

PROJECT NO: COLL-CT-2003-500399



LOWHEAT

The Development of a New Domestic Heat Recovery
Technology for Low Grade Heat in Waste Water

Collective Research (Coll)

Horizontal Research Activities Involving SMEs

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COORDINATOR: The Institute of Plumbing and Heating Engineering (IPHE)

SME EXPLOITATION MANAGER: AK Industries Ltd

IAG Enterprise Groupings:

IPHE
PKTSGGiK
MEGSZ

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Metallisation Ltd
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Angewandte System Technik
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CRS Engineering Ltd

RTD PERFORMER CONTRACTORS:

Pera Innovation Ltd
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AIMPLAS

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ABSTRACT

A Consortium of European SMEs has completed a successful 6th Framework project to produce a prototype of an intelligent network management of heat recovery devices for the plumbing and heating market.

This project has solved the problems of conventional heat exchangers not being suitable for low grade applications under low flow conditions, overcome perceived thermal efficiency problems and successfully addressed water and building regulatory difficulties.

The Low Heat project delivered the intelligent network management of heat recovery devices for the purpose of recovering low grade waste heat energy from wastewater going to drain in both commercial and domestic situations and returning it to the hot water system.

Capably lead by the three Industry Association Group's the SME's and Researchers, have created this innovative, award winning heat recovery technology, that has been recognised across Europe by many different organisations, culminating in Low Heat being Highly Commended by the UK National Energy Efficiency Awards 2006.

Key Words:

Energy Efficiency, IAG, SME, Heat exchanger, Drain device, Radio Frequency, Controller, Heat pipe, Heat energy, Commercial, Domestic, Retrofit, Plumbing, Heating.

Overview

In today's society, it is taken for granted that hot water is readily available. A significant amount of energy and money is required to heat and store hot water. However, once the hot water is used, it is simply forgotten, being allowed to drain away.

The increasing costs of oil and gas, together with the adverse effects being experienced to climate change have prompted changes in legislation. Sustainable management techniques, in terms of water conservation and energy efficient systems in the plumbing and heating industry are now becoming more prominent.

Low-grade temperature wastewater heat recovery would greatly reduce the amount of fuel and cost required to heat water to meet current and future demands. By recovering the energy available within wastewater as it is discharged down the drain, it can effectively be used as a pre-heat for various hot water and heating applications to reduce their energy requirements.

However, conventional heat exchangers are not suitable for low-grade applications under low flow conditions because the thermal efficiency is too low. In Europe at present, there are no heat exchangers currently available that work efficiently for low flow rates or temperatures particularly in the region of 25-65°C. Heat exchange systems available in the United States do not conform to European Legislation for heating and water systems.

In addition, wastewater will almost certainly contain the characteristics of dissolved chemical additives and quite possibly organic matter. The chemical properties of wastewater properties, such as dissolved and suspended solids, soap (pH), disinfectant and grit can all contribute to considerable reduced life span to system components.

It is also important to consider that wastewater could also contain fats, grease & oils. If allowed to accumulate, the substances contained within this type of discharge may cause fouling, resulting in poor heat transfer and odours.

As such, a European Consortium of small to medium sized (SME) companies, Research Performers and Industry Association Groups (IAG), lead by the Institute of Plumbing and Heating Engineering have just successfully completed a three year European Research project to develop a low cost and efficient intelligent network management of heat recovery devices for the plumbing and heating market, called Low Heat.

The Low Heat project has developed a system that effectively recovers heat from a trapped gully (3 litre capacity) situated appropriately within the wastewater system, from which a low energy driven pump, capable of providing 4 litres per minute passes the cold water over the in line heat exchanger transferring the energy back into the heat generator.

It is capable of recovering up to 50% of the wasted heat energy being discharged to drain, with flow rates in the region of 5-20 litres/minute, thus effectively reducing energy consumption and CO₂ emissions in buildings when the Low Heat Device is installed.

Project Objectives

Our project objective was to develop a low grade heat exchanger, with an economic return of 24 months or less, for use in the commercial and domestic sector to recover up to 40% of the heat energy from wastewater, to supplement commercial and domestic boilers. In doing so, we aimed to reduce the overall energy consumption of commercial and domestic dwellings by 7%, saving over 1,000 kWh per dwelling per year or expressed as a European total, the saving of 10 billion kWh of energy at a target market penetration of 6%, thereby also reducing the increasing levels of the greenhouse gas, CO₂ into the atmosphere.



3D CAD Concept of Developed Heat Exchanger

Additionally, the project aimed to create new jobs in the plumbing sector. With over 150,000 SMEs, this sector has been traditionally slow to innovate and needed new added value products with enhanced features to help them combat increased competition. The predicted sales for the technology were approximately €1.67 billion in Europe alone, creating over 10,000 jobs.

Specific objectives included:

- Developing an understanding of the effects of heat exchanger geometry on the fluid dynamics and how these effect the heat transfer process for low-grade waste water at temperatures of between 25°C- 80°C and flow rates of 5-20litres/minute.
- Developing an understanding of the effects of surface micro-roughness, (between 1 micron and 100 micron) on the improvement of heat transfer coefficient of wastewater and the ability of micro-roughness to move low efficiency laminar flow into high efficiency turbulent flow conditions, at the above flow rates and temperatures.
- Developing an understanding of the interaction of fluid dynamics and surface roughness when combined in a single heat exchanger on the heat transfer coefficient for low-grade heat recovery from low flow fluid.
- Developing an understanding of the different wastewater energy discharge characteristics of different domestic appliances (timing, duration, temperature, flow, volume).

In addition, we also recognised that a programme of dissemination and exploitation would also be required to promote the results of the research.

Approach

To achieve the objects of the *Low Heat* project an ambitious programme of research and development was undertaken, under the Framework 6 Programme, to achieve the consortium's aims and objectives.

The scientific research work was required to meet the following targets: -

- The ability to recover low-grade heat from low flow fluids for the range of temperatures, 25°C to 80°C, and flow rates 5 litres/min to 20 litres/min with a heat recovery efficiency of 40%.
- Achieve a heat transfer co-efficient improvement of low grade low flow water (from a typical value of 1000 at laminar flow levels to 1500 under turbulent flow conditions) from micro surface roughness.
- The heat exchanger technology to be capable of being retrofitted into domestic and commercial buildings via existing plumbing network processes.
- The ability for the heat exchanger device to maintain its performance without the need for maintenance or frequent cleaning in the presence of wastewater contaminated with soap, detergents, hair and fibres.
- Develop a synchronised, retro-fit, master/slave control system that can, (using the scientific knowledge above) control and co-ordinate the waste-water discharge cycles of domestic appliances to optimise the performance of heat recovery devices, (flow delay not to exceed 30 seconds).
- Achieving a manufactured cost that will offer an economic return based on the energy saved by the householder, within 24 months. The target cost for the new heat exchanger is €30, the master controller €65, the slave units €15, and the installation costs €80, foreign body trap €10. Thus the total cost for consumers, (assuming a typical average of 2 slave units) is estimated to be €215.

The enabling innovation related objectives included:

- Contacting leading Plumbing and Heating Organisations across Europe, to access the 150 000 SME in the industry and indeed eventually through to potential domestic customers.
- Dissemination of information through the World Plumbing Council.
- Contacting leading Energy conversation, standards and regulatory bodies across Europe to make them aware of the technology and highlight the potential to enhance standards and building efficiency.
- Formulating the project results into a protectable form and to apply for patent protection on defined aspects of the device.
- To transfer knowledge from the RTD performers to the SME participants through technology transfer events.
- To broadcast the benefits of the developed technology and knowledge beyond the consortium to potential industrial user communities.

The Framework 6 programme offered the majority of the SME partners access for the first time to the world class research expertise of three European Research Teams in Norway, Spain and the United Kingdom. Together with the industrial drive, economic and market driven focus that the SMEs provided, the collaborative research team followed the planned project approach to achieve all of the projects objectives.

Project Results

The project progressed extremely well with the consortium working well together to develop the Low Heat system that consists of 3 simple components:

- Heat Exchanger
- Drain Device
- RF Controller

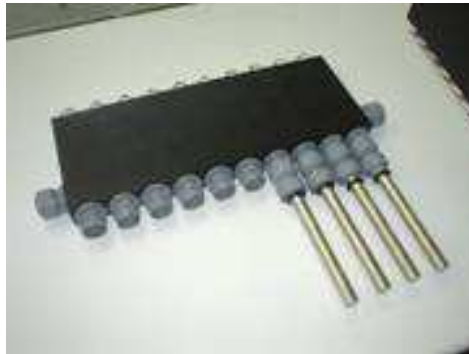
The Lowheat device works by capturing the heat energy from the warm waste via a heat exchanger. Energy is transferred to the cold side of the heat exchanger where it is redirected into the appropriate part of a hot water system.

When the system detects warm wastewater discharged down the drain at a temperature greater than 30°C, the pump is activated. This diverts the low-grade wastewater into a compartment within the heat exchanger. The energy collected is transferred from the wastewater, via heat pipes to the closed loop hot water circuit. In doing so no contamination of water can occur due to the air gap within the heat pipe, thus conforming to legislation between potable water and dirty wastewater.

In addition, the software incorporated within the low heat device is capable of clearing blockages located in the filter by reversing the pump action. This effectively removes any unwanted debris by discharging back into the drainage system, making the system a low maintenance application.

The initial proof of principle was proven by month 12, enabling the consortium to develop Low Heat into a more commercially viable product during the second project period.

The final prototype was completed by month 24, with the drain device and slave unit integrated into the test rig.



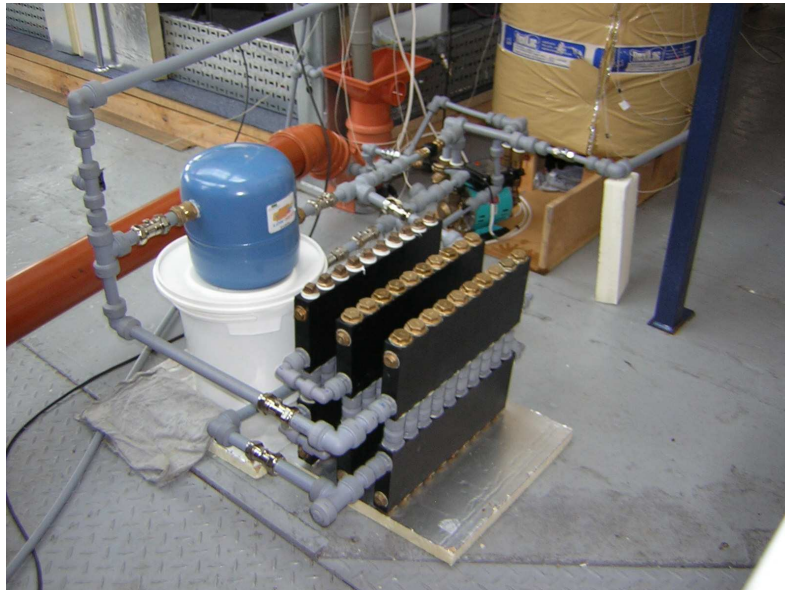
Inline Heat Exchanger

The heat exchanger is capable of transferring heat effectively and also ensures that no contamination of water & wastewater occurs. A unique element of design has allowed for the inclusion of a number of heat pipes to ensure an efficient transfer of heat and that no contamination of the potable water could take place.

The original design of the Heat Exchanger was capable of a power performance of 2.3kW. However, an improved three panel heat exchanger is now capable of a power performance of 4.5kW at typical household discharge temperatures, thereby providing a supplementary energy source and a 'pre-heat' to incoming cold mains water to the existing hot water storage cylinder or other heat source.

The heat pipe itself is a simple yet extremely effective heat conductor that can absorb and transfer thermal energy. It is basically a sealed vessel that contains a small amount of fluid contained within its own vapour, which contains a capillary wick lining system.

Once a change in temperature is detected on the surface of the heat pipe, this causes the liquid contained within the pipe to change to vapour. In so doing, the liquid quickly changes state allowing the heat to be transferred with minimum heat loss. There are no moving parts within the heat pipe, nor does it rely on any external power except that of the thermal loading making it a very simple yet highly effective piece of engineering.



Fully installed 3 times Heat Exchanger

Drain Device

The volume of low grade temperature from waste water is captured within the drain device, which effectively consists of a 4 litre gulley, with sophisticated hardware and a pump. When useful energy in excess of 30°C is present the pump activates and circulates the low grade hot water to the heat exchanger.



The pump is a low energy device that operates on 16 volts DC, providing 4 litres per minute, at 2.3 Amps. The unit consists of two motors, each requiring 36.8 watts.

Radio frequency (RF) Controller

The wireless wall device enables the end user to monitor the amount of energy being saved by the Low Heat device.



A simple, yet effective display allows easy access to the following information:

- Real-time performance of the heat exchangers
- Accumulated kW/h performance
- € saving over 'user' set period of time
- Reset button
- Any maintenance required

The battery operated wireless wall device is easy to install and uses a low power IEEE 802.15.4 radio wave to receive data up to 30 metres from the device.

Test Results

Two heat exchanger concepts were developed, designed and manufactured to achieve as high a heat transfer rate as possible.

From testing the prototypes in the test rig facility, we have ascertained that the 'in-line' device, as a heat exchanger, is almost 100% efficient, with negligible heat losses between the wastewater and the cold-water temperature increase. The performance of the second system, the 'gatlin gun', as a standalone device is not as efficient as the in-line device, but still offered the consortium the option of a neat pipe work solution and therefore was not ruled out as a potential device.

Unfortunately, surface roughness testing did not prove to give the wanted heat transfer required and so alternative technologies were evaluated. Heat-pipe technology was evaluated as a good solution. Heat-pipes are relatively costly to produce and technologies to reduce this cost were investigated. Replacing the internal wire mesh in the heat-pipes with a porous layer created by Metallization, combined with a diffusion bonding, electron beam welding or brazing of moralized half-pipes was selected as alternative and less costly production method for heat-pipes.

Once a prototype heat exchanger and drain device had been developed, extensive testing on these device's, produced the following figures when installed on the test rig:

Appliance	Heat recovery (%)
Bath	12.2%
Basin (Sink)	36.1%
Shower (5min)	36.2%
Shower (10min)	31.1%
Washing Machine	84.1%

Typical Power transferred by inline heat transfer

Temperature	Power
65°C	2200 watts
55°C	2130 watts
45°C	1900 watts
35°C	1400 watts

Therefore it can be seen that on average in a typical domestic installation the LOWHEAT technology achieved its key technical objective of recovering at least 40% of this waste energy.

Taking the shower results as an example, if a shower temperature is 44°C, and is in use for 5 minutes only, then Lowheat will be operational for 440 seconds. This has the effect of increasing the cold mains incoming water to the water system by over 6°C, thereby converting and inserting 0.23kwh of free energy into the water cylinder system.

Cost analysis has shown that an installed LOWHEAT system is anticipated to have a payback of approx. 4 years. This is very commercially viable proposition, when comparing current economical payback of solar or ground source technologies, whose payback is approx. 20 years.

Marketing Plan

The dissemination activities that were defined and used for marketing purposes have been numerous and varied. These ranged from the production of a DVD in association with the EC, that resulted in European television exposure to local events and magazine articles.

All consortium partners were briefed upon the different possibilities for appropriate design criteria and installation techniques along with test results and potential benefits to ensure a generic approach in dissemination. All of which has been placed on the project specific website, developed by the task leader.

The local events and magazine articles have ensured that the dissemination of the technical and practical based knowledge has been conveyed beyond the realms of the consortium. Beneficiaries' of this knowledge include consultants, design engineers, plumbing and heating practitioners, builders and the general public. In addition, there was a concerted effort to ensure that the appropriate Government departments were identified and made aware of the energy savings.

The first targeted event was to coincide with the IPHE's flagship event of the year, their centenary Conference and exhibition which took place on the 1st June 2006 in Torquay, UK. Since then, a number of presentations have been given across Europe by various consortium members and have been well received by the industry and public alike.

In addition, numerous trade journals and national news papers were targeted and various articles have been produced by the IAG members and other consortium members. The technology was also featured on the television channel Euronews.

By securing a patent, this has allowed for full technical details to be made available on the LOWHEAT website at an appropriate point in the future.

A project specific website has been set up, which is currently located via the IPHE main page on <http://www.iphe.org.uk/> then by clicking on the lowheat logo.

Or alternatively, visit directly at www.lowheat.iphe.org.uk

The website currently gives only basic details of the Lowheat project to pave the way for further dissemination activities.

Through the various dissemination methods available, the optimum transfer of technical and system application information to a "large" group of SME plumbers, designers and the general public was achieved.

In addition, the results have been disseminated to the appropriate government departments and ministers responsible for the environment and standards

The production of marketing literature for trade articles was extensive and various exhibitions and seminars were presented at and the development of the website opened the path for other sectors such as builders/architects, leisure (hotels/restaurants etc.), health/hospitals, food/chemical industries to view this technology and understand the potential benefits.

The potential market for the product is vast and has initially encompasses both the commercial and domestic plumbing and heating energy efficiency market.

Conclusions

In conclusion, Low Heat successfully achieved all of its project objectives and also identified new opportunities for this innovative heat recovery technology.

Low Heat's potential has been recognised across Europe by many different organisations and this has been demonstrated by the fact that Low Heat was Highly commended by the UK National Energy Efficiency Awards 2006.



The Low Heat Consortium receiving the energy efficiency award in London.

The Low Heat project has been successful in developing the intelligent network management system of heat recovery devices, for the purpose of recovering low grade waste heat energy from wastewater going to drain in both commercial and domestic situations and returning it to the hot water system.

The devices are compatible with most types of heating and hot water systems and all domestic and commercial applications, including laundries, hotels, sports complex's, restaurants and community homes.

If taken to market, it has been proven that Low Heat would have a beneficial effect on the overall energy consumption of commercial and domestic dwellings and help building occupiers improve their carbon footprint.

In addition, Low Heat would also help the European plumbing and heating industry address the latest Regulatory requirements that have recently been imposed upon them, regarding Water and Building Regulations and their directives for water and energy efficiencies.

The Low Heat consortium would like to recognise the European Commission's support in this project, via its Research funding programme, without which, the Low Heat project would not have been possible.

Acknowledgments

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The partners would especially like to thank Mr German Valcarcel, the project's Scientific Officer, and Mr Antonio Cherenti, the projects Financial Officer, for their help and guidance throughout the project.



**SIXTH FRAMEWORK
PROGRAMME**



The Institute of Plumbing and Heating Engineering (UK)
 A K Industries Ltd (UK)
 AIMPLAS – Instituto Tecnológico del Plástico (ES)
 Angewandte System Technik GmbH (DE)
 Convex Electrical Ltd (IE)
 K. Lund AS (NO)
 Metallisation Ltd (UK)
 Pera Innovation Ltd (UK)
 Polska Korporacja Techniki Sanitarnej Grzewczej Gazowej Klimatyzacji (PL)
 Robert Prettie & Co Ltd (UK)
 Stiftelsen teknologisj Institutt (NO)



The Consortium:

The project partners, lead by the IAG coordinator IPHE (UK), are spread throughout six member states with two other IAG plumbing institutions supporting this project named MEGSZ and PKTSGGIK, based in Hungary and Poland respectively. The project gains industrial support from AK Industries, CRS, Metallization & Robert Prettie whom are based in the UK; Convex from Republic of Ireland, K. Lund based in Norway and AST located in Germany.

The geographic locations of the companies, who make up the consortium, provided this project with an even spread across Europe.

The project and associated benefits was only made possible by the financial support of the European Community.

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