITED STATES DEPARTMENT OF COMMERCE
National Bureau of Standards
Gaithersburg, Maryland 20899

December 16, 1986

Dr. Carmine F. Vasile
4 Cordwainer Lane
Huntington, NY 11743

Dear Dr. Vasile:

We wish to inform you of the results of our evaluation of your invention entitled "System for Recovery of Waste Hot Water Heat Energy". The evaluation was conducted in fulfillment of our responsibilities set forth in Section 14 of the Federal Nonnuclear Energy Research and Development Act of 1974.

Your invention has been selected for recommendation to the Department of Energy (DOE) as worthy of consideration for possible Government support. Please note that our recommendation does not insure financial support by DOE for your invention, and that our recommendation to DOE should not be construed as an endorsement of the invention. We are forwarding a copy of the disclosure and the evaluation report to DOE for their consideration; a copy is enclosed for your information.

When our recommendation is received in DOE, an invention coordinator in the Inventions and Innovative Programs Office, Conservation and Renewable Energy will be responsible for determining the type and amount of support, if any, to be provided to you. You will receive a letter from DOE describing the information that you will be required to furnish them to determine the type of assistance. The decision depends upon our recommendation, a review of the proposed work, the availability of private sector funds, and the availability of Federal funds. Generally the information needed to make the determination will include description of additional technical development and testing required, a marketing plan, and a business plan. DOE will provide more specific details on the information needed.

Your participation in the evaluation program is appreciated. If you have any questions, please do not hesitate to contact us.

Sincerely,

George P. Lewett
Chief, Office of Energy-Related Inventions

Enclosure

TITLE PAGE FOR
ENERGY-RELATED INVENTION DISCLOSURE

TITLE OF INVENTION: System for Recovery of Waste Hot Water Heat Energy

THE ATTACHED DOCUMENTS ARE THE PROPERTY
OF AND WILL BE RETURNED TO:

INVENTION SUPPORT DIVISION
CONSERVATION AND SOLAR
U.S. DEPARTMENT OF ENERGY
WASHINGTON, D.C. 20585

The information contained in this disclosure was provided to the Office of Energy-Related Inventions at the National Bureau of Standards to enable evaluation in accordance with Section 14 of the Federal Nonnuclear Energy Research and Development Act of 1974 (Public Law 93-577). The information has been provided to the Department of Energy (DOE) for consideration for support under the same law. The information should not be used for any other purpose. Access should be restricted to those persons who have been designated for receipt of the disclosure for evaluation or administrative purposes. The information contained herein should not be shown to or discussed with anyone else. All requests for access or for further information by persons other than those who require the information for processing purposes should be referred directly to the DOE Invention Support Division.

THIS DOCUMENT MAY CONTAIN INFORMATION WHICH IS (a) A TRADE SECRET OR (b) COMMERCIAL OR FINANCIAL INFORMATION THAT IS PRIVILEGED OR CONFIDENTIAL.

TAB A

Final Technical Review

by

Jogander S. Dhillon

FINAL TECHNICAL REVIEW
System for Recovering Waste Heat
OERI No. 009925

INTRODUCTION

The invention entitled "System for Recovering Waste Heat" was submitted by Dr. Carmine Vasile on January 9, 1984, for evaluation under Section 14 of the Federal Nonnuclear Energy Research and Development Act of 1974.

It was entered into first-stage evaluation on February 13, 1984. Two consultant opinions were obtained at the first-stage level. The invention was subsequently rejected on May 2, 1984, mainly due to its high initial cost and expected long payback period. The inventor submitted new information in which he addressed most of our technical objections and stressed that the invention is cost effective. Another first-stage consultant opinion was obtained and the invention was subsequently entered into second-stage level on November 29, 1984. Two second-stage reviews were conducted, one by Mr. Harvey Stenger and the second by Mr. Milton F. Pravda. Their reports are included under Tab B. The second-stage reviewers contributed heavily towards redesigning this invention which should be acceptable on the market. Total evaluation time for this invention was 30 months.

This invention is currently at a prototype development and test stage. A patent for this invention has been applied for.

DESCRIPTION

The invention is a counterflow heat exchanger (HX) intended for recovering heat from waste water to preheat the incoming cold water in a home. Both streams of water in the HX have essentially equal mass flow ratio. The HX proposed by the inventor is a double-walled metallic (copper) pipe as shown in the attached sketches A-1 and A-2 drawn by Mr. Stenger. Warm waste water flows through the inner drain pipe while the cold water flows in the outer jacket, thus recovering part of the energy from the waste water. After initial tempering, part of the water in the cold pipe flows through a conventional heater to raise its temperature to the appropriate level. The hot water from the water heater and luke-warm water from the HX are mixed at the shower head. The mixed warm water along with the soap suds flows into the drain and through the HX in the vertical section of the drain pipe in the basement.

DISCUSSION

Many heat exchanger (HX) designs have been put forward in the past to economically recover heat from the waste water in a residence. The efficiency of such HXs is generally low while the installed cost is generally high. Therefore, such HXs are not economically appealing for energy conservation. The current invention also makes an attempt to recover heat from the waste water in an economical manner.

It is different from previous HX designs in two ways. First, it utilizes a thin falling film principle to transfer heat from the waste water to the incoming cold water. It is a very efficient way of transferring heat and keeping the HX surface relatively clean. Fouling of the heat exchanger surfaces does not appear to be a significant problem according to the inventor's experience with the prototype. Due to a vertical nature of the heat exchanger, solids and sediments do not have opportunity to settle on HXs inner surface. Instead, periodic flow of shampoo and soap suds may help to keep it relatively clean.

The thickness of the waste water film will be 11.5 mils for 0.5 gpm flow rate in a 3-inch diameter pipe. This thickness increases to 27.2 mils for a flow rate of 3.11 gpm. Dr. Harvey G. Stenger, Jr. conducted experiments in the laboratory which proved that at 3 gpm flow rate in 2.5-inch diameter pipe, the water adheres to the inner surface of the pipe. No flow separation was observed from the pipe surface. The proposed HX is an ideal application in vertical portion of the main waste pipe in the basement of a house.

Second, the proposed HX uses balanced mass flow rates of the waste water as well as the incoming cold water. All the incoming cold water passes through the HX. Then part of the water goes to the water heater for further heating to an appropriate temperature level (120°F). The remainder of the luke warm water goes to the various fixtures. This set-up will recover significantly more energy from the waste water compared to a set-up in which the cold water quantity equivalent to the hot water flow is allowed through the HX. This feature may also help in reducing the piping cost by consolidating all the cold water and the lukewarm water in a single piping run.

Another side benefit could be the reduction of cold water pipe sweating down stream of the HX. When the temperature of the incoming cold water is lower than the dew point temperature of the inside air, moisture will condense on the pipe. The temperature of the lukewarm water coming out of the HX is 10-15%°F higher than that of the incoming cold water. The sweating will be prevented only during showering and some time thereafter.

The lukewarm water from HX is piped to the toilets in the current design. If a family member flushes a toilet while the shower is in use, it would result in a small wastage of recovered heat. However, the likelihood of using a flush toilet and a shower simultaneously is small.

The governing health authorities may require a double-walled separation between the potable water and waste water. Approval from health authorities must be acquired before finalizing the design and construction of the prototype heat exchangers. Mr. Pravda has suggested a double-walled HX design which satisfies this requirement. This HX design appears to be fairly simple and could be mass produced with current level of technology.

The proposed HX will recover heat only during showering and when the sinks are used for washing hands or during food preparation, etc. There will be no opportunity to save energy from such operations as taking a tub bath, using the laundry machine, or using a dishwasher since hot and cold water do not flow simultaneously through the HX.

Dr. Vasile has performed a patent search for his invention. The search indicates that Mr. Johnson's HX is quite similar to the proposed invention except that it utilizes a circulator to pump water through the HX. In our opinion, a circulator is not required. The city water pressure will be sufficient to overcome the HX pressure drop and deliver hot water at the fixtures at adequate pressure. The circulator will use electric energy, thus reducing net energy recovered. To our knowledge, this product is not available on the market. Mr. Raymond Hunter's invention was recommended by this office (OERI No. 9516) to the Department of Energy for government support. Mr. Hunter's HX recovers heat only from individual shower drains using flooded type HX, while Dr. Vasile attempts to recover heat at the main waste pipe using thin falling film principle. The proposed HX is suitable for retrofitting in homes with basements and vertical waste pipe.

The material proposed for the heat exchanger is copper, however other corrosion resistant materials can be used. Copper has a very high thermal conductivity but cheaper materials should be explored for substitution. Plastics should also be explored for this application even though they have relatively lower thermal conductivity. If significant waste heat can be recovered using plastic materials they would be viable materials for the proposed heat exchanger. Plastics should be considered only if heat transfer calculations show a favorable payback.

Energy Saving Potential

As noted in Mr. Pravda's report, the annual U.S. consumption of energy for residential water heating is about 2.23 x 10^{15} Btu. Assume 60% water heater annual fuel utilization efficiency (AFUE) and that 30% is wasted during showering due to evaporation, conduction and convection. Further, assume that 36% hot water is used for non-energy recoverable operations such as, laundry machines, dishwasher, tub baths, etc. The energy available for recovery in the waste pipe is about

$$2.23 \times 10^{15} \text{ Btu} \times 0.60 \times 0.7 \times 0.64 = 0.6 \times 10^{15} \text{ Btu.}$$

Assuming 50% homes have basements which can use the proposed invention assuming 5% market penetration and using 53% HX effectiveness as calculated in Mr. Pravda's report, the invention has the potential to save

$$0.6 \times 10^{15} \times 0.5 \times 0.05 \times 0.53 = 7.94 \times 10^{12} \text{ Btu} \quad (2.33 \times 10^{9} \text{ KWH})$$

or 1.35 x 10^{6} barrels of oil equivalent per year. For electrically-heated water, this energy savings will be twice the amount calculated above. The overall energy savings will be much greater if the application of the proposed HX is extended to installations with high hot water usage, such as apartment buildings, restaurants, schools, nursing homes, dormitories, motels and barracks.

Marketing Considerations

An average residence consumes about 87 gallons per day of hot water. The energy required to heat the water from an average city water temperature of 55°F to 120°F is 1.72×10^7 Btu per year. Taking into account the assumptions in the previous paragraph, such as 36% hot water is used for non-energy recoverable operations, 30% energy is lost during showering, and 53% HX effectiveness, the net recovered energy is

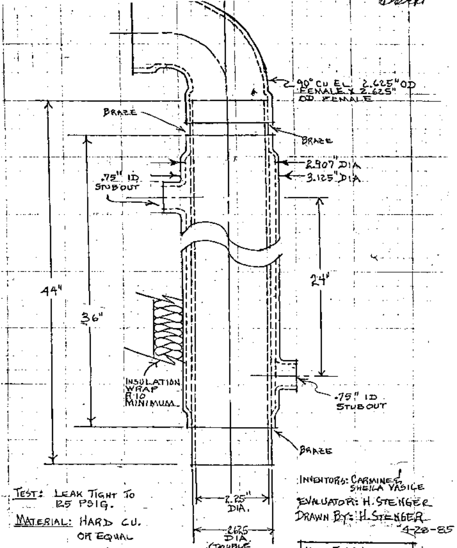
$$1.72 \times 10^7 \times 0.64 \times 0.7 \times 0.53 = 4.08 \times 10^6 \text{ Btu per year.}$$

This would result in about 2 years' payback period for homes with electric water heaters using 8.66 cents per kW electric rate. The payback would be 6-1/2 years for houses with natural gas-fired water heaters using 63.5 cents per therm for the cost of gas. The payback would be 4 years for homes with oil-fired water heaters using $1 per gallon the cost of oil. It is evident that the proposed HX is not very cost effective for homes with gas-fired water heaters, and only marginally cost effective for homes with oil-fired water heaters. But it is very cost effective for homes with electric water heaters.

For a family having less than 4 members, or fewer showers than 3 taken per day, the payback period will be longer. Also, if more than one tub bath per day is taken, the energy savings will be smaller since the opportunity to recover waste heat is very low. On the other hand, if a family has more than 4 members, the payback period for the HX could be shorter. The proposed HX could be particularly useful for installations which use significantly more hot water, such as motels, dormitories, barracks, and apartment buildings.

To our knowledge there is no such product currently on the market for domestic use. Since major capital investment is required for tooling and production of a marketable product in large quantities, licensing may be an appropriate route for this invention. The product could be introduced as a retrofit product for do-it-yourselfers through local hardware and plumbing stores. Next, volume homebuilders could be approached for use of this HX in the new construction.

Before this product is marketed, approval must be obtained from local health authorities. It appears a double-wall separation will be required between the potable water and the waste water. Mr. Pravda has proposed a HX design with double-wall separation.



TEST: LEAK TIGHT TO 125 PSIG.

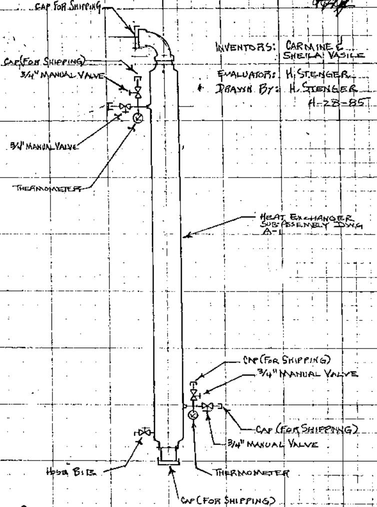
MATERIAL: HARD CU. OR EQUAL

INVENTORS: CARMINE & SHEILA VASILE
EVALUATOR: H. STENGER
DRAWN BY: H. STENGER 4-28-85

PROPOSED-PROTOTYPE DESIGN
WASTE WATER HEAT RECOVERY UNIT

HEAT EXCHANGER SUB-ASSEMBLY

DWG: A-1



PROPOSED PROTOTYPE DESIGN
WASTE WATER HEAT RECOVERY UNIT

VALVE AND HEAT EXCHANGER ASSEMBLY

DWG A-2

CONCLUSIONS

1. The proposed heat exchanger is technically sound. It recovers waste heat from the warm waste water and it transfers to the incoming cold water.

2. It has the overall potential to save 1.35×10^6 barrels of oil per year.

3. Payback for this product is expected to be about 2 years for an average home equipped with an electric water heater. Payback will be less for users of high volume hot water.

4. A design development and test program is needed for the proposed HX.

   a. A practical HX system should be engineered and design drawings prepared, keeping in view the retrofit application for a majority of homes. Approval of the HX design from appropriate health authorities should be obtained before proceeding with fabrications. The appropriate HX material should be selected based on various factors involved, such as initial cost, ease of fabrication and installation, optimum energy saved and shorter payback.

   b. A detailed cost analysis should be prepared to determine the HX cost effectiveness.

   c. Fabricate prototype heat exchangers.

   d. Conduct a prototype test/demonstration program. For example, install the prototypes in homes occupied by average families and barracks (or dormitories) in various geographic locations of the United States. Monitor the energy savings and HX efficiency for a period of one to two years. At the end of the test period, the formation of scum on the HX surface should be checked and its effects on HX performance should be determined. If the reduced HX performance results in uneconomical payback, the support should be terminated.

   e. If test results are favorable and HX is as cost effective as anticipated, commercialization should be encouraged.

12-15-86
DATE

J. S. Dhillon, NBS/OERI