Energy use in the chilled food sector

Case study – Blast chilling of pies in a UK factory

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Summary

A case study has been carried out of a blast chilling operation in a chilled pie manufacturing plant in the UK over a complete two week period of production. The primary aim of the case study was to provide data on energy used in the blast chilling of hot pies post cooking under real use conditions in a manufacturing environment.

In the plant after the pies were removed from the oven they were placed in a purpose built ambient cooling system for 30 minutes prior to de-tinning and re-racking on to trolleys for blast chilling.

The average pie temperature when loaded into the chiller was 63.3°C (range from 40.0 to 78.2°C) and on exit the average was 5.8°C (range from -1.7 to 45.2°C). Using data on the composition of the pies the amount of heat that had to be removed from the pies to cool from the specified 70 to 3°C in the chilling system was 56.4 kWh/tonne. However, when recalculated to take into account the variation in measured temperatures of pies entering and exiting the chiller this value varied from a minimum of 44.6 to a maximum of 55.5 kWh/tonne (mean 48.4 kWh/tonne). It was also calculated that an average of 16.7 kWh/tonne had been removed in the 0.5 hours of ambient cooling.

The mean specific energy value over the two-week production period was 47.1 kWh/tonne. Specific energy consumption was significantly higher (65.8 kWh/tonne) on the day of lowest production.

The overall efficiency (effectiveness) of the cooling process (heat extracted/energy used) ranged from 0.84 to 1.19 with a mean value of 1.04.

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Introduction

The chilled convenience food sector is a major and growing user of energy for refrigeration in the food industry. Products are often heated (cooked) to temperatures of typically 85°C before being cooled to average temperatures below 5°C before packing, storage and distribution. In many plants, the cooling operation is carried out by placing a batch of hot product into an air based blast chiller. However, there is little, if any detailed data available concerning the energy consumed by blast chilling systems under real use conditions in the UK.

The primary aim of this case study was to provide data on energy used in the blast chilling of hot pies post cooking under real use conditions in a manufacturing environment. The data would become a benchmark for comparison with other blast chilling operations.

The site was chosen as it is an example of a blast chilling operation that utilises ambient cooling which is considered a potential method of reducing energy consumption in operations where hot products require rapid cooling post cooking/heating. FRPERC has also a built up a good relationship with the pie manufacturing company during a two year Knowledge Transfer Partnership, providing the benefit of unrestricted access to plant and manufacturing data.

Method

The specification of the pie blast chilling operation at the plant requires that racks of pies are cooled immediately post cooking, from a minimum cooked temperature of 85°C, down to a final chilled temperature of 3°C.

Ambient cooling is used for the first 30 minutes (Figure 1) prior to de-tinning and re-racking on to trolleys for blast chilling (Figure 2).

Figure 1. Two views of a trolley of hot pies being cooled in the ambient cooler prior to de-tinning

Figure 2. De-tinning of pies prior to re-stacking on trolleys and blast chilling

Pies enter the blast chilling tunnel on trolleys through the entrance door and are incremented through in single file until they are removed through the exit door at the other end (Figure 3).

Figure 3. Example of push through blast chiller

The energy consumption of the blast chiller was recorded over two full weeks of pie production using a portable energy monitor (Sinergy e-Tracker Mk2, Stockport, UK). The three phase supply was recorded (Figure 4) using a 6 minute integration period (providing a log of true RMS voltage and current ±2% of reading, Hz, kW, kVAr and power factor).

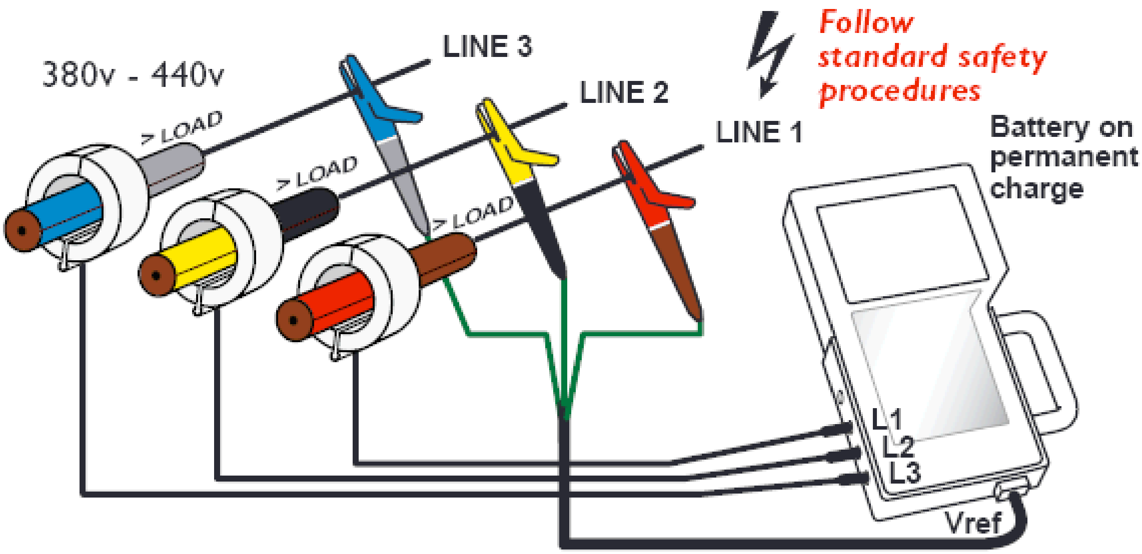

Figure 4. Three phase energy monitor attachment setup using direct voltage measurement and three clamp on current transformers (Source: Sinergy, UK)

The blast chiller refrigeration system (Figure 5 and Figure 6) comprised of a multiple compressor pack (6 x Copeland ZS45K4E-TFD-265 scroll compressors, Emerson Climate Technologies), horizontally mounted condenser unit (Searle, UK) and custom designed push through rack tunnel with ducted cross flow air cooled by two evaporator/fan coil units (Searle, UK).

Although the factory has two blast chiller tunnels that can run from the same refrigeration system, at the time of the test only one had been commissioned which meant that up to three of the six scroll compressors were in use. The control system was such that as the load on the refrigeration system varied, it could bring either one, two or three compressors into operation.

In order to calculate the specific energy consumption of the pie blast chilling operation, a record of the throughput of pies during the energy-recording period was maintained. The quantity and time of transferring racks of pies from cooking to ambient cooling and time in and out of the blast-chilling tunnel were noted for the two-week production period. The internal temperatures of sample pies within each trolley were also recorded at the time of each transfer.

Figure 5. External housing of multi-compressor pack (black frame) and horizontal condenser fan unit (foreground)

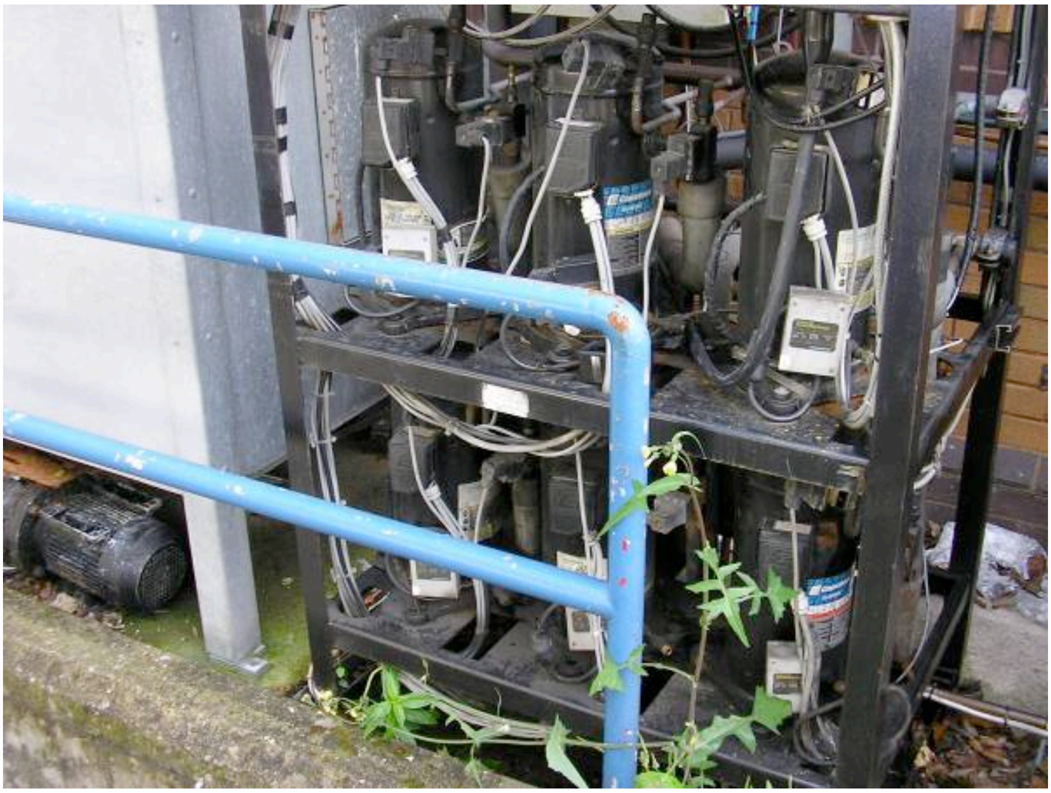

Figure 6. View of the multiple scroll compressor pack (3 above, 3 below)

Results and discussion

The chiller power and air temperature measured during a typical day of operation (Thursday week 1) are shown in Figure 7.

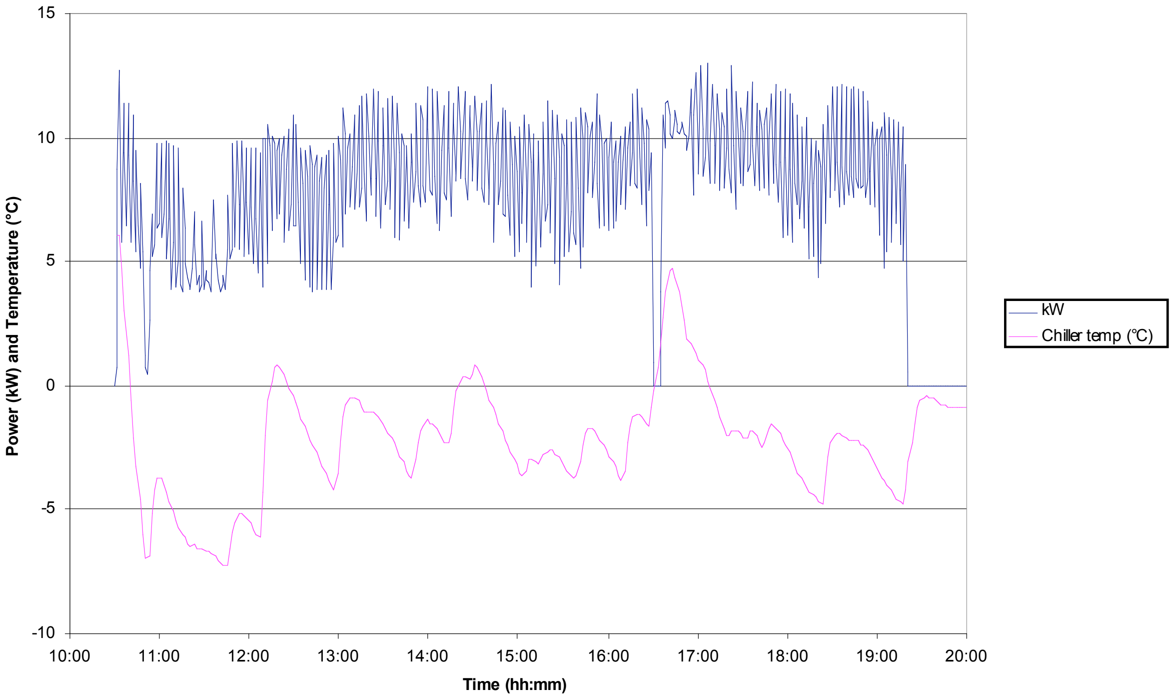

Figure 7. Plot of chiller power and air temperature during a typical day of operation

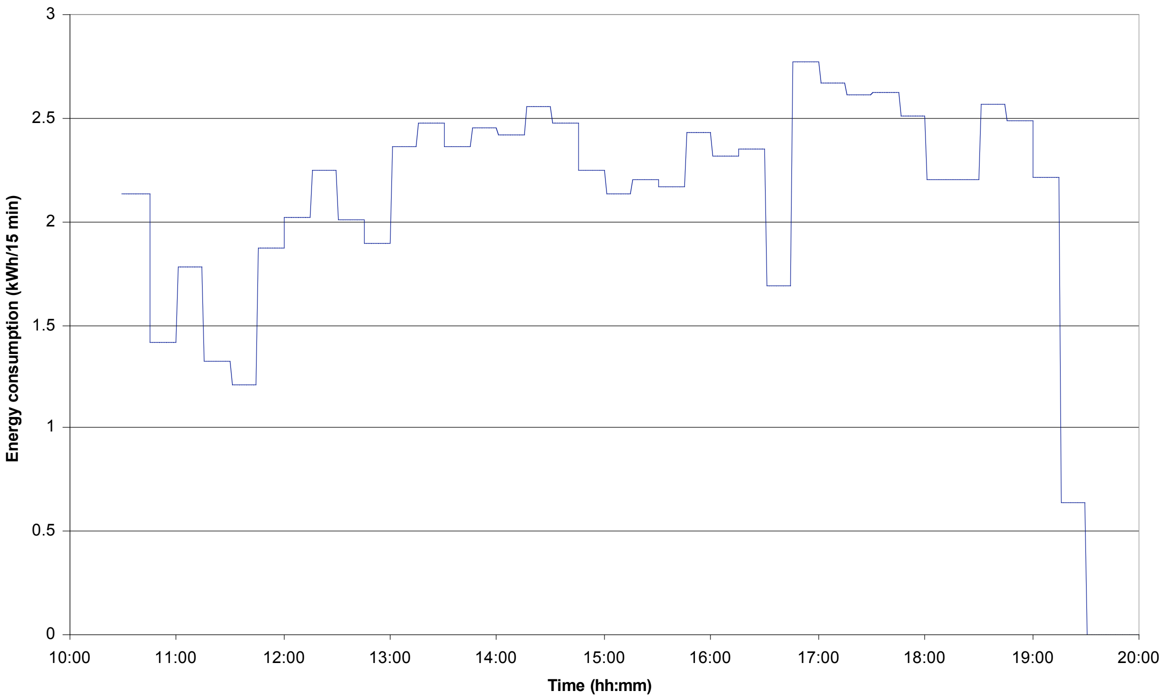

Figure 8. Plot of energy consumption during a typical day of chiller operation

The energy consumption for each 15 minute period throughout the same typical day of operation is shown in Figure 8. The peak energy consumption occurred at about 17:00 following a defrost cycle and soon afterwards the addition of a trolley of hot pies, denoted by the rise in chiller air temperature.

Table 1 provides a summary of daily throughput and energy data for the pie blast chilling operation over two complete weeks of production. The number of trolleys of pies chilled per day varied from a minimum of 10 to a maximum of 19 (mean 16.3 trolleys per day). Typically there were 15 trays containing 24 pies weighing approximately 270 g each on a full trolley being loaded into the blast chiller. Therefore, the daily throughput varied between 0.972 to 1.847 tonnes of pies per day with a mean of 1.584 tonnes per day or just over 7.9 tonnes per week.

Table 1. Daily throughput and energy data for pie blast chilling operation over two weeks of production

Day/Week	*Number of trolleys (trolleys/day)*	*Pie throughput (tonnes/day)*	*Daily energy consumption (kWh/day)*	*Specific energy consumption (kWh/tonne)*
Week 1				
Monday	18	1.750	71	40.6
Tuesday	15	1.458	70	48.0
Wednesday	13	1.264	61	48.3
Thursday	18	1.750	74	42.3
Friday	18	1.750	70	40.0
Week 2				
Monday	16	1.555	70	45.0
Tuesday	10	0.972	64	65.8
Wednesday	18	1.750	77	44.0
Thursday	18	1.750	76	43.4
Friday	19	1.847	98	53.1
Mean	16.3	1.584	73.1	47.1
Std. Dev.	2.9	0.279	10.0	7.7

The average pie temperature when loaded into the chiller was 63.3°C (range from 40.0 to 78.2°C) and on exit the average was 5.8°C (range from -1.7 to 45.2°C). Using data on the composition of the pies the amount of heat that had to be removed from the pies to cool from the specified 70 to 3°C in the chilling system was 56.4 kWh/tonne. However, when recalculated to take into account the variation in measured temperatures of pies entering and exiting the chiller this value varied from a minimum of 44.6 to a maximum of 55.5

kWh/tonne (mean 48.4 kWh/tonne). It was also calculated that an average of 16.7 kWh/tonne had been removed in the 0.5 hours of ambient cooling.

Energy consumption of the refrigeration system including the compressors and condenser unit fans ranged from a minimum of 61 kWh/day to a maximum of 98 kWh/day with a mean of 73.1 kWh/day over the two-week production period. When converted to specific energy consumption this yielded a range from a minimum of 40 kWh/tonne to a maximum of 65.8 kWh/tonne with a mean value of 47.1 kWh/tonne.

The overall efficiency (effectiveness) of the cooling process (heat extracted/energy used) therefore ranged from 0.84 to 1.19 with a mean value of 1.04.

On the Tuesday of week 2 the value of blast chilling specific energy consumption was far higher than at any other time (65.8 kWh/tonne). Finding the reason for this poor performance might provide useful guidance for improved process efficiency. On further scrutiny it was noticed that this coincided with the day when the least number of pies were put through the chiller. Although the daily energy consumption was the lowest, as the blast chiller was switched on for a shorter time, it was thought that the energy used for initial cool down of the chiller from ambient was a bigger proportion of the total daily energy. Therefore, it is recommended that once the chiller is switched on and cooled down at the beginning of the day (fixed overhead) efficiency will be improved the longer it can be used to usefully chill pies – i.e. short production days are less efficient in terms of blast chiller energy consumption.

It was also noted that on the days when the specific energy consumption was lower that the temperature of the sampled pies in the last trolleys to exit the blast chiller were higher than the specified final temperature. Therefore, the full chilling process was incomplete and the product heat load on the blast chiller refrigeration system was correspondingly less. Removing these "part chilled" trolleys and corresponding energy use from the daily analysis yielded higher specific energy consumption values closer to those measured on days when all trolleys were fully chilled (approximately 48 kWh/tonne).

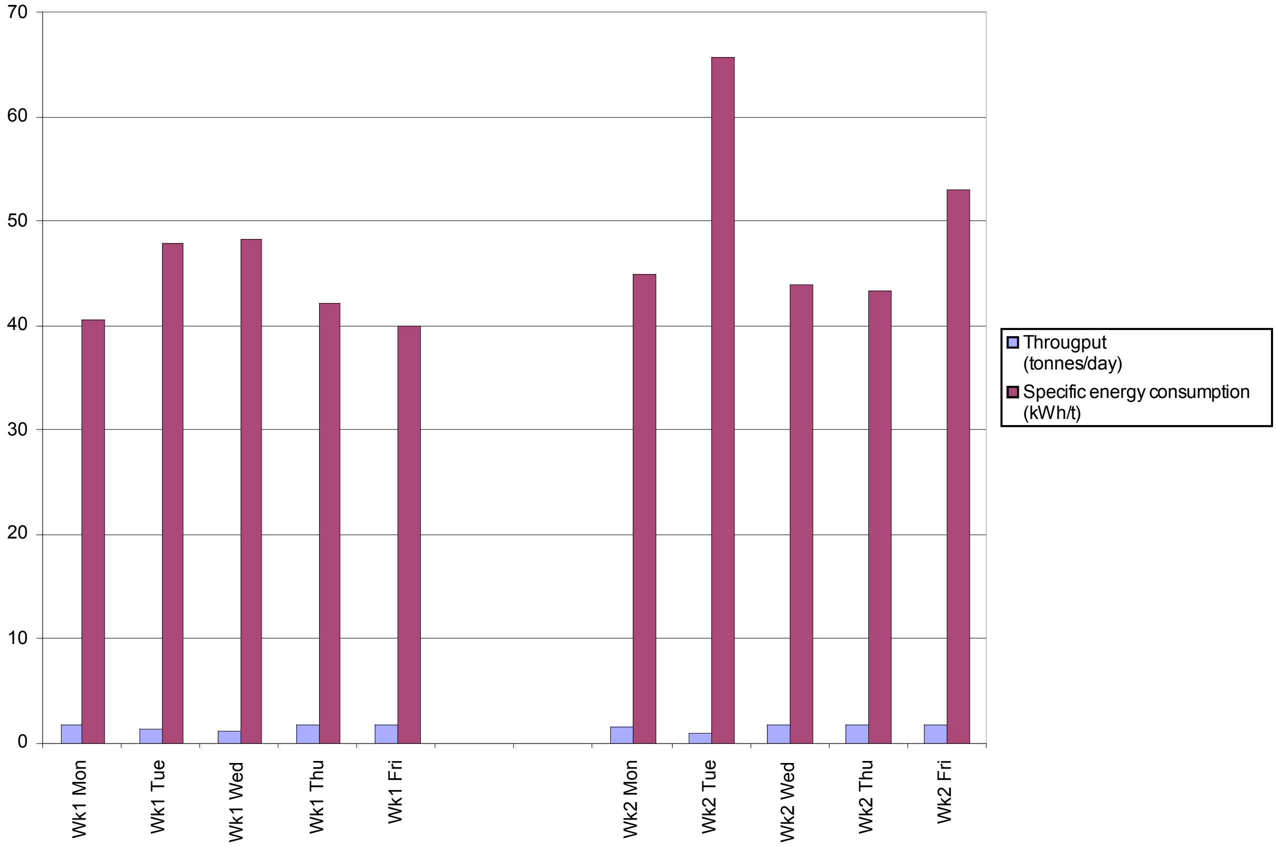

Figure 9. Chart of daily throughput of pies (tonnes/day) and daily specific energy consumption (kWh/tonne) for pie blast chilling operation over two weeks of production

Conclusion

This case study provides a benchmark specific energy consumption value for a specific "real life" pie blast chilling process in a UK chilled pie manufacturing plant. The mean specific energy value over the two week production period was 47.1 kWh/tonne.

Specific energy consumption was significantly higher (65.8 kWh/tonne) on the day of lowest production.

Further analysis is required to determine the specific energy benchmark for the complete pie cooling process including the ambient cooling and effect of additional variable system elements (e.g. defrost heating etc.) and environmental effects (e.g. winter/summer operation).

The overall efficiency (effectiveness) of the cooling process (heat extracted/energy used) ranged from 0.84 to 1.19 with a mean value of 1.04.