UTILISATION OF WASTE HEAT FROM FOOD FACTORIES

This executive summary describes work on the project AFM248Br, which involved CCFRA and Bristol University as a research consortium and the collaboration of Shipston Mill, Kerry Aptunion, Kraft Europe, Kellogg's UK, Warburtons, Unilever, RHM Culinary Brands, Greencore, Weetabix and Glaxo Smith Kline Nutritionals.

AFM248Br was a one year Bridge-LINK project that finished in October 2007. The project identified sources of waste thermal energy from food processes that could be recovered to produce mechanical power using Stirling engine technology. In the context of the project 'waste thermal energy' implied any source of heat released from a process that was rejected to the environment. Flue gases from combustion processes, hot air from baking ovens, steam or steam condensate from cooking operations were a few examples found in the food industry.

The project proposed the assessment of Stirling engine technology to achieve this purpose. Stirling engines are external combustion heat engines, with several advantages that make them suitable for waste heat streams (no contact between heat source and moving parts, scalable to application, low maintenance). They have high theoretical efficiencies and have been developed for several applications (micro CHP systems, biomass and solar powered), although they have not reached yet full commercial development except for very specific niche applications.

Waste energy survey in the food companies

Ten different food factories were visited to gather information on waste energy streams released from processing operations. The nature of manufacturing operations studied was varied because the companies chosen for collaboration in the study belonged to different food sub-sectors. These included bread and cereal manufacturing, wheat processing, fruit processing, production of coffee, elaborated and prepared foods and soft drinks.

The survey was concerned with collecting information on energy usage, identifying the key processes contributing to energy consumption and waste energy, and obtaining quantitative data. The key parameters studied for the identified waste energy streams were: temperature, mass flow rate, media of rejection, presence of contaminants and accessibility. The first three parameters allowed the heat load (exergy) in the stream to be calculated. The exergy content and the temperature at which energy was released from a system were the key parameters for evaluation of its quality and usability for power generation. More than 30 energy streams were identified across the 10 factories visited, and from these, a total of 16 were accurately quantified (specific figures for temperatures and flow rates were known). The calculations gave a total value of 9.7MW of energy lost from these factories. The following Table presents these data.

Table 1: Summary of calculated energy available from the waste energy streams

Type	Process of origin	Stream Temp (°C)	Mass Flow (kg/s)	Exergy (kW)
Air	Coffee roaster	370	0.08	29
Air	Continuous oven	186	0.17	29
Air	Rack oven	129	0.38	42
Air	Hot water boiler	171	0.37	57
Air	CHP steam boiler	177	0.43	70
Air	Oven stage 4	116	2.36	229
Air	Oven stage 3	120	2.34	237
Air	Oven stage 2	140	2.23	271
Air	Oven stage 1	160	2.13	303
Air	Hot air drier	60	31.84	1,282
Air	Post coating drier	120	26.97	2,731
Steam	Continuous steamer	100	0.17	56
Steam	Blow-down steam	175	0.20	136
Water	Finished product cooler	30	7.00	293
Water	Continuous vacuum condenser cooling loop	40	12.50	1,045
Water	Batch vacuum condenser cooling loop	45	28.00	2,927

Stirling engine technology

Bristol University carried out a review on Stirling engine technology, from its thermodynamic working principles to the current state of the art and commercial development. This assessed the technical feasibility of producing electricity from waste thermal energy streams. Thermodynamics showed that thermal to mechanical energy conversion efficiency increased with the temperature of the heat source, and this proved to be a limiting factor given the range of operating temperatures in food processes. The research identified that at the moment there are no commercial Stirling engines (or any other type of engine) which would be economically viable considering the energy stream temperatures originated in food processes.

Discussion and Conclusions

The project showed that although a significant amount of energy was lost through food manufacturing operations, the range of temperatures at which it was released (typically in the range between 30 and 200°C maximum) did not allow for an efficient and cost effective transformation into mechanical power. It concluded that exploitation of this potential was constrained by the lack of suitable technology. Attractive alternatives to the Stirling are now emerging: for example rotary scroll compressors for refrigeration and automotive air-conditioning. Together with new methods of manufacturing compact heat exchangers and reactors (direct laser deposition, DLD), these could form the basis of a new rotary heat engine using a recuperated rotary Ericsson cycle. This “scroll” engine will have the same theoretical efficiency as the Stirling, but will achieve a higher proportion of it in practice, at commercially acceptable costs. A research proposal on this concept was submitted to Defra following the finalisation of this project.

However, another potential application for heat engines within food processing facilities was identified. This comprised the concept of utilising high grade primary energy (from gas burning) to run a Stirling engine and produce electricity, and then use the remaining thermal energy to run the food process (e.g. baking oven).