AUSTRALIA

INDUSTRY
TOURISM
RESOURCES

Pasteurisation Options for Breweries

Big Energy Project Innovation Workshop Report 2002

energy efficiency
best practice

Big Energy Project innovation workshop

Pasteurisation options for breweries

Overview

The Big Energy Project (BEP) is an innovation workshop process developed by ISR to identify ideas and opportunities that will lead to large efficiency gains through redesign. Workshops draw on the considerable experience and expertise of company employees with support from external specialists who have knowledge of specific, relevant technologies. The ideas generated can provide efficiency gains for new facilities or through retrofitting to existing plant.

This report provides a summary of outcomes of a two-day BEP workshop held on June 20th and 21st 2001. This BEP was conducted by ISR under the Beverage Industry Innovation, Training and Benchmarking project.

This report is in two sections:

- The first being an abridged version of a discussion paper drafted before the workshops to assist in the understanding of pasteurisation process in breweries, and to assist in specialist support and workshop program development.
- The second being an abridged version of the final report on the workshop procedure and outcomes.

Section 1:

Big Energy Project - Pasteurisation background briefing.

1 Background

This paper was intended to provide background information for workshop participants. It explores a range of issues of potential relevance, but may not be comprehensive. Data in the paper are indicative only.

Pasteurisation is a widely-used process applied to food and beverage products to reduce or eliminate microbiological contamination and hence extend storage life. With many products, a secondary purpose is to inactivate enzymes to stop ongoing chemical reactions in the product that would change its characteristics during storage.

This Big Energy Project is intended to explore innovative options for substantially improving the energy efficiency of pasteurisation within the beverage industry, but also taking into account the potential for application of outcomes more widely.

Traditionally, pasteurisation is carried out using relatively low temperature heat – for example at 60 to 75^{O}C. However, alternative methods of pasteurisation are used. These include micro-filtration, microwave treatment, and irradiation using a variety of energy sources.

Depending on the product and the process chosen, the pasteurisation process may occur for shorter or longer periods, and at different temperatures. The conditions are influenced by the extent of microbiological contamination, the desired level of reduction, the side-effects on product quality of exposure to heat, and the characteristics of the process technology. In general, the shorter the duration and the lower the temperature, the less impact on product quality – but the less effective the process usually is. Also, for a given level of pasteurisation, a shorter, hotter exposure generally has lower impact on product quality, as it has a lesser ‘cooking’ effect.

Pasteurisation is potentially an energy-intensive process, as it involves heating, often followed by active cooling, of large quantities of food or beverages. Data on the energy use of pasteurisation are difficult to come by, probably reflecting the integration of this process into the overall systems of plants. One study (URS, 2000) suggests that up to a quarter of gas use in breweries is for pasteurisation: this would be equivalent to 0.25-1 MJ per litre of product. Further costs would be incurred for electricity used to operate pumps, conveyors, fans, etc, as well as cooling. At the low end of this gas use range, the amount used is sufficient to heat each litre of liquid by 50 ^{O}C (assuming 85% efficiency of gas utilisation). At the higher end, it is sufficient to heat the liquid by 200 ^{O}C: this suggests potentially significant scope for efficiency improvement in existing plant. As discussed later in this paper, best practice is significantly better than these figures, but there is still substantial scope for improvement.

2 Functional Requirements

Since the level of bacterial load in products varies widely, and the impact of the treatment process on product quality varies, the pasteurisation process must be adapted to each product. In this paper, the focus will be on pasteurisation of beer, but the outcomes should be applicable to other products if the process is designed with flexibility in mind.

The objective for beer is to reduce the microbiological contamination level to zero from an initial count of 30 to over 500 organisms per millilitre in Bright Beer (unpasteurised beer from the brewing process) without adversely affecting product taste.

The main micro-organisms that have to be dealt with are:

- Brewing culture yeast. ie: Saccharomyces cerevisiae and Saccharomyces carlsbergensis. These are present in beer after filtration (in Bright Beer),due to filter bleed or some other reason.
- Lactic acid bacteria (anaerobes).
- "Wild Yeasts". These are non-brewing /contaminant yeasts. eg: Brettanomyces sp.
- Aerobic bacteria, eg: acetic acid bacteria, water-borne bacteria etc. These are referred to as "general contaminants"

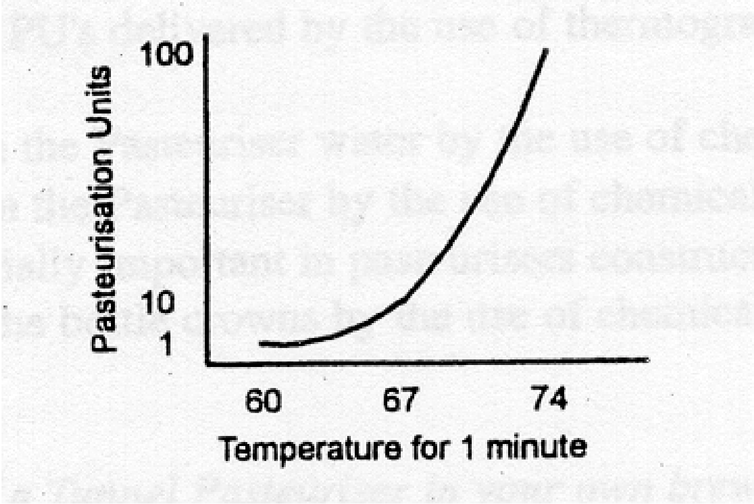


Figure 1. Relationship between pasteurisation temperature and number of Pasteurisation Units in a period of one minute.

The extent of pasteurisation is measured in *Pasteurisation Units (PUs)*. One pasteurisation unit is the extent of pasteurisation achieved by treatment at 60 ^{O}C for one minute. As temperature increases, the time required to achieve one PU declines – or, put another way, the number of PUs per minute increases, as shown in Figure 1. For beer, pasteurisation levels of 10 to 20 PUs are typical. The more confident producers are of the sterility of their process, the smaller the number of PUs that may be specified. Also, the more delicate the flavour of the beer, the less pasteurisation can be carried out without affecting flavour: typically less than 10 PUs is preferred.

It is important that the pasteurisation process achieves an appropriate level of reduction of pathogen activity. In practice, a "PU" meter can be used for immediate checking, supplemented by laboratory micro checks, which take up to 72 hours to process.

From an energy perspective, pasteurisation by heating involves heating either the product in bulk or in packages to a temperature between 60-65 ^{O}C, holding it there for a specified time, then cooling it as quickly as possible to room temperature or lower.

Mechanical pasteurisation processes aim to remove the maximum number of microbes from the product.

Irradiation processes aim to destroy pathogens and insects by breaking DNA chains. A variety of types of radiation may be used, including accelerated electron beams, X rays and radioactivity. Ultrasonic processes (very high frequency sound waves) and application of high pressure are also able to break DNA chains and pasteurise without heating, however these approaches are still experimental. During the workshop it was also noted that high pressure can be used for pasteurisation.

Possible Pasteurisation Techniques

3 Pasteurisation using heat

Flash Pasteurisation

For bulk beer and some other liquids, *flash pasteurisation* is commonly used. In this case, the incoming liquid passes through a heat exchanger, where it absorbs heat from the outgoing hot liquid, and is further heated to a relatively high temperature for a short period – for example, one minute at 69 ^{O}C or 15 seconds at 74 ^{O}C. Beers with delicate flavours may be heated to a lower temperature to avoid quality problems, and may thus be less thoroughly pasteurised. Flash pasteurisation is potentially very energy efficient. It is claimed by one source (Lom & Associates) to consume up to two-thirds less energy than tunnel pasteurisation, presumably because only the product is treated, treatment is of short duration, and the efficiency of heat recovery is higher for the simple system.

Additional energy is often used to sterilise containers, and to cool the pasteurised beer to 4 ^{O}C so that containers can be filled without excessive foaming. An example of the design of a flash pasteurising unit is shown in Figure 2.

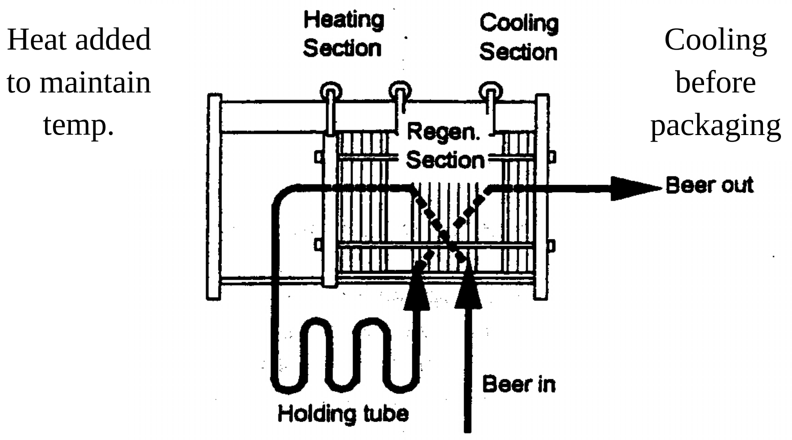


Figure 2. Flash pasteurisation. The ‘Regeneration Section’ is a heat exchanger where cold incoming beer is heated using heat from the outgoing hot beer. The holding tube maintains the beer at the pasteurisation temperature, and has sufficient capacity to hold beer for the required retention time of 15 seconds to a minute or so. Additional cooling may be required.

A disadvantage of flash pasteurisation is that it is carried out before packaging. This means there is potential for contamination as the liquid is transferred to the packaging or through inadequate sterilisation of the packaging.

The energy cost of sterilising containers may be significant. A calculation of the energy required for steam to heat a steel keg suggests that the energy required to heat a 15 kg steel keg holding 50 litres of beer using steam produced from gas at 75% efficiency is likely to be around 0.012 MJ/litre – almost a quarter as much energy as is used to pasteurise the beer.

A well-designed heat exchanger could transfer up to 85-90% of the heat from the outgoing liquid to the incoming liquid, thus requiring very little additional heating. 15% of the energy required to heat a litre of beer by 70 ^{O}C at 75% efficient gas utilisation suggests an energy requirement of around 0.06 MJ/litre.

The relatively small quantity of liquid being pasteurised at any one time and the short duration of the heating period mean that the size of the holding tube (see Figure 2) is relatively small, so heat losses during the high temperature holding period should be very low, thereby contributing to the high efficiency.

To cool beer after pasteurisation to a temperature suitable for filling containers may involve chilling the beer by around 10 ^{O}C to 4^{O}C. If a COP of 4 is assumed, this would require 0.01 MJ/litre of electricity (0.003 kWh/L).

How do these estimates compare with actual practice? One source suggests that a flash pasteuriser treating 22,500 litres/hour uses 235 kW of heat and 255 kW of cooling, as well as 22 kW for pumping.

Heat use of 235 kW is equivalent to gas consumption (at 75% efficiency) of 1,130 MJ/hour, giving a heating energy requirement of 0.05 MJ/litre, close to the calculated value of 0.06 MJ/litre.

The cooling energy requirement of 0.011 kWh/L is almost four times the estimated electricity consumption. However, if the COP of the chilling system were around 4, this cooling energy requirement would match the calculated electricity consumption.

To summarise:

- Sterilisation of containers: around 0.012 MJ/litre
- Pasteurisation: 0.05-0.06 MJ/L of gas and 0.001 kWh/L of electricity for pumping
- Cooling: 0.01 MJ/L (0.003 kWh/L) of electricity to run chillers

If only the pasteurisation process is considered, it does seem that flash pasteurisation requires a third as much energy as best practice tunnel pasteurisation. However, energy use for sterilising containers closes this gap. Non-heating options for sterilising containers, such as UV treatment, may help save energy.

Tunnel pasteurisation

Packaged beer is usually pasteurised in *tunnel pasteurisers* where the containers of beer pass through a tunnel in which they are heated by water sprays or steam/air. Typically this process may last 30 to 40 minutes at temperatures of up to 65 ^{O}C. Tunnel pasteurisation equipment usually occupies a relatively large floor area (typically 8x20 metres, the area of a house), as up to half an hour’s production (up to 60,000 cans or bottles) must be held within the processing facility because of the long duration of the process. Beer typically enters the tunnel pasteuriser at a temperature of around 5 ^{O}C. It passes through a series of conveyor systems, being sprayed by water at increasingly higher temperatures. After the beer leaves the high temperature zone, it is sprayed with cooling water in a series of stages: this cooling water is used in appropriate stages for pre-heating of the incoming containers, so that a significant proportion of heat is recovered and re-used. The temperatures and energy flows are shown in Figure 3.

In theory, a perfectly efficient pasteurisation process that uses heating could require almost zero energy (apart from initial system warm-up) if the final temperature of the product is close to its initial temperature. With perfect energy flows, the heat removed as product is cooled should be sufficient to heat up an equivalent amount of product.

In practice, a tunnel pasteuriser would require energy to heat up to operating temperature on start up plus would lose approximately 10% in the heating system and 10% in the regeneration section thus being approx 80% efficient. Additional losses occur in heat production and distribution. Where the product leaves the unit at a higher temperature than it enters, it takes away a proportion of the heat used by the system (see below).

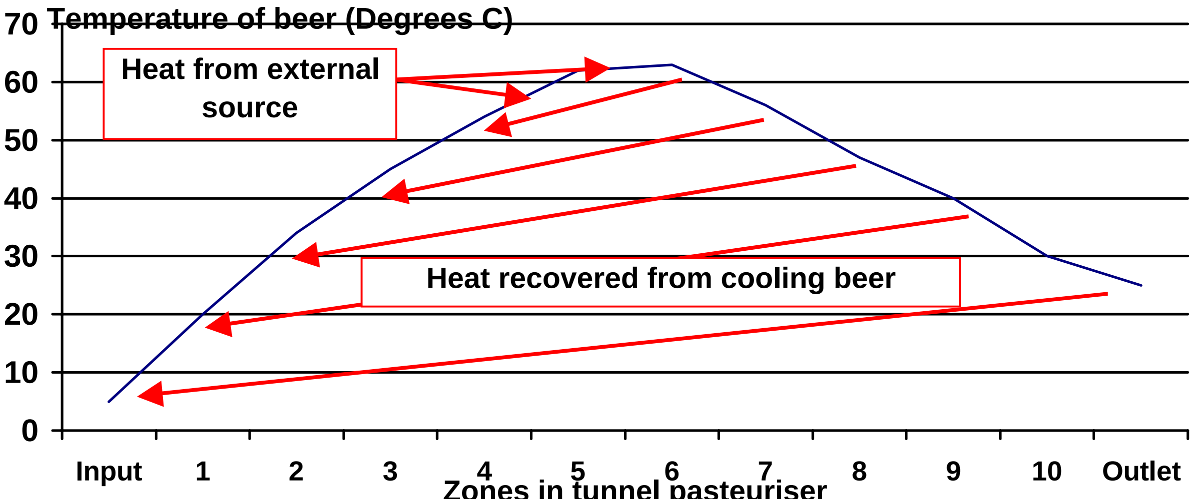


Figure 3. Energy flows in a tunnel pasteuriser.

Data for best practice equipment indicates an energy consumption per litre of product of 0.15 MJ/L of gas (0.045 kg steam, produced at 3.3 GJ gas/tonne of steam) and 0.0033 kWh/L electricity (mainly for pumping). This is equivalent to around 0.012 kg CO_2/litre, of which almost three-quarters is associated with heating. This energy loss is equivalent to heating each packaged litre by 25 ^{O}C (assuming 75% efficiency of gas utilisation), so there is still significant scope for efficiency improvement. However, it should be noted that up to three-quarters of this energy loss is accounted for by the higher departure temperature of the beer relative to its initial temperature.

If the URS data above (0.25-1 MJ/L) are correct for existing practice, achieving best practice could deliver 40 to 85% savings in heating energy. Alternatively, their estimate is excessive. For comparison, assuming 75% energy conversion efficiency and no heat recovery at all, 0.37 MJ/litre of gas would be required to heat bottles of beer by 60 ^{O}C.

In practice, energy is lost from tunnel pasteurisation in a number of ways, and these losses could be addressed in various ways, as shown in Table 1. Opportunities to improve energy efficiency within a conventional thermal pasteurisation process would involve addressing some or all of these issues with the aim of minimising losses. For example, switching from a remote boiler to a local hot water generator could cut energy requirements by 20-30%. Further heat recovery, so that bottles leave the pasteuriser at a lower temperature, could potentially recover significant amounts of heat, too.

For tunnel pasteurisation, the characteristics of heat transfer to and from the container and within the container are critical to efficiency, as these affect the rate at which the container can be heated and overall processing time and, in turn, the size of the processing facility and the rate of heat loss from it. Further, for some materials, there may be constraints on the rate of temperature change and heat flow. For example, glass is a much poorer conductor than aluminium and significantly worse than PET. And if the temperature is too high, plastics may distort. Thermal stresses in glass are also an issue.

Table 1. Energy loss from a tunnel pasteuriser and options for reducing them.

ENERGY LOSS	RESPONSE OPTIONS
Energy to heat up the system at the start of a shift or operating period	Minimise thermal capacity of system, store heat overnight, use stored solar/renewable heat
Energy use for pumping and movement of product	Minimise pumping, use high efficiency pumps and motors and variable speed drives
Temperatures of incoming containers are low, after filling	Containers could be pre-heated using ambient air, waste heat from a number of possible sources, or solar heat.
Thermodynamic inefficiencies in generating heat at temperatures higher than the end use requires, as more heat is lost via flue gases and heat losses in the supply system	Boiler only approx 75% efficient producing steam – hot water generator up to 94% efficient at 50-70 ^{O}C. Heat pump (electric or gas driven) could upgrade heat and provide ‘coolth’ to enhance heat recovery. Heat could be provided by cogeneration. If steam not used, sufficient capacity to supply peak requirements at start-up must be provided
Losses from heat distribution systems delivering heat from its source (eg a boiler) to end use	These losses are often more than 10% of total energy use. Generate hot water at pasteuriser to avoid them.
Losses from the tunnel pasteuriser	The unit has a large surface area and little insulation.

itself	Insulating the higher temperature zones of the unit would reduce losses, although cost-effectiveness may be an issue.
Losses in heat exchangers (visible as a requirement for a higher heat source temperature)	Avoid heat exchangers by generating hot water instead of using steam
Losses in heat transfer through containers and through the product itself (due to the need for a higher driving temperature)	The temperature drop across the glass (2-2.5mm thick) is estimated at 5-15 ^{O}C for the rates of heat transfer required (100-300 watts/375 ml bottle). Thinner glass or more conductive materials would lower the driving temperature
Additional process time due to low driving temperature and/or thermal resistance to heat flow extending the length of process time and thus increasing plant size and the length of time over which heat losses occur.	The rate of heat flow is proportional to the temperature difference, so the smaller the differential the lower the heat flow and the longer it takes to heat or cool the container – and vice versa. Temperature differential is limited by concerns about glass breakage and possibly risk of spoilage if beer near extremities is over-pasteurised relative to that near the 'cool spot'. More even heating/cooling (see discussion below) could allow higher heat transfer and shorter process time
Inefficiencies in heat distribution through the product (eg when containers are sprayed, a 'cool spot' just above the centre of the bottom of the container occurs, which takes longer to heat – this extends process time and may reflect the lack of internal convective heat flow	When spraying from above, internal convective effects work against even product temperature. Immersion, spraying from below, or other heat transfer systems may increase internal convection and allow process time to be shorter (see discussion below)
Inefficiencies in heat recovery from the hot product as it is cooled	This relates to heat transfer within the container and through the container walls, as discussed above.
Energy removed from the system by liquid and containers leaving at temperatures higher than that at which they entered	Since containers commonly leave the pasteuriser around 20 ^{O}C higher than they enter, around 0.12 MJ/litre of purchased energy (assuming 75% energy conversion efficiency from gas to heat) is lost. Additional heat recovery would reduce this energy loss. However, in humid weather this may lead to

	condensation on outgoing containers.
Energy required to operate cooling equipment (where used)	Where/when temperatures are suitable, evaporatively cooled water, absorption or ejector cooling with waste heat or other strategies may be used.

Where glass containers are used, rapid and uneven heating and cooling can create concerns about breakage of the containers. According to a source from a glass packaging supplier, heating or cooling with a temperature differential of up to 42 ^{O}C can be achieved without thermal stresses leading to breakage as long as the process occurs uniformly over the surface of the container. The glass is more sensitive to thermal stress during cooling, when tensile stress on the cooler outer surface of the container may lead to failure if there is uneven cooling or surface discontinuity. Compressive stress, which occurs during heating, is less likely to cause failure.

The present approach of spraying from above seems to create two sets of problems:

- When heating the container from above, lack of convection within the liquid tends to limit mixing and leave a ‘cool spot’ near the bottom of the container. Also, liquid in the neck of a bottle may cool quickly and cause local thermal gradients. This extends the time required for heating, and makes it more difficult to achieve a uniform degree of pasteurisation of the contents of the container. This is not such a problem during cooling, as the convection tends to raise the warmest beer to the upper levels where the cool water is being sprayed.
- In terms of thermal stresses, spraying from above means the base of the container is at a significantly different temperature from the upper zone. When cooling, this can create sufficient tensile stress to cause breakage, if the temperature differential is too great.

It seems that immersion, spraying from below, or other strategies that provide more even heating (such as microwaves) could reduce thermal stresses and significantly shorten the heating and cooling time, thus reducing the size of the pasteurisation system and contributing to energy efficiency improvement. In theory, it seems possible to heat a bottle of beer to 65 ^{O}C in as little as 3 minutes, and cool it in a similar time. If temperatures within the beer can be kept even, a shorter pasteurisation period at higher temperature could also be used, so that total pasteurising time could be less than 15 minutes.

There are significant transient energy issues involved with tunnel pasteurisation, both at the beginning and end of operating periods, and if there is an energy supply interruption. If energy supply is interrupted, carefully managed procedures are required to avoid excessive heating of product, and to manage partly-pasteurised product.

Microwaves or radio frequency energy (dielectric energy) to supply heat

Microwaves or RF energy provide a means of delivering heat almost uniformly and instantly throughout a substance in a precisely controlled manner. The advantages of dielectric heating are that it can be applied to products after they have been packaged (as long as they are not in metal containers such as cans), it is fast, heating is achieved uniformly throughout the product, the facility required is compact, and the technology is relatively well-proven. The following discussion relates to microwaves, but RF energy can be used in similar ways.

Microwaves have been used to pasteurise a variety of products. If simply heating to the desired temperature, microwave is close to 90% efficient in converting electricity to heat, and losses from the material being treated are small. However, unless the electricity is generated efficiently (eg with cogeneration) or purchased at a low price (eg off-peak), operating costs can potentially be relatively high. To raise a litre of water's temperature by 50 ^{O}C would consume around 0.07 kWh and cost about 0.42 cents at 6 cents/kWh.

Since microwaves cannot pass through metal, they would not be suitable for pasteurising drink in cans, unless this was done before filling. This approach introduces a small risk of contamination, but this risk is already dealt with where flash pasteurisation is done.

Microwaves can be used in conjunction with other forms of heating. For example, they could 'top up' the temperature beyond that achievable through heat recovery and use of waste heat, or they could be used on a variable basis to achieve a specified temperature in a context where variable heat sources were available or product flow rates vary. They could also be used to provide targeted heating, for example of the 'cool spot' that occurs in conventional tunnel pasteurisation.

If the microwaves have additional effects on the bacteria, effectiveness may be greater, or the energy requirement lower.

Microwave generation equipment is already very efficient, at close to 90% efficiency, however ongoing improvements are being achieved. Large primary energy efficiency improvements can be created by improving the efficiency with which the electricity is produced (eg cogeneration) or by using electricity from renewable energy sources. Also, the efficiency with which the microwaves are directed to the product, and the extent to which the heat added to the product is utilised either for pre-heating in the process, or for other heating activities in the plant, can be optimised.

At present, most magnetrons (which generate microwaves) are relatively small in capacity, being a few kilowatts. However, units of up to 100 kW are becoming commercially available: for example, CSIRO’s Dr Chris Strauss has been collaborating with Italian company Milestone MLS in this development. Luk Nadj, one of the specialists involved in the workshop, was also aware of other sources. In any case, a number of modular units can be used in combination. A 100 kW microwave unit could raise the temperature of 1,000 litres of liquid by around 75 ^{O}C each hour, or 3,000 litres per hour of pre-heated liquid by 25 ^{O}C. For large quantities of liquid to be pasteurised, the cost and space occupied by additional electricity supply transformers is also a factor to be considered.

A dilemma when considering use of microwaves for pasteurisation is that use of microwaves alone, while being quick and effective, leaves large quantities of residual heat that is a potentially valuable resource. So there is an argument for heat recovery and pre-heating, but this would add to the space required and the complexity of the processing equipment.

The operating costs of using microwaves are interesting. Relative to an inefficient pasteuriser (using 1 MJ/litre of liquid) with gas costing $4/GJ, microwaves using electricity at 6 c/kWh would cost around 50% more (0.6 c/L compared with 0.4 c/L). Relative to good conventional practice at 0.25 MJ/L, the cost of microwaves would be six times as high. If grid electricity were used (at around 1 kg CO_2/kWh), the greenhouse impact with microwaves would be between 50% and seven times higher than conventional gas-based systems, although the difference could be reduced if the conventional steam supply was inefficient. However, cogeneration or purchase of electricity at off-peak rates could reduce the cost of microwaves by a factor of two or three, and pre-heating with waste heat would further reduce the amount of microwave energy required and reduce operating costs. Cogeneration would reduce the effective greenhouse impact of electricity for the microwave system by up to three-quarters, and combining it with pre-heating/use of waste heat would further reduce greenhouse gas emissions.

An uncertainty with microwave heating is the extent to which there is a risk of breaking or bursting glass containers if the liquid in them is heated rapidly. It is likely that controlled rates of heating could overcome any such problems.

4 Pasteurisation using non-thermal methods

Mechanical treatment

Various forms of microfiltration have been successfully used to remove bacteria from drinks, to achieve the equivalent reduction in biological activity to pasteurisation. Filtration systems have experienced limits to capacity, and involve significant pumping energy. However, as they avoid heating, they can minimise flavour change due to heating effects, and they may also filter out haze-forming particles to make the beer more stable and visually appealing.

Three main types of filters are used:

- *Kieselguhr* filter using a very fine powder, usually followed by a final polish or membrane filter
- Sheet filters using cellulose mesh as the medium. This also includes some electrostatic effect whereby the microbes are attracted to the fibres
- Membrane filtration, using a very fine sieve to trap the microbes

Ongoing developments aimed at reducing the pressure drop across the filters will reduce pumping energy. Further, additional strategies such as centrifuges, which increase effective pressure driving product through the filters, may have application – although this may create foaming problems with aerated drinks, which could possibly be addressed by operating them in a pressurised environment. There is also scope to optimise pumping energy efficiency through selection of motors and pumps, design of pipework, etc.

Microfiltration must be carried out before packaging, so it faces similar problems to flash pasteurisation in that there is potential for contamination between the pasteurisation process and packaging.

Irradiation

Irradiation of food and beverage products with various forms of radiation has been shown to be effective at killing harmful bacteria and moulds, controlling insects and slowing or stopping chemical processes. Because it is very quick and avoids heating of the product, it offers the potential for improved product quality and reduced energy consumption.

Irradiation uses the energy of the radiation to break the DNA of the contaminating microbes, killing them or rendering them unable to replicate. Major advantages of irradiation for pasteurisation include its speed, and hence its compact size, which is an advantage in a production plant. Also, it avoids the need to heat, and therefore avoids any ‘cooking’ effects or other flavour changes. It can also be carried out after product has been packaged, so risk of further contamination is avoided. Irradiation offers the potential to save floor space, as it requires little space.

While irradiation with radiation from radioactive sources (usually Cobalt 60) has been used for some time, recent developments by companies including *Surebeam* in the USA have led to use of accelerated electrons or X-rays for irradiation. The electrons are accelerated to near the speed of light and have energies of 1-5 Million Electron Volts, sufficient to penetrate up to 300mm into food products. This is a much smaller penetration depth than for gamma rays, but is ample for use in treatment of packaged beverages. Electrons and other forms of radiation can pass through metal and other types of containers.

Because heating of the product is avoided, there are potentially large energy savings. However, the indirect energy costs of preparation and management of radioactive sources, or the energy requirements of equipment to generate high energy electrons would need to be considered. One supplier of accelerated electron beam pasteurisation equipment has indicated that equipment with capacity similar to existing tunnel pasteurisers would consume around 80-100 kW to generate an 8 kW electron beam. Since existing tunnel pasteurisers use around 75 kW of electricity just to run pumps, this would avoid all heating energy requirements while using little more electricity than existing processes. Greenhouse gas emissions would be less than half of best existing practice tunnel pasteurisation, and use of electricity from cogeneration or renewables would further reduce this.

S*urebeam* comment that products treated with accelerated electrons will probably have to meet the same labelling requirements as conventionally-irradiated products. In the United States, the process is currently approved for red meat (including ground beef), poultry, pork, almost all fruits and vegetables, wheat, spices, flour, and pet food. A petition allowing foods that fall in the category of "further processed" (hot dogs, sausage, lunch meat, RTE food, etc.) to be *SureBeam* pasteurised is currently under governmental review with approval pending (*Surebeam* website, 2001). In the USA, *Surebeam* and its partners have put substantial effort into differentiating electron beam irradiation from other irradiation processes. Concerns about food safety in the USA have possibly meant that consumers are more prepared to accept an irradiation process that offers superior food safety.

Irradiation has been linked to the debate on genetic engineering and modification of foods, because it breaks the DNA of bacteria and other contaminants. At least until 1999, there was a ban on irradiated food in Australia and New Zealand, administered by the Australia New Zealand Food Authority. This was under review as of 1999. AQIS has approved trials of food irradiation for export. It is likely that food products that have been irradiated will require labelling, although there is debate about the nature of that labelling. Trials of irradiation have been occurring in Australia recently.

The position taken by the Australian Consumers Association (ACA 1999) was:

"Fresh food is available year-round in Australia and there are other methods of keeping food safe and fresh, such as refrigeration, pasteurisation and sterile packaging. So food irradiation has limited application in Australia and is difficult to justify.

"It should never be substituted for proper handling and cooking of food. CHOICE is concerned that irradiation may be used to mask poor food safety practices. If the ban on irradiation is lifted, we'll be pushing for the strictest controls on its use."

The ACA lists the following arguments for and against irradiation:

"There are three major potential benefits of food irradiation:

- By controlling bacteria and moulds, it could make food safer, reducing the likelihood of food poisoning.
- It can keep food fresher for longer, so there's less wastage
- For some foods like herbs and spices, it could provide a better alternative to chemical fumigation to control pests.

"Arguments against are:

- Irradiation doesn't necessarily kill all the micro-organisms that can make you sick, and it can leave intact the toxins they produce.
- Vitamins C and B_1 (thiamine) are destroyed in varying amounts, depending on the dose, the nature of the food and the particular vitamin. This may only be a problem if you have a borderline intake of these nutrients.
- Of greatest concern is that irradiation could undermine efforts to improve hygiene standards by giving people a false sense of security.

It can be seen from this quote that use of irradiation for pasteurisation of drinks within a production process may not be a core concern of groups such as the ACA, as the 'arguments against' do not really apply. Nevertheless, there is a need to work through the issues in an appropriate manner, so that irradiated beer is not unfairly treated in the marketplace. Of further concern is the potential for competitors to undermine public acceptance of irradiated beer by linking it to public concerns about genetic engineering and radiation. The growth of 'boutique' beers with a 'natural' image makes such marketing tactics more likely.

Ultrasonics

Ultrasonic waves are very high frequency sound waves. Recent research has shown that they can have a similar effect to irradiation, in that they can disrupt the DNA chains of bacteria. At present, research is being carried out at Food Science Australia's Werribee laboratories on treatment of food. It may be possible to apply this process to beverages, although the possibility of driving the CO_2 out of solution and causing container failure due to the high pressure is an issue that would have to be evaluated.

Other options

Ultraviolet radiation is used for sterilisation, and may have application in this situation. Also, work is being done on use of pressure to kill contaminating bacteria, and this may also have potential.

5 Opportunities for Innovation

Flash pasteurisation seems fairly close to optimum performance. Further refining of heat exchanger efficiency, and ensuring that heat loss from the holding section is minimised, while maximising the efficiency with which heat is generated and supplied (or use of waste heat from other sources) and minimising pumping energy offer potential, as would use of renewable energy to provide the required heat. Sterilisation of containers may be a potential energy waster, and cooling of the beer to a temperature sufficiently low for filling containers is another energy consuming issue of significance. Ambient temperature filling is being applied to soft drinks, and this may have application here.

Tunnel pasteurisers seem to offer substantial scope for efficiency improvement. A number of possibilities for improvement were noted in the earlier part of this paper, and there is scope for a thorough analysis of opportunities at every stage in this process. A key issue is to clarify why the process is designed to take so long to heat up product, and why lower temperatures are used than in flash pasteurisation. If this is because of localised cooking effects or other issues, it will be necessary to understand these before improvements can be made. One concept for an improved and more efficient heat pasteuriser is outlined in Appendix 1.

Microwave heating seems to offer significant potential for pasteurising packaged product (except that in cans), but seems unlikely to be able to compete with existing flash pasteurisers for bulk product, especially if they are further optimised. Combinations of microwave and pre-heating/heat recovery seem to have strong potential to increase process speed and energy efficiency.

Microfiltration has increasing potential for treatment of bulk product, and for product that is sensitive to flavour changes if heated. However, it is not suited to treatment of product after it has been packaged.

Irradiation of various kinds has potential as an alternative treatment for both packaged and bulk product. It avoids heating and is rapid, and it penetrates product rapidly so uniformity is ensured. Electron beam irradiation seems likely to offer significant energy savings and reductions in greenhouse gas emissions. There may also be some public acceptance and regulatory issues to be dealt with, and impact on flavour needs to be assessed.

In a number of cases, there is potential for pasteurisation processes to either supply or receive heat or ‘coolth’ from other sources within the plant, and from cogeneration or gas engine driven equipment. Such strategies also have potential to assist with management of peak electricity loads and maintenance of system reliability.

6 Conclusion

A number of opportunities exist for application of innovative approaches to pasteurisation to achieve energy efficiency improvements and reductions in greenhouse gas emissions. Some options could be retrofitted to existing facilities, while others involve new equipment.

7 References

ASHRAE (1989) *Fundamentals* USA

Australian Consumers Association (1999) *Future Food: at a supermarket near you?* **CHOICE** May 1999

Sander Hansen website

Surebeam website and advertising brochures

URS (2000) Unpublished background paper prepared for Department of Industry Science and Resources, Canberra

West, George (1998) *Food Irradiation – its benefits and limitations* from Steritech website.

Section 2:

Big Energy Project - Pasteurisation innovation workshop proceedings and outputs report

First day report

1 Workshop introduction

The facilitator opened the workshop sessions and introduced the rest of the day. A summary of the expectations of the group was generated to ensure common purpose:

- Explore alternatives to current practice
- Reach conclusions on potential of options
- Explore outside current practice (especially regarding space savings)
- Generate a shortlist of possibilities with metrics
- Seeking significant step change (eg greater than 20% saving in real estate)
- Develop network links especially around allied areas not the focus of the workshops
- Other means of achieving marketable product from a ‘microbial’ point of view
- Outcomes such as action plans and implementation options
- Energy and greenhouse (CO_2) savings

2 Experts report on site visit

The invited experts response to the site visit earlier in the morning generated the following:

Luke Nadj Microwave heating could achieve space and energy savings. Microwave technology offers ‘instant’ energy that can be a higher power application if the package can cope. There is generally a space saving with microwave applications and there need not be any water involved. The initial capital costs may be higher and fine tuning and commissioning may take longer. A hybrid thermal pasteurisation process would help with heat recovery. The question was raised, ‘Why use water as a heat transfer medium, what about air?’ Microwave pasteurisation lines would be in parallel making the production system more resilient. The problem of heat distribution in package would at least be partly overcome with microwave technology. Microwave cannot effectively pass through cans so would only be applicable to glass and PET packages. A pilot scale plant, say 1% of production, could be established within months.

In response, there was some discussion of past experience with microwaves that endorsed the ‘scale-ability’ of microwave technology. One solution might involve multiple domestic scale magnetrons to provide a production line. Water usage costs and associated hygiene management with water as a heat transfer medium would be worthwhile avoiding if possible. With microfiltration, some adjustment may be able to be made to the number of pasteurising units (PUs) required by the beer.

Randall Pearce All options should be reviewed in light of whole-of-site energy needs to realise opportunities for integration of thermal systems. In the food industry, the usual driving forces for process improvement are quality and food safety. New processes or technologies are usually implemented under the guidance of someone who pushes the improvement. It is likely that most companies will also require personal commitment to move innovation forward.

Non-thermal options for pasteurisation of beer could potentially include:

- Pulsed electric field
- High pressure
- Ultrasonic
- Ultraviolet
- Electron beam
- X ray
- High pressure (CO_2)

Some of these are applicable to in-package pasteurisation and others to in-line pasteurisation. (The list is reviewed and culled later in the workshop.) Randall noted that the packaging hall is extensive rather intensive and thus site services generation and distribution should be reviewed for integration and improvement options to provide context for pasteurisation improvements. There are probably limited options for making improvements to keg sterilisation. On a more general note, Randall asked ‘Why pasteurise at all?’ (This was discussed at several points during the middle of the day and resolved by the end of the day.) Short and longer term pasteurisation options need a strategic context in which to be framed.

Len Taylor There may be several significant opportunities for heat recovery around the plant, but the site tour did not look at either the refrigeration or boiler plant so it is difficult to assess. The temperature required for pasteurising is up to 63^{O}C process temperature. Cooling towers on the refrigeration systems, and heat recovery from the warm bottles exiting the tunnel pasteuriser are two immediately obvious sources of ‘waste’ heat. This heat could be upgraded with a heat pump to provide useful pasteurising heat or used at an intermediate temperature within the existing tunnel pasteurising equipment. Application of heat pumps in this way would improve the thermodynamic performance of the existing tunnel pasteurisers.

A whole-of-site energy balance and a working fluids temperature definition map are standard information required to identify suitable waste heat sources and would also help integrate all other plant thermal services. Refrigeration condenser cooling water is likely to be an easily utilised heat source.

Temperature differences used to ‘drive’ the pasteurisers should be kept to a minimum to reduce ‘irreversibility’ losses. Boiler efficiency, and high efficiency pumps and motors are other possibilities.

Currently two thermal pasteurising options are used, packaging before pasteurising (tunnel pasteurising) and pre packaging pasteurising (flash pasteurising).

3 Report on CFD modelling of beer can

Dr Amir Eghlimi and Joseph Aboutanios of CfD RES presented the finding of a small modelling consultancy they completed looking at beer cans. The key outcomes were that immersion modelling indicated that a significant reduction in the required heat transfer time might be achievable. Immersion models indicate seven seconds for ten degrees temperature rise, whereas spray models indicate around 2 minutes for the same temperature rise. Current tunnel pasteurisers that heat by water spray from above cause a ‘cold spot’ at the base of the can which extends about a third of the way up the package. A group participant recalled immersion pasteurisers from his early days in breweries and that they were considerably smaller than current tunnel pasteurisers. The stated reason for moving away from immersion pasteurisers was the possibility of contamination/infiltration of water under the crown seal.

It was clear from the presentation and subsequent questions and discussion that computational fluid dynamics could be useful in understanding what is happening in thermal pasteurising processes, and assist in expediting the development of new thermal pasteurising processes.

4 Defining solution pathways

An extensive discussion around the need for pasteurisation was started by asking the need for pasteurisation and the means of determining marketable product as far as ‘bug load’ is concerned. The outcomes were that in the Australian climate, with the transport distances and expected shelf life, pasteurisation of beer is essential to manage the risk of product not meeting customer expectation. Pasteurisation is necessary to mitigate against a risk to brand position and value. In the light of this outcome of the need for pasteurisation, the following table of options was generated:

	Pre-package application	In-package application
Thermal pasteurising	Microwave Flash pasteurisation Ohmic heating Heat recovery optimisation Heat source optimisation	Microwave Tunnel pasteurisation -flooded -spray -air
Non-thermal pasteurising	High pressure Ultrasonic Radiation -gamma -electron beam -X-ray Filtration Pulsed electric field Pressurised CO_2 (Prax-air)	Ultrasonic Radiation -gamma -electron beam -X-ray

Table 1. Pasteurisation technology options

Two other issues raised during the generation of the above table were methods for sterilisation of packaging, and the possibility of hybrid solutions.

An attempt to prioritise the options above so that four of them could be reviewed in more detail on day 2 yielded the following:

Option 1 would be to look at microwave technology for in-package pasteurising.

Option 2 would be to look at improving the current tunnel pasteurising system.

Option 3 would be to look at ultrasonic pasteurising for both in-package and in-line application.

Option 4 would be to look at electron beam technology and/or pressure and filtration systems.

Second day report

5 Review of Day 1.

Alan Pears – If thermal pasteurising is to be used then there are several important parameters that need clarification in order to optimise new or improved pasteurisation systems. Improvement opportunities are to control exit temperature closer to the wet bulb temperature, to heat and cool as quickly as possible, use a different heat source or raise the temperature difference between the heating medium and the product. In order to do these things, the rate limit for heating the glass packaging is required. ACI suggest this is 42^{O}C for both heating and cooling. The breakage mode for the bottles is essential to understanding the rate limit of heating and cooling. Company staff responded that CO_2 level and fill height are important factors in bottle breakage and that the base and to a lesser extent, the neck are the breakage points. Glass thickness, distribution and shape are key parameters, but up to 35^{O}C is possible, limited by the exiting of the hottest part of the tunnel pasteuriser.

As temperature difference increases to speed heating and cooling, so heat optimisation becomes more important from an efficiency point of view.

Finally, why use steam (from a large central boiler) to provide 65^{O}C water to pasteurise? Compare the thermal efficiency of steam generation and distribution to current best domestic hot water services of around 90% conversion from gas to hot water.

Luke Nadj – Cost of power and sourcing the electrical capacity (transformers, switchboards and cabling) will be issues requiring careful consideration. Energy recovery needs some attention but with microwave heat source, there will be less to capture. The non-energy benefits such as predicted space savings need to be properly accounted for. Microwave is a known and established technology and the next steps of application development are clear.

Randall Pearce – High pressure treatment may have problems with carbonated beverages due to the volume of the 'bubbles'. The Prax-Air (proprietary) process of high pressure treatment under CO_2 has been used in orange juice pasteurisation. The process involves adding CO_2 to OJ at 80MPa then raising the pressure to 400MPa for 2-5 minutes. Application of vacuum to reduce CO_2 to 100ppm completes the process. This extends shelf life from 14 to 30 days. Beer is the next product that Prax-Air are targeting. Non thermal processes don't impact on spores. It was noted that CO_2 injection for stripping volatiles is being phased out in the brewing industry so may mitigate against the use of this technology.

Ultrasonic pasteurisation may be possible for both in-line and in package applications. Requires testing and application development. The issue was raised of possible problems with cavitation/outgassing. Reduction of frequency helps reduce the amount of de-gassing experienced.

Len Taylor – The use of heat pumps for heat recovery could be reviewed again at the site. Note that current method of providing heat probably requires about 1.45 times the energy delivered into the pasteuriser to be provided to the boiler primary fuel (natural gas). The use of an electric heat pump with suitable heat source would reduce this primary energy requirement to about 0.6 times the heat required by the pasteuriser. About the same reduction in energy use can be realised by the use of gas engine driven heat pump with engine waste heat recovery system, but with the benefit of different (cheaper) primary energy sources.

Cogeneration might also be used in association with heat pumping. Best practice hardware and professional component matching would reduce primary fuel consumption in all of these pasteuriser heat supply systems.

The use of heat pumps or any other source of heat energy to achieve thermal pasteurisation must be preceded by careful optimisation of the thermal pasteurising equipment. Attention to insulation, heat regeneration within the pasteuriser, temperature matching etc clearly should be assumed to precede any action to optimise the primary fuel use by the pasteuriser heat supply system.

Other contributions:

– High pressure pasteurisation was used at UniLever for ice cream. The process used two streams of product fired at each other to cause cavitation which has an inactivation outcome.

– The modelling outcomes showing stabilisation to temperature is impressive and needs to be empirically checked. It was indicated this should be relatively easy to verify by immersing a bottle in a controlled temperature bath.

6 *Break-out group discussion topics*

The end of the feedback session gathered together the options for discussion for the rest of the day. Building on the previous day's tabulation of options for discussion shown in table 1, the group moved into an evaluation exercise. The scoring was based on six point for high, two points for medium and one point for low. The results are shown below in table 2.

	CO_2 impact	Technology reach	Manufacturing process impact (complexity)	Product impact	Can do in-package	Capital cost	Process energy (cost/litre)	Space saving	Total score
Microwave	H	H	H	H	H	M	M?	M	36
Ultrasonic	H	M	H	M	H	H	H	M	36
High pressure	H	L	M	M	L	M	M	L	17
Electron beam	H	M	H	M-L	H	L	M	H	30
Improve tunnel pasteurising	H	H	M	H	H	M	H-M	M	34
External heat sources	H	H	M	H	H	M	H	L	35
Filtration	H	H	L	H	L	L	M	L	24

Table 2. Evaluation of options for discussion in break out groups

The first evaluation of this table suggested microwave technology and the methods of improving current tunnel pasteurisers.

7 Morning break-out session on solutions

Microwave heating - The group looking at microwaves started with how microwave technology could be used to provide all the heating energy to pasteurise the product. Benefits would be to have a consistent temperature through the product which would allow smaller zone for ‘hold’ and a lower target PU for same contamination risk. The proposition that there would be space saving (real estate saving) looks unlikely in practice as there is a lot of space required for access and for the materials handling equipment (conveyors etc). The length of the line also appeared to be a problem. The bottles have to pass through the microwave field in single file as there is around 15mm penetration. There are practical problems with arranging multiple (parallel) paths for the bottles and so to have the production speed required would require about 180 metres of conveyor. Apart from taking up considerable space, this may be unacceptable from a reliability and bottle breakage point of view.

To heat the product at a flow rate of 20000litres/hour production would need an electrical supply capable of 1.5MW. This would present considerable difficulties and cost, as new transformers/substations etc would be required.

The possibility of using microwaves in a hybrid arrangement, by providing a dry section of tunnel pasteuriser to heat from below and avoid the ‘cold spot’ was canvassed. It may be possible and removes some of the space problems with microwave only heating. The use of a hybrid system also means heat recovery is possible. With microwave only heating, the requirement for cooling is still there, and the heat would have to be removed and rejected by conventional means. A hybrid may use a flooded cooling arrangement or combination flood/spray, depending on thermal gradients and materials limits of the glass.

The key problem with microwaves is the large amount of space required in this application.

Improved tunnel pasteuriser – Several options to improve the current tunnel pasteuriser were reviewed.

The simplest is to use hot water heated locally rather than using reticulated steam. Given a boiler efficiency of 75% and distribution losses, we might expect a conversion efficiency of around 50% from gas to heat into the pasteuriser. Current best efficiency hot water heaters operate around 90% conversion efficiency and if sited locally, would have very low distribution losses. This suggests a 5/9 gas requirement or a saving of around 45%. In practice, savings may be smaller, but still seem potentially substantial. Issues are condensate acidity, flue discharge, gas supply requirements and safety. This option should be reviewed further, particularly if installing a new pasteuriser. It also offers an upgrade option for existing tunnel pasteurisers. After the workshop, a further issue was raised regarding the importance of having sufficient peak heating capacity to cope at start-up or after a stoppage. Possibly an insulated storage tank or high capacity gas burner could deal with this situation.

The second option to improve current tunnel pasteurisers is to capture more of the heat leaving the system in the product. A very smart control system would be required to keep the heat flows in balance. An add-on pre-heat and/or post-heat would be required which would take up space in addition to that currently required. In principle, the objective would be that outlet container temperature should be as low as possible to minimise the amount of energy lost, but should not fall below the dew point, as condensation would then affect labelling and packaging. [It was also noted subsequent to the workshop that the incoming containers are very cold. Use of ambient heat, waste heat from elsewhere in the plant, or solar energy]

The third option for improving the current tunnel pasteuriser is to change from a spray to flooded arrangement of heat transfer. This could be achieved by having a slight rise on the conveyor with a hold section in the middle and then a heat reclaim on the second half of the tunnel pasteuriser by a slight rise on the second half of the conveyor. The water would then flow from the hold zone down to the entry where the (cold) bottles come in. The water would then be pumped to the outlet end and flow back towards the hot zone cooling the bottles as it goes. The heat loss would be made up before the water goes back into the 'hold' zone reservoir. This would require complete redesign of the pasteuriser.

The fourth option was incremental tweaks such as VSDs, efficient motors, insulation on the hottest sections of the pasteuriser, improved pumping efficiency, steam system optimisations such as heat exchanger improvement.

An area which is worth review is the droplet size in the spray sections to assess the evaporative heat loss in these sections.

Break-out session one review - After the two groups reported back to the workshop, a review of prioritisation table (Table 2.) was undertaken. This revealed that microwave technology had reduced CO_2 reduction potential, would add some complexity in conveyors, would probably have lower cost than initially thought for the magnetrons but higher overall cost due to extra electrical infrastructure, and would not save space. The prioritisation score for microwave heating technology was revised down to 25 in view of the above.

Improving the existing pasteuriser showed that initial assessment was about right, although there may be a small space penalty for some of the options. If immersion heat transfer is as good as the CFD model's prediction, then there may be a space saving for the sloped flooded tunnel pasteuriser. The prioritisation score for improving current tunnel pasteurisers was reviewed and moved from 34 to 33.

8 Phone conference with Surebeam

A phone link was established with Michael Daysh of Surebeam. Surebeam is an electron beam treatment process that has been used in the US on meat products and to remove insect infestations in fruits. Michael is Surebeam's Australian representative. Michael went through a list of questions faxed through earlier. Below is an outline of his responses.

Surebeam technology is an electronic pasteurisation technique using linear accelerators to accelerate electrons to treat meat (ground beef) for food safety. It has also been used to treat tropical fruit in Hawaii and is being installed in Australia for disinfestation of insects. There appears to be a significant energy saving for the pasteurising of beer.

As far as impact on flavour goes, there has not been much work to date. Gamma radiation has been shown in one study to affect beer flavour. Gamma radiation is different to X-radiation and electron beam radiation. The public perception in the US is the Surebeam process is ok for red meats and fruits where there is no alternative technology.

There is some heat and ozone emission when the accelerator is operating but none when the machine is turned off. Labelling requirements by the USFDA include words to the effect that the product "is treated by radiation using Surebeam process…". In Australia and New Zealand there are no approval pathways available at present. ANZFA standard 817 uses four phrases including, "treated with ionising electrons/radiation" possibly on the carton, but certainly on the cans/bottles. Requires food approval in Australia.

Safety in plant is readily dealt with by existing labour and industry laws. For example, the Queensland Department of Health is knowledgable about the technology via medical uses. There is a clearly defined process for licensing. Staff are required to wear dosimeters for X-rays. The electrons are a 5MeV beam and there is no residual radiation when the accelerator is turned off.

The maintenance requirements for the linear accelerator are minimal as there are no moving parts to wear out. The transport equipment for the product is conventional technology and has the normal wear and tear problems and solutions. Conveyor speed is the means of controlling the dose to the product so speed has to be variable. Surebeam does not sell the equipment so technology support would flow through a partner agreement. (Surebeam sells the pasteurising service.)

Quality control and monitoring is achieved through providing a uniform dose to the passing product. This requires consistent product quality input.

The penetration depth of the electron beam is around 80mm so there is the possibility of treating whole cases by having a beam from above and below. Power demand is able to be delivered at the production rates expected. An 8kW beam is required which would have an electrical draw of around 80-100kWe for 20,000litres/hr. Michael claims peak power input equals run power. Inrush current at switch-on is unknown.

In closing Michael indicated there are several issues to resolve. The initial taste test for beer treatment failed because of the large dose. This may be refined. Michael claimed there appears to be a clear energy saving benefit. (Subsequent calculations by Len Taylor suggest there may not be a saving in primary energy and hence no saving in greenhouse gases with conventional energy sources. See Appendix 2 for calculation.)

Surebeam expect at least a two year approval process due to data requirement after testing. The capital cost would be in the context of a joint venture arrangement but would typically start at around $10M. The alternative is to ‘buy’ pasteurisation on a cents/volume treated basis. Surebeam expects the initial product testing results over the next few weeks. The space requirement would be on the order of 800 square feet (ie 20 foot by 40 foot) plus the conveyors and materials handling gear.

After the telephone conference concluded it was clear that the Surebeam technology is not a ‘near-term’ or ‘off-the-shelf’ option for pasteurising beer. The technology may be useful in the longer term so a watching brief is required to identify when developments yield a more favourable solution path.

9 Afternoon break-out session on solutions

Ultrasonic pasteurisation - The group looking at ultrasonic pasteurisation considered in-package methods of applying the ultrasonic energy. Anticipated capital cost for the ultrasonic generator would be in the range of $1-2M. Expect the necessary kill to be achieved in around three minutes. No reasons are apparent for any impact on the taste, although this would need to be confirmed by tests. Clarity would also be subject to application testing. A major issue is the degree to which ultrasonic energy might cause degassing and pressure increase, with an impact on the level of CO_2 in the beer.

Initial rough estimates were made of power requirements, based on those expected for a pilot scale system for the treatment of carbonated drinks. The estimated energy requirement is around 600-800kW electrical input for 1,000 bottles per minute (60,000 per hour, or 22,500 litre/hour)This would correspond to heating of around 24^{O}C due to the ultrasonic energy input. This temperature rise would be of assistance in avoiding condensation on the packages after they leave the pasteuriser. There may be a need to treat at temperatures above ambient to maximise the cavitation effect, which is the main mechanism of ‘bug destruction’. If this were necessary, heat exchange between the warm outgoing and cold ingoing bottles could be used to achieve this.

There could be a considerable real estate saving with a bath based ultrasonic pasteuriser. Estimate around one quarter the space of current tunnel pasteuriser, if there is no need to preheat the incoming bottles. Glass packages would lend themselves to ultrasonic treatment. Cans are likely to be ok, but PET would require testing for transmission of ultrasonic energy. It may not be suitable.

The operability of ultrasonic transducers is good, with low maintenance as they are self cleaning. Immersion of the whole bottle, at least up to the fill level would be required. This may cause some materials handling issues and might lend itself to a batch process approach. A typical bath might be 24 metres long by 500mm wide. Alternately, a flow through arrangement may be possible, particularly if there is a flash (partial) pasteurisation in line before the ultrasonic transducers. The ultrasonic devices would be arranged around a 150mm diameter cavity, through which the liquid would flow in a tube. The bottles have to be in a liquid for transmission of the ultrasonic energy.

Actions required are to find out:

- Transmission effectiveness through glass bottles, aluminium cans and PET bottles.
- Effects on the CO_2 level in the beer and pressure in the packages.
- Capabilities of ultrasonic energy in pasteurising beer (ie rate of kill).
- Relate optimum bath/beer temperature to required ultrasonic power delivery.

External heat sources – The group looking at external heat sources considered waste heat recovery options at the site. Several had already been covered in earlier sessions, particularly the remainder of the heat in the product leaving the tunnel pasteuriser. The main outcome of this group was to endorse and expand on the idea of capturing the heat rejected by the refrigeration system. It was explained that many brewery refrigeration systems operate all the compressors in parallel with hot gas lines feeding to evaporatively cooled condensers that are also in parallel. Peak refrigeration load for a large brewery is about 11MWth but is 6 – 8 MW on average. Refrigeration systems, which typically have some direct expansion application, as well as supplying chilled water and glycol as a secondary coolant, have a total refrigeration charge of around 15,000kg of ammonia. In a common refrigerant pipe work arrangement as now used, this size of charge is considered a significant safety risk in the long term.

The ideal solution might look like a collection of packaged, skid-mounted units having the same cooling capacity but with only 120kg charge of ammonia for each unit. Several such units would be required. The secondary refrigerant would pass out of the packaged refrigeration unit to provide cooling services elsewhere in the brewery as required. The heat rejected from the close-coupled condenser/evaporator sets to the cooling towers could be captured and stored as hot water for use in the plant where required, in particular for thermal pasteurisation. Rather than use a separate heat pump to upgrade the heat from the refrigeration plant, one option would be to control the refrigeration plant to have the hot side at the temperature required for the ‘waste’ heat use (ie pasteurising). This would probably mean some reduction in COP for the refrigeration plant since the compressors would have to work harder against higher discharge pressures. (Although with fixed volume ratio screw compressors this effect would probably be small.) The loss of COP would incur an increase in electricity use. The benefit of this heat recovery will be viable if the marginal increase in electricity use/cost is less than the cost of gas generated heat which has been displaced.

Refrigeration units would have to be selected and specified to perform this function right from the initial purchase. The hot water so generated would be stored in a large buffer tank which would be allowed to stratify so that the refrigeration plant would be operating against the lowest possible discharge pressure. The draw off would be from the top and could be used for pasteurising, or as pre-heated boiler feed water make-up.

Auxiliary heating for the buffer tank, either by direct gas firing or by heat exchange from the steam system, could be provided to ensure correct temperature water is always on hand if the refrigeration system is not providing adequate heat due to reduced refrigeration load at the time. Discussion of whether this could be provided in-line after the buffer tank suggested this would require a large capacity heat exchanger, and careful control systems. The optimum would be to have a smaller heat exchanger in the large buffer tank around half way up the tank. This will retain the stratification and allow heat to continue to be dumped into the buffer tank by the refrigeration system.

The refrigeration system would still require some capacity to dump heat to atmosphere if the buffer tank was up to temperature and the refrigeration system was still required to operate and thus dump more heat.

A further benefit of this arrangement of dumping heat from the refrigeration system into a tank of water is that there are less likely to be large ambient temperature-related changes in electrical demand. This may have a positive impact on peak demand charges.

The key next steps for this are to do some indicative calculations on practicality and viability. In particular, the capability of compressors and the impact on longevity and maintenance from the higher pressures. Also the capacity of the heat exchangers (condensers) to cope with higher pressures requires investigation. Part of the cost of this approach may be justified on the grounds of safety improvement, potentially enhancing its financial viability.

10 Next steps

The final plenary session of the workshop looked at where the various technology paths can be taken and the next steps involved.

Microwave technology requires a watching brief. Evaluation of rate at which glass containers can be heated may yield improvements in the options for microwave heating. The main problem was space consideration based on the rate at which bottles can be heated.

Tunnel pasteuriser improvement requires investigation of local hot water generators. Flooded channel or upward spray design requires follow-up. If the evaluation of material constraints on glass packaging yields option of faster heating with immersion or rearranged sprays, then next step is to approach manufacturers. Either the Food Industry Machine Manufacturers Association (FIMMA) or a current tunnel pasteuriser supplier, such as Sander Hansen, should be approached. The preferred option is to keep the idea in Australia if possible.

Ultrasonic pasteurisation requires the following to be resolved:

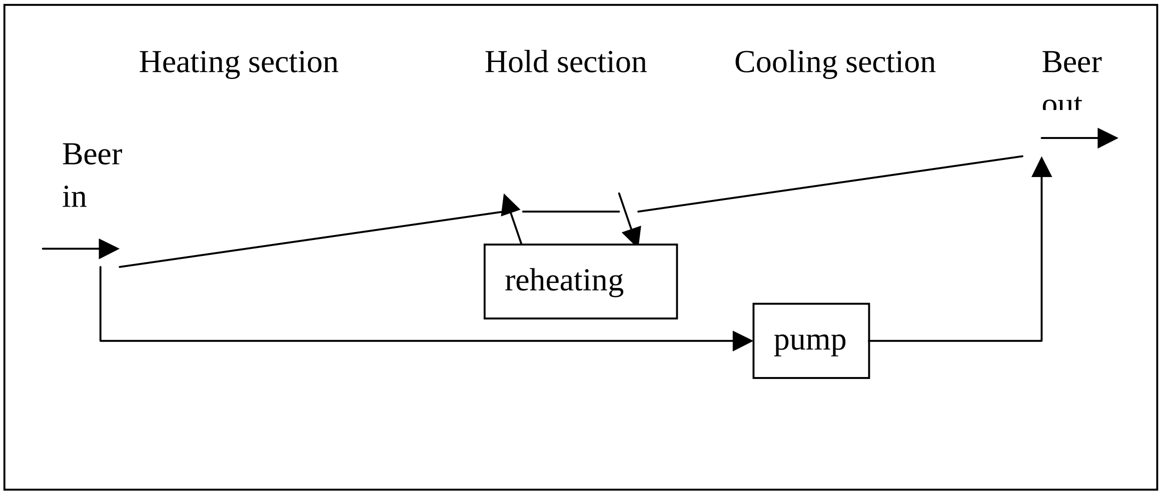
- Transmission effectiveness through glass bottles, aluminium cans and PET bottles.
- Effects on the CO_2 level in the beer and pressure in the packages.
- Capabilities of ultrasonic energy in pasteurising beer (ie rate of kill).
- Relate optimum bath/beer temperature to required ultrasonic power delivery.

Randall Pearce indicated that it might be possible to include beer on the list of product types to be tested in an upcoming round of trials at FSA laboratories. If not, the necessary research trials could be performed on a normal commercial basis.

Appendix 1. Flooded channel tunnel pasteuriser – development proposal.

During the recent ISR funded Big Energy Project based around pasteurisation an exciting concept evolved. Current tunnel pasteurisers suffer from slow heat transfer to bottles, excessively large footprint and undesirable breakage levels; there is room for improvement.

The concept for improvement in tunnel pasteurisers was loosely called ‘Flooded channel tunnel pasteurising’. The means of improving heat transfer rates by having a bath of water for the bottles is achieved by having a slight slope on the conveyor mechanism and letting water flow slowly back against the bottles. Thus the hot water will cool as it passes down the heating section and will warm again in the cooling section. Make-up heat is provided to the circulating water in the hold section to maintain the desired temperature in the hold section and to accommodate heat losses in the system. This concept is introduced in the diagram below:



There are a number of actions required to assess the viability of the concept and then to progress the idea to pilot trial and eventual production and use. The first stages are outlined below:

1. An evaluation of material constraints on glass packaging. Options of faster heating with immersion will only be available subject to material constraints imposed by packaging.
2. An approach to manufacturers with the concept . This summary or a development of it should be presented to either the Food Industry Machine Manufacturers Association (FIMMA) or the current tunnel pasteuriser supplier, Sander Hansen. The preferred option is to keep the idea in Australia if possible.
3. Meet with manufacturers interested in the concept to progress the next stages of testing the idea (proof of principle), building a laboratory or pilot scale version for testing, and then building prototypes.

Appendix 2. Surebeam pasteurising energy use.

Michael Daysh's comments that there are clear energy saving benefits to their technology are not supported by subsequent calculations completed by Len Taylor as below:

Improved tunnel pasteuriser energy use.

The present two tunnel pasteurisers have maximum capacities of 45,000 bottles per hour each or a total of 33,750 litres per hour. Using specific gravity of beer = 1.027 and specific heat of 3.98kJ/kgK and glass specific heat of 0.84kJ/kgK and mass per bottle of 0.018g gives theoretical minimum pasteurising energy of:

$(90*10^3*0.375*1.027*3.98)/3600 +(90*10^3*0.18*0.84)/3600$ kW/K

=38.3 (beer) + 3.78 (glass) = 42.1kW/K (total)

In a typical tunnel pasteuriser, total temperature rise is about 61^{O}C but with regeneration about 15% of this heating load is required to be added from an external source:

0.15*42.1*61 = 385 kW for heating in a conventional tunnel pasteuriser

If this heating input was to be supplied from an improved local hot water heater (as suggested on page 14 of this report) having an assumed 85% conversion efficiency, then the primary fuel use rate for the simple improvement in heat source would be:

385/0.85 = 453kW of primary energy for an improved tunnel pasteuriser.

If the improved tunnel pasteuriser was to be supplied by more sophisticated thermodynamic system as suggested in section 9 of this report, the primary fuel energy use rate to run the tunnel pasteuriser at 33,750 litres per hour would be expected to be only about:

0.6*385 = **231kW of primary energy for an improved tunnel pasteuriser.**

Surebeam energy use.

The Sure beam suggestion is that 8kW beam energy is required for a throughput of 20,000 litres per hour. Surebeam claim there is an electrical draw of 80-100kWe to supply this (assume 90kWe). Using an thermal electric generation efficiency of 33% and scaling to 33,750 litres per hour, the primary energy use for Surebeam pasteurising is:

90/0.33 * 33,750/20,000 = **460kW of primary energy for Surebeam pasteurisation.**

It is not clear that Surebeam technology will save (primary) energy.

[Note that this analysis ignores existing tunnel pasteurisers use 75 kW or more of electricity to run pumps, conveyors, etc. If radiation avoids this it makes the primary energy savings look much better.]