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Solar Power for Dairy Farms.

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Introduction

Context and Aims

This report offers an overview of the potential for the use of solar water heating in dairy units.

It is intended both for dairy farmers interested in using solar water heating to cut their energy costs and reduce their environmental impacts, and for consultants and other interested parties evaluating the benefits of solar water heating to farmers, or the possibility of reducing agricultural carbon emissions.

The report documents the concepts users need to know before choosing or designing a solar water heating system.

We welcome comments, questions and feedback from readers.

It must be kept in mind, that hot water is only one aspect of dairy energy use, and attention should also be paid energy used in vacuum and cooling systems. It is suggested that water heating typically accounts for 40% of electricity used in the milking parlour[9].

Although it is possible to achieve refrigeration from solar heat using adsorption chillers, this is outside the scope of this paper, and this document will focus on solar energy for hot water production.

We would like to thank the dairy farmers inside and outside the GNP area who have helped our research, along with the Dairy Hygiene Inspectorate who have kindly clarified the statutory and ‘best practice’ requirements for us.

Left (centre), a contraflow heat exchanger for cooling milk prior to storage in refrigerated tanks.

Although this research has focused on the applications of solar water heating, measurements on one farm indicated that increasing the water flow could provide significant further cooling for the milk.

It is likely that the cost of the additional water would be significantly less than the provision of additional refrigeration, and much of the water might be fed to cattle or otherwise reused.

Types of Dairy and Scope of Report

Traditional dairies have carried out milking as a twice-daily batch process and the bulk of milking is still carried out in this way. In the course of milking, each milking station is used by a number of cows, then hot washed at the end. Recent trends however, have seen some farms move to continuous fully automated robotic milking, see pictures below.

While automated milking has a number of benefits in terms of reduced labour intensity and improved utilisation of buildings, it may use more hot water by performing a hot wash after milking each cow. This report will concentrate on traditional milking parlour based systems as these are still much more common, but energy use in automated plant will no doubt become a significant issue in the years to come.

Top left, Fullwood Merlin automated milking system on the Nottingham University farm. Bottom left, the automatic milking station is cleaned after each cow uses it. Right, the internal hot water cylinder and level control equipment.

Statutory Provision and Good Practice

The Food Standards Agency publish good practice guidance and the full text of the regulations to the farming community in the booklet,

"Milk Hygiene on the Dairy Farm. The Dairy Products (Hygiene) Regulations 1995 (as amended). A Practical Guide for Farmers".

Farmers are obliged to follow the requirements of the Dairy Products (Hygiene) Regulations 1995 SI No.1086, as amended, under Council directive 92/46/EEC which identify the required levels of hygiene that must be achieved. These are interpreted and enforced (schedules 1, 3 and 7) by the Dairy Hygiene Inspectorate on behalf of the Food Standards Agency.

The Practical Guide for Farmers identifies ways in which the required levels of hygiene can be achieved.

From the Practical Guide for Farmers and conversations with the staff of the Dairy Hygiene Inspectorate, it is clear that the largest enforced use of hot water in the dairy is the twice-daily hot washing of the internal surfaces of equipment after each milking. This requires a minimum of 10 litres of water at 85°C, and possibly as much as 18 litres at 96°C per milking unit depending on the cleaning method employed.

Other uses for hot water in the dairy are relatively infrequent, and alternative processes using cold water may be available to farmers. The best return on investment will be obtained by addressing the most frequent daily needs of the dairy, so it is on the provision of water for these twice daily 'hot recirculation washes' that this study will focus.

Some farmers have commented that dairies could carry out one hot wash per day if the bacteria counts from their milk stay in the top band. The Dairy Hygiene Inspectorate deprecate this approach, and firmly recommend the use of two hot washes per day. This study will base its assumptions about minimum hot water consumption on two hot washes per day.

UK Solar Energy Availability

In Britain each square metre of a south-facing roof receives up to 1000 kWh of solar radiation in the course of a year[12]. With appropriate equipment in the UK, it is possible to use the sun to provide most of the water requiremed from about April to September, and to obtain some useful pre-heating of water during the other months. About 70% of UK annual radiation is received over the period April to September, with a mean daily summer insolation of around 5kWh per square meter per day. Over the other six months, solar radiation can only deliver 30% of the year's total energy, with a mean daily winter insolation of around 1kWh per square meter per day[13].

If this energy can be harvested, the displacement of fossil fuels has a cash value which is increasing all the time as the cost of primary energy sources increases.

Types of Solar Thermal Equipment

Solar energy can either be exploited passively by using the design of buildings to trap energy, or actively by using various kinds of solar collector.

Active solar energy use depends on various kinds of 'collectors' to capture energy from the sun.

Two main 'active' solar technologies are in use at the moment, solar *water heating* and *electricity production* by photovoltaic cells.

Photovoltaic cells may be very important in the future, but the present generation of equipment is relatively expensive and inefficient so they are not an economically competitive way to provide significant amounts of energy, except in off-grid locations. While this might be of use in isolated farm buildings where there is a modest demand for high grade electrical energy, photovoltaics are not a useful technology for water heating, and are therefore outside the scope of this report.

By contrast, in the right circumstances, collectors for solar water heating can convert much of the energy that falls on them into heat, and the more hot water is used from the system, the shorter the time taken to recover the capital cost.

Solar water heating systems comprise a solar collector and a means of transferring heat to a heat store. These must be controlled to ensure efficient operation, and the system as a whole must operate safely and not be damaged or pose any threat, even at extremes of temperature or in the event of power failure or failure of the control system.

Solar Water Heating Collectors

Solar water heating collectors use a dark surface, generally of sheet metal, to absorb radiant heat from the sky and conduct it away to be used. To attain high temperatures, these collector assemblies must have a very transparent front aperture and a well insulated enclosure.

The 'glazing' of the aperture must absorb as little energy as possible, especially infrared radiation, but reflectivity and transparency at various wavelengths, heat retention, life expectancy, weight, and durability under attack from vandals or seagulls must all contribute to the final choice of glazing material and panel.

Given the critical role of the insulation in achieving good performance, some systems go as far as constructing the collectors inside a vacuum to cut heat losses. Atmospheric pressure places a lot of mechanical stress on vacuum systems so these tend to be based on cylindrical tubes, while non vacuum systems can be fabricated more easily around large rectangular flat plate collectors. Solar water heating collectors are thus broadly divided into flat plate and evacuated tube devices.

Flat Plate Collectors

Flat plate collectors typically use a thermal absorber of 1.5 to 3 square metres in a single enclosure. This is generally fabricated in a single metal sheet, or metal strips attached to pipes, the pipes being either fixed to the plate, or formed from layers of sheet metal. This assembly is placed in a waterproof insulated housing. All the insulating materials must be selected to withstand temperatures well in excess of 300°C so that the panel can withstand exposure to direct summer sunlight with no thermal load, a condition referred to as 'stagnation'. A variety of transparent materials can be used to form the front of the collector, though this must be transparent to infrared radiation as well as visible light, able to withstand heavy snow, hail and the worst case temperature the panel will reach, and ideally weigh little. The use of glass is traditional, but soda glass is best avoided as it can absorb up to 30% of the energy in sunlight. Low iron glass performs better, but among others acrylic, Tedlar®[2], and triple wall polycarbonate plastics may be used and offer a weight advantage. Where systems are 'glazed' with triple wall polycarbonate sheet, experience with conservatory rooves suggests the user should anticipated replacing this material at least once during the life of the system which is likely to exceed 25 years.

Flat plate collectors are relatively efficient at low and medium water temperatures, though as system temperatures rise, heat is lost to the surroundings by re-radiation from the collector, conduction through the insulation, and the heating of air in front of the absorber plate which circulates by convection, transferring energy to the window at the front of the panel which is cooled by the outside air. Sometimes more than one layer of glazing may be used at the front of the collector to reduce heat losses to the air, but these also reduce the levels of radiation reaching the collectors, and many collector designs go no further than single glazing. Flat plate solar collectors may be mounted over existing roof tiles, or set into a

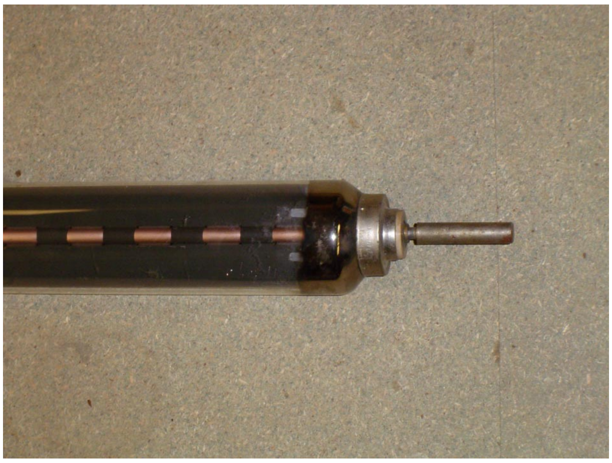
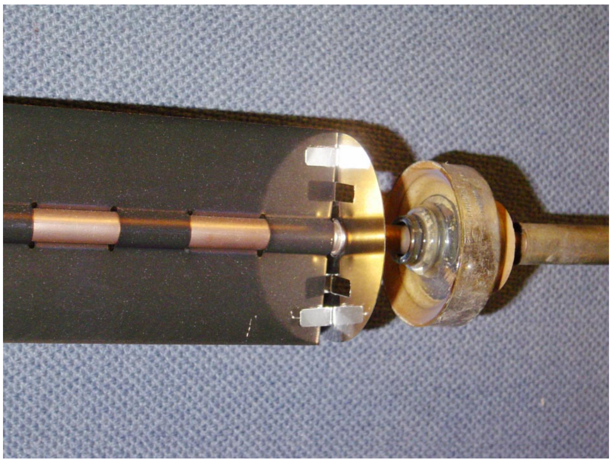
A 2.75m2 Zen flat plate collector with the low iron glass front removed, being set into a roof.


Above, 2.75m2 Zen flat plate collectors with the low iron glass front, left 'in roof', and right 'on roof'.
roof.

Evacuated Tube Collectors

Evacuated tube solar collectors also use dark collector surfaces which transfer heat to pipe-work via sheet metal absorbers, but these are mounted inside a tube surrounded by a thermally insulating vacuum. The pipe-work may either be sealed into tube such that the light passes through a single layer of glass before striking the collector in the evacuated space, or the collector may be mounted inside a double wall vacuum tube, effectively a vacuum flask, such that the light passes through two layers of glass before striking it. In either case the vacuum prevents heat loss from the collector plate by convection, so systems based on these collectors may be more efficient than flat plate, especially in cold conditions or at high working temperatures. Where the collector uses a glass to metal seal this is critical to performance as the vacuum depends on it. Elimination of this seal in the double wall flask designs may improve their robustness in the long term, but at the expense of the light having to penetrate more layers of glass, perhaps reducing the efficiency of the collector.

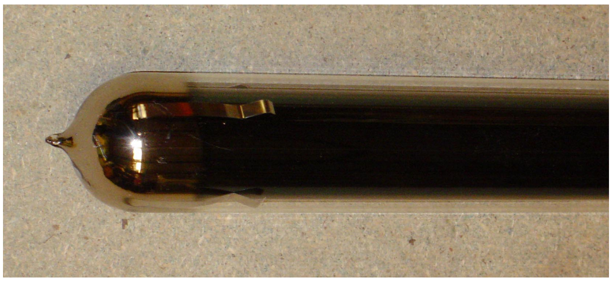
The evacuated tube of the collector has to be fabricated in glass to withstand the force nate

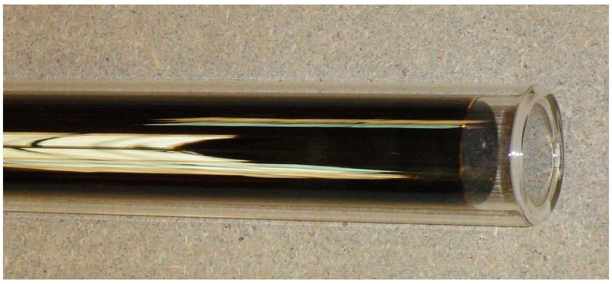



Above, an obsolete design of evacuated tube, intact, and broken to reveal the glass to metal seal.

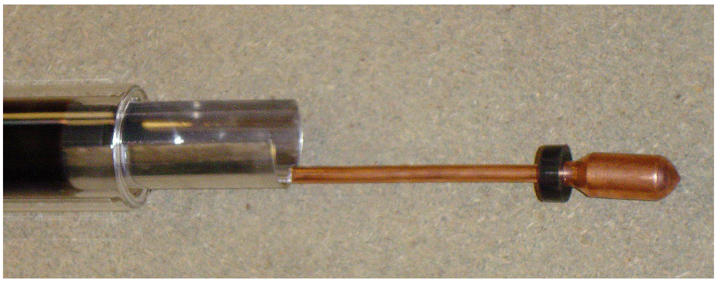
Left, an array of Nippon Electric Glass DP6 single wall evacuated tubes mounted on a secure frame.

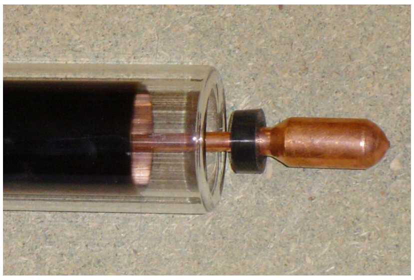
This frame provides protection from side impact as it has been used on a vehicle. In static applications, a triangulated rectangle of galvanized Dexion is recommended.





Above, the ends of an Apricus flask evacuated tube with no glass to metal seal. Below left, insertion of the heat conducting metal spring and heat pipe. Below right, tube assembled ready for insertion into manifold.





Below, Apricus tubes mounted in their manifold on the roof.

imposed by atmospheric pressure. The comments on handling and implosion hazards identified in the later section entitled “Making a Safe Installation” should be noted with care.

Although evacuated tube collectors are generally mounted above roof tiles, products are emerging to integrate them into the roof, though these rely on covering them with yet another sheet of transparent material which will further reduce operating efficiency.

Heat transfer

In most designs of solar water heating system, heat is stored remotely from the solar collector. Mass flow of water is generally used to transfer heat from the collector to the store. While it is possible to use convection to move water between the collector and the heat store, this requires wide bore pipe raising the thermal capacity of the primary circuit which reduces the speed of its response to sunlight. It also imposes the requirement that the heat store be higher than the collector, and is relatively inefficient because the flow of convecting water is not adequate to transfer heat from the panel at full efficiency. Some estimates suggest that only 60% of available heat is delivered to the heat store by convection driven systems, and it is now normal practice to pump water through the collector and heat store, though this requires a control system to work efficiently.

Solar Heat Stores

All practical solar water heaters require a well insulated heat store. This may be integrated with the collector, but usually consists of a separate water cylinder, calorifier or accumulator.

Left, a Consol Baijing solar water heater with integral heat store. The evacuated tubes transfer heat directly to the cylinder at the top reducing heat losses from pipework, while eliminating the need for pump, controller and electrical supply.

These may contain water in a gravity fed or mains pressure system, or use some other medium to store the heat, perhaps involving the latent heat of a phase change to improve the energy storage density.

Left, a large solar preheat cylinder prior to installation. Right, the cylinder in its insulating cladding. This preheat cylinder is heated only by solar collectors, and delivers warmed water to a second cylinder to be heated for use.

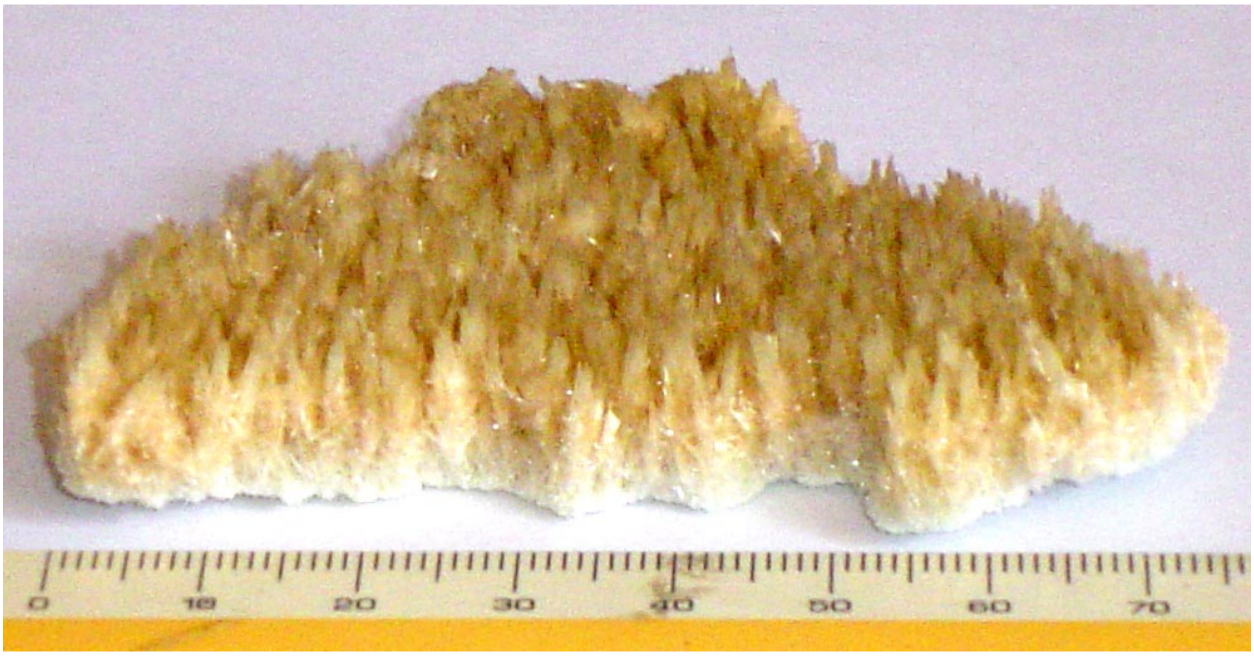
Direct and Indirect Systems

Solar water heating systems may also be divided into direct and indirect configurations. Direct systems circulate water from the heat store through the collectors to transfer heat.

Collectors for direct systems must be able to prevent the water they contain from freezing in cold conditions. They are simple, efficient, and quickly plumbed in as the existing water cylinder is usually retained when they are retrofitted, and relatively little access is needed to existing pipe work.

Please note that direct systems are also more prone to damage caused by hard water. Before the installation of a direct system at a site with hard water, steps must be taken to reduce the risk of harm to the collector.

Indirect systems use a heat exchange coil in the heat store which isolates the stored hot water from the fluid that circulates through the solar collectors. This heat exchange coil is frequently made of Intergron, an alloy of copper and nickel that facilitates the efficient transfer of heat. This should have a surface area of about $0.5m^2$ per square meter of installed collector.



The threat from lime-scale should not be underestimated. The above sample was removed from a 14 year old water cylinder from a house in Nottingham City centre. Clearly deposits such as these would severely compromise fluid flow and collector heat transfer in a direct solar water heating system.

Frost Protection

All solar water heaters used in the UK require protection from frost. If this is not adequate, damage to the system will result sooner or later. A number of strategies have been used to provide this.

Freeze Tolerance

Perhaps the most elegant approach is simply to fabricate the collector from materials which will withstand freezing, remaining intact by expanding and contracting around any ice that forms inside them, though this severely limits the choice of collector and the range of materials that can be used in its manufacture.

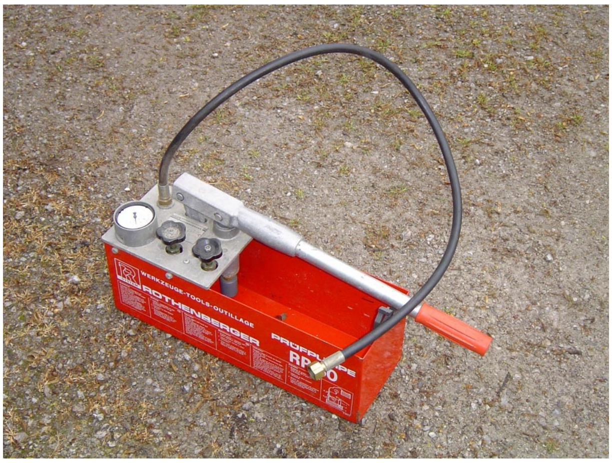
Water Movement

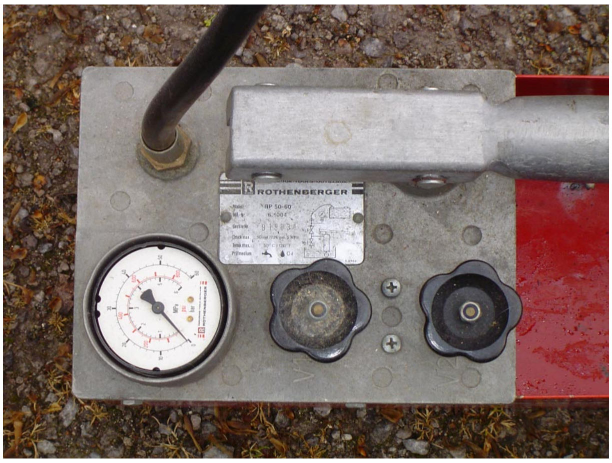
Another simple approach is to keep the water moving using the system pump once the exterior temperature gets below a few degrees above freezing. This function is supported by many solar controllers, but in addition to the risk of misconfiguration of the equipment and lack of opportunity to check the configured behaviour when the system is installed, running the pump to circulate water consumes electricity, has a vulnerability to power cuts, and will also cool the heat store a little.

Antifreeze

Perhaps the most common approach is to add an antifreeze to the circulated fluid to eliminate possibility of freezing in indirect systems. Enough antifreeze should be added to protect against at least '50 year frosts', i.e. the system should withstand the lowest temperature that is likely to occur within a fifty year period. The cost of glycol is not prohibitive given the quantity required, but care must be taken to select an appropriate product. **Automotive antifreeze is *not* a safe product to use.** This is generally based on ethylene glycol or methanol, both of which are extremely toxic. The heating industry has however produced a number of products based on propylene glycol which is of relatively low toxicity. Especially in the dairy industry, a product aimed at food chilling applications with certified and low toxicity is indicated.

Below, a hand operated pump for introducing premixed chemicals into heating systems. It is easier to get the antifreeze concentration correct by introducing it at the correct concentration than adding pure antifreeze and topping up with water.

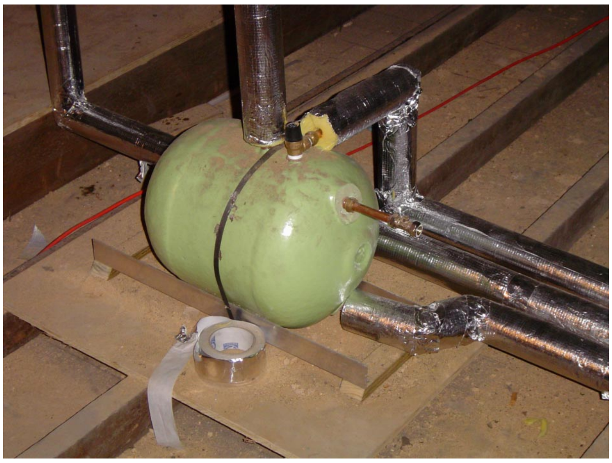




Drainback Panels

Another strategy is to use a system which allows the water that transfers heat from the collector to drain back into an intermediate storage vessel when not in use. This means that all the primary circuit pipe runs must slope back towards the drain back vessel and may not run flat. If this storage vessel is in part of a building which can be guaranteed to be frost free, no antifreeze will be required. Such systems are referred to 'drainback', and rely on syphonic action to draw water out of the collector where it might otherwise freeze during periods of non use.

The drainback vessel must be well lagged to avoid heat losses. As drainback systems sometimes have other advantages, they may on occasion be used with the drainback vessel outside the heated envelope of the building, but with antifreeze added to the circulated water.



Left, installation of a drainback vessel for a Filsol flat plate system in a loft, outside the heated envelope of the building. Note the quality of insulation.

Indirect System Design

Pressurised

Although indirect solar water heating systems can be gravity fed to fill and pressurise the primary circuit, this is seldom seen in modern installations which seek to minimise contamination and oxygen ingress. Most systems are pressurised through a double check valve to a working pressure of 1 to 2 bar on installation, and an expansion vessel is used to prevent excessive pressure increase as the system heats up in service.

Where systems are filled from the rising main there is a duty to comply with water byelaws which specifically forbid any filling arrangement which may allow back-flow to the main, and it is normal practice to use a 'fill tail' hose when charging the system which is disconnected when not in use to isolate the main from any possibility of contamination by back flow.

A better practice is to premix any antifreeze with water and introduce it with a hand operated pump. This makes it easier to administer the correct concentration of any additives and eliminates the risk of contaminating the main supply.

Drainback

Again the drainback system provides an alternative. These are normally filled at atmospheric pressure, but may be sealed, and run under pressure while the sun is shining. They may also be controlled to restrict temperature by turning off the pump when the desired cylinder temperature is reached (which would cause boiling and loss of the heat transfer fluid in other types of system), and have the advantage that in the event of power cuts or other periods of non use, the circulating fluid will neither be boiled off nor thermally degraded. All the commercially available drainback systems we are aware of are indirect.

Control Systems and Displays

The most basic of solar water heaters that integrate the collector and heat store, or use convection to move heat from the collector to a heat store need no control system, but may benefit from a temperature display.

Where heat is transferred by the movement of pumped fluid, the pump needs be controlled to prevent operation when the temperature of the water in the solar collector is cooler than the thermal store. This can be done by running a small low voltage DC pump from a small photovoltaic collector. As the pump speed is roughly proportional to the amount of sunshine, this gives good first order control of the system, but does not give a guarantee that the pump will never run when the collector is colder than the heat store, or not fail to run when the sun fades but the collector is still warmer. On the other hand, if the pump runs from solar electricity, there is no ongoing electricity cost to running the pump. Such systems have the virtue of extreme simplicity, but both the pump and PV panel may be expensive items, and any temperature display will be completely separate.

The most widely accepted approach is to use a mains powered electronic controller. The core function of the controller is to compare the temperature of the water available in the collector with that in the coolest part of the solar heat store, and to switch the pump on when the collector temperature becomes a little hotter than the store. This is referred to as differential temperature control. The precise amount by which the panel must be hotter than the store to switch the pump on, and then cool before switching it off are usually adjustable, and many controllers include additional functions to display a number of temperatures in the system, to run the pump for direct systems in freezing conditions, and to turn off the pump should the heat store over heat. Small mains powered central heating circulating pumps are generally used. While cheap, these are sometimes larger than desirable, and in small and moderately sized systems, can frequently be used on the pumps lowest speed setting.

Left, a basic but reliable Resol solar water heating system controller.

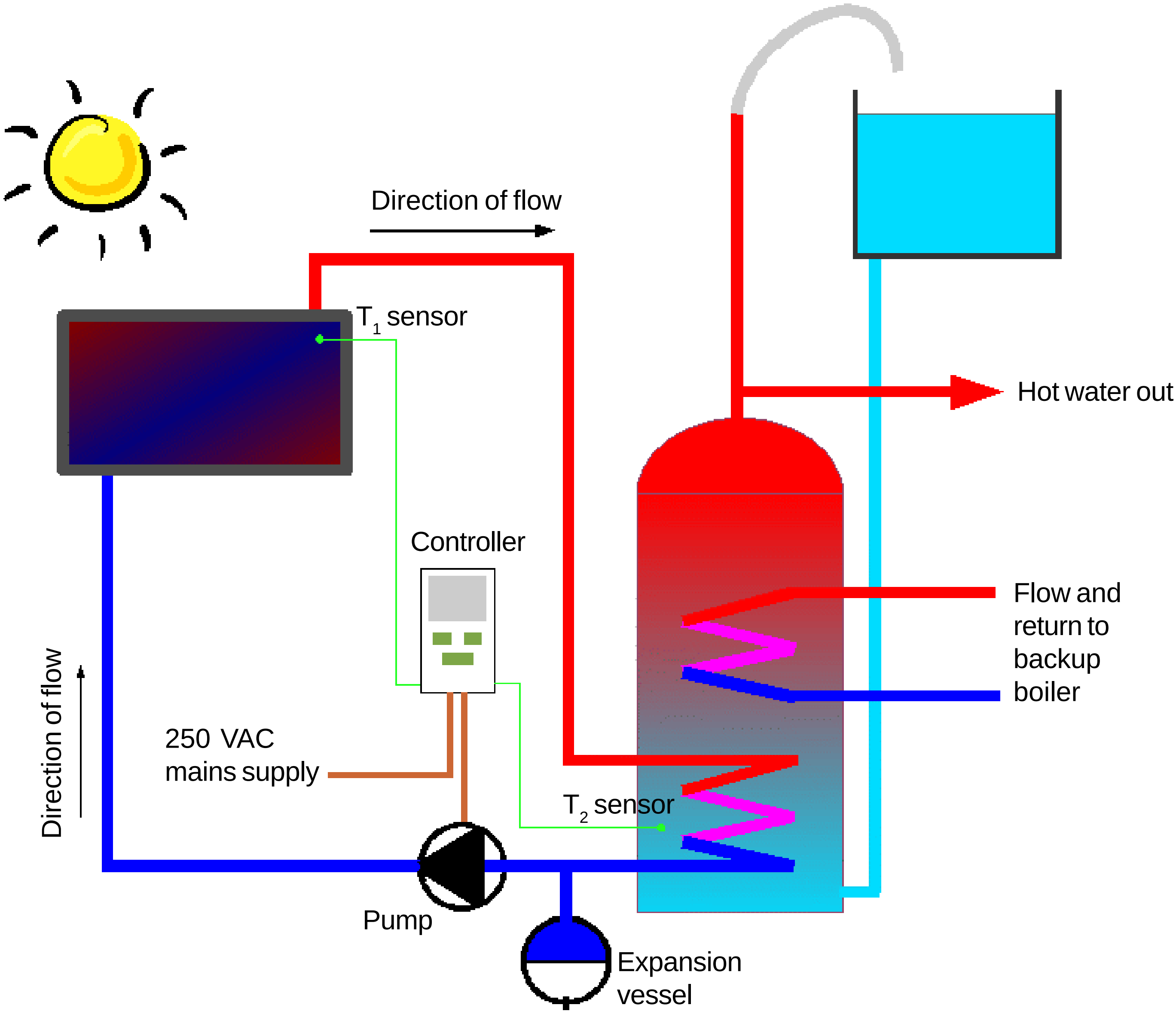
More advanced controller functions include data logging, computer interfaces, provision for multi panel 'east / west' systems in which panels facing east and west gather most heat at different times of the day, and interfaces to integrate with other heating systems. Little more than a basic differential temperature controller is usually required however, and there are many commercially available products to choose from.

Most controllers can only switch the pump on and off, but a few can vary the pump speed electronically in proportion to the temperature difference between the panel and the heat store giving finer control.

The following diagrams illustrate the broad outline of typical indirect pressurised, gravity fed direct, and indirect drainback systems.

Our thanks to Solartwin[7] and the Nottingham Energy Partnership SunGain scheme[6] for granting permission to use their diagrams on pages 20 and 21 of this documentation.

Although the direct system shown uses a flat plate collector, direct systems may also be constructed using for example, Apricus evacuated tubes.

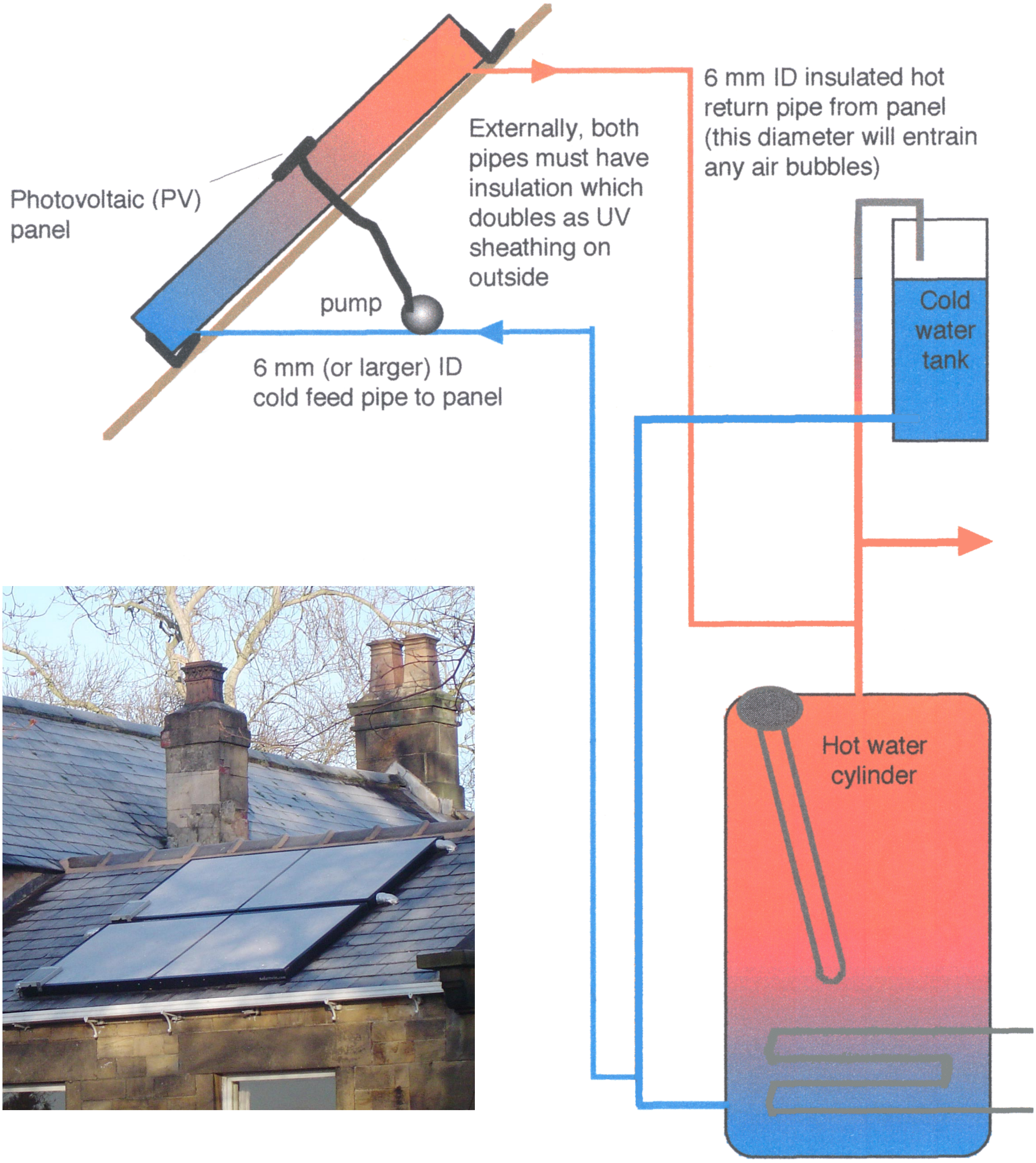


Above, outline of a typical pressurised primary indirect system using a differential temperature controller and mains powered pump.

The controller turns on the pump to transfer heat when the temperature reported by the sensor at the top of the panel T_1 exceeds the temperature reported near the bottom of the solar heat exchange coil T_2.

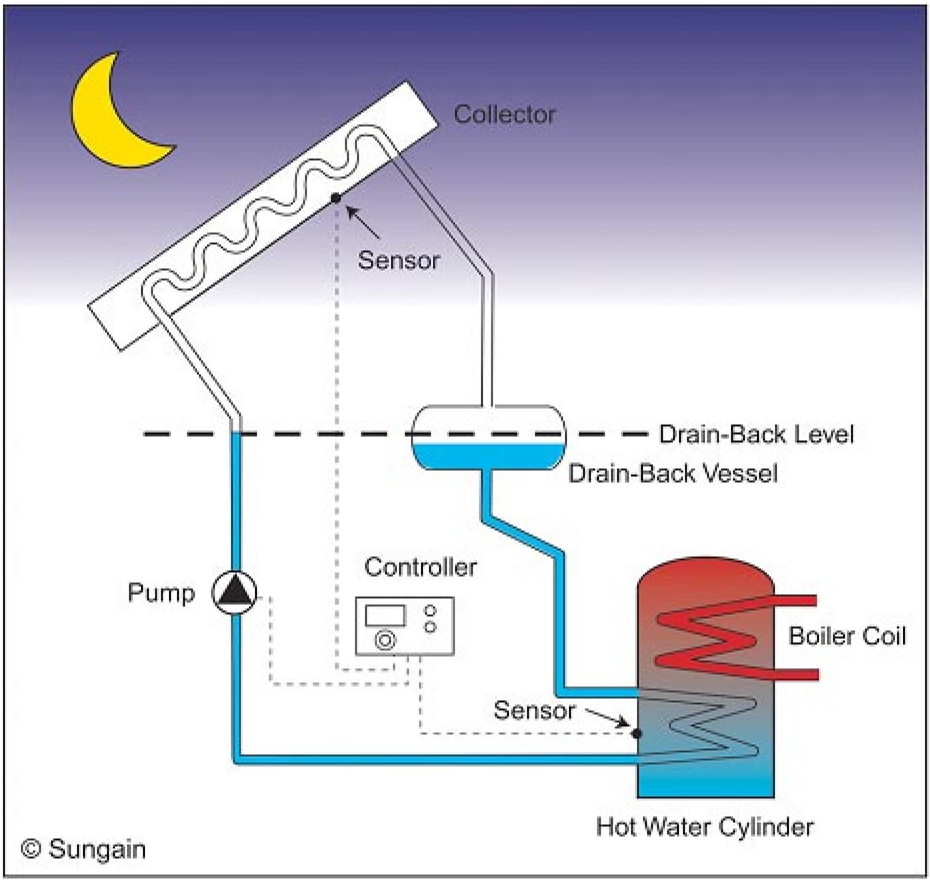
The expansion vessel minimises pressure changes in the system by accommodating the volume change of the heat transfer fluid as the system heats up.

Backup heating of the cylinder can be delivered via the top heat exchange coil in the water cylinder from a fossil fuel boiler, or from an immersion heater if fitted.

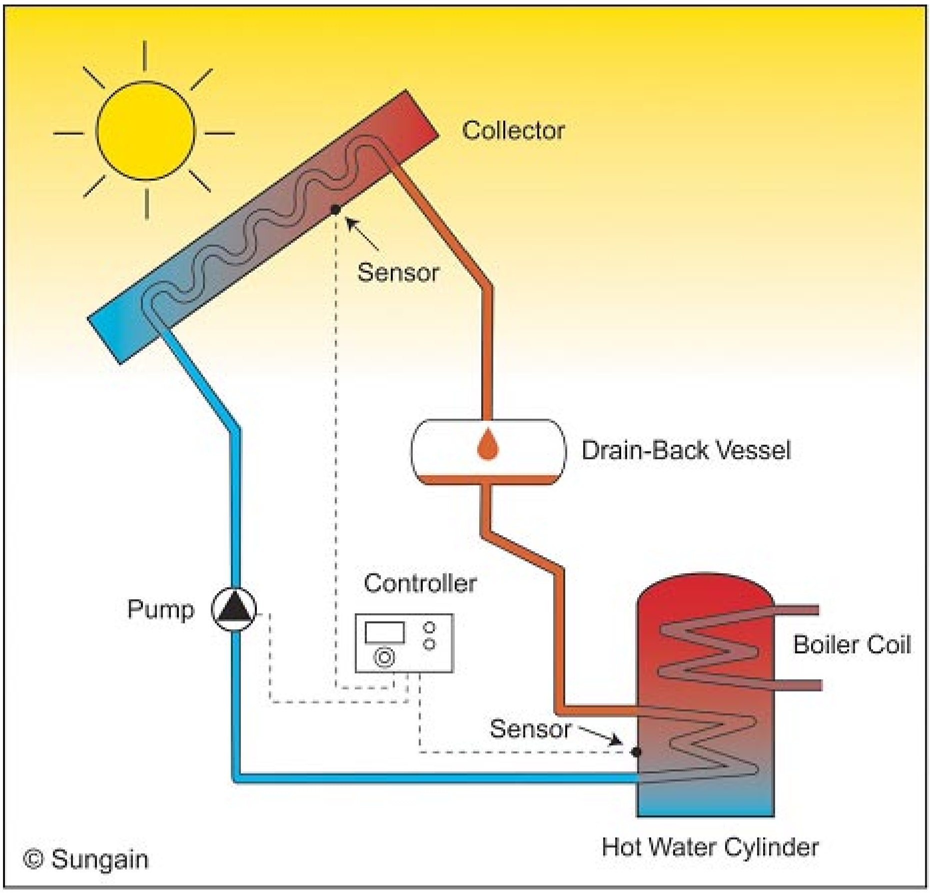


Above, Solartwin panels with the PVs to the bottom left corners. Diagram illustrates the broad outline of a Solartwin direct system. Rather than using a differential temperature controller, this uses a small photovoltaic panel to deliver DC power to the pump in proportion to sunshine intensity.

Note that while in general it is possible to 'pick and mix' the components used in solar water heating systems, the Solartwin direct flat plate panel, pump and the photovoltaic electricity producing panel that powers the pump, have been carefully designed to work together in such a way that the use and expense of a differential temperature controller is avoided. Replacement of any of the key components with parts sourced from other manufacturers will in all probability result in inefficient operation. Consequently individual components are not sold separately and in this instance it is not possible to 'pick and mix' from other suppliers.

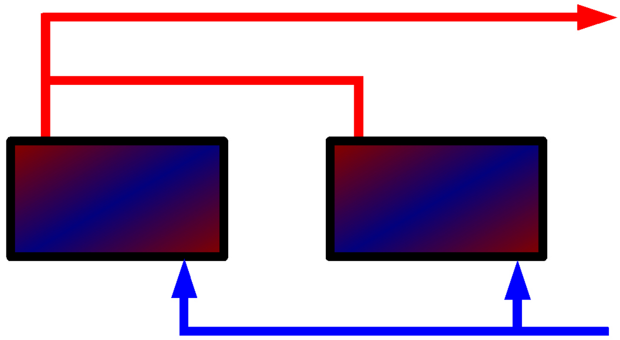


Above, diagram illustrating a drainback system with the pump off and heat transfer fluid drained back to the internal storage vessel. Below, the pump turned on by the controller and heat transfer fluid running through the collector because the collector is hotter than the heat store.



Designing Larger Scale Systems

Note that solar water heating systems of any size may be constructed, but large systems require multiple panels, and the flow of water through them must be balanced.



Balancing the flow through groups of solar collectors involves ensuring that the resistance to flow through each collector is the same.

Note that pump and pipe-work must be sized to carry the heat collected, and if an expansion vessel is used as in a conventional indirect system, this must be sized to accommodate the worst case expansion of the circulated fluid. There is no advantage to using bigger pumps or pipes than are required to move the maximum amount of heat the panel can deliver.

If the solar controller is fixed speed, i.e. the pump is turned on or off, most of the industry accepts a flow rate through the solar panels is about one litre per minute per square meter of solar collector.

Some controllers may vary the pump speed electronically in response to the temperatures in the system which may provide some further optimisation, but where the controller provides only on / off control, the primary circuit flow should be set using a flow gauge. Most flow gauges also incorporate a ball valve to allow adjustment of the flow.

Below left, flow gauge with adjustment screw and graduated scale. Middle, typical pump used in small and medium scale solar applications. Right, a complex larger scale project using both flat plate and evacuated tubes. Note that using both together requires careful design.

Selecting Buildings for Solar Installations

To justify the installation of a solar water heating system, a dairy must be in an unshaded location, with an appropriate orientation, and have a compatible pre-existing hot water system.

Location of Sites

Although it is possible to extract useful amounts of solar energy on buildings with roofs facing east and west, sites should ideally have a south facing roof which is not in shadow for a significant proportion of the day, and which will not become shadowed by growing trees or any anticipated development.

Orientation Of Solar Collectors And Time Of Use Of Hot Water

The following general principles should be borne in mind.

Most buildings have sunlight fall on them for at least part of the day, but for a much shorter period in winter than summer[1].

A solar collector will gather most power when it is at 90 degrees to the rays coming from the sun.

The sun's rays deliver most power when the sun is high in the sky when the atmosphere scatters and absorbs less of the energy.

The sun is highest in the sky in the middle of the day, and higher in summer than in winter. In summer there may be a surplus of solar energy if the collectors are large relative to the thermal load, so it may be appropriate to pick a more vertical collector orientation that is optimised for spring and autumn performance to extend the season of use.

Once a solar water heater has collected heat, this is lost slowly from the thermal store, but the bigger the store, the less heat it will loose per unit volume of water stored at a given temperature. (A reasonably good domestic cylinder will typically loose about 2.5kWh per day, and more if the cylinder is unusually hot.

The sooner the heated water is used, the more efficiently heat is delivered to the user. A typical well lagged domestic hot water cylinder might get up to 50 or 60°C during the day if heated by a flat plate collector, but even with no water use, the cylinder temperature might fall by 10 degrees between dusk and dawn. Evacuated tubes may reach higher temperatures by dusk and suffer greater falls in temperature over night, but should still deliver higher water temperatures than flat plate the following morning given similar patterns of usage. Although the heat losses from larger heat stores will be less significant, the design should take account of the delay before the use of hot water, as well as optimising the initial collection of heat.

It helps to collect the most heat just before it is used. The sun may not be in the sky for long before morning milking even in the summer months, so east facing collectors may bring little benefit even though the length of time between collecting and using heat would be small. For evening milking, collectors facing somewhat west of south will minimise the delay before water use, and any excess heat can be stored for use during morning milking, though the available temperatures may not be high if the design significantly dilutes the solar heated water with cold, refilling the heat store cylinder with cold water from the bottom as hot water is consumed from the top. A better approach might be to avoid such dilution, using the solar heated water in batches.

If buildings are listed or in conservation areas, or if the construction or condition of the roof imposes health and safety constraints, panels can be set up on stands in a garden or yard. Solar collectors do not have to be put on a pitched roof. They can be mounted at an angle on walls, on stands on the ground, or on a flat roof. When designing such frames, it is important to think in terms of the structure surviving the highest winds that may be encountered in a fifty to a hundred year period. Consult the manufacturer of the equipment for mounting requirements. Evacuated tubes are less vulnerable in high winds than flat plate collectors because of the gaps between the tubes.

Backup Hot Water System

While making significant energy savings, for many days of the year, even the best solar water heating systems will not meet the full temperature requirement for washing dairy equipment. As a result it will always be necessary retain a backup heating system, which in winter may need to provide up to 100% of the heat required, but which may not be needed at all on some summer days.

Solar water heaters can only be integrated with existing water heating systems if the input temperature and pressure ranges are matched.

Most solar water heating designs are gravity fed systems at an operating pressure of no more than 1 bar.

If water is required at a higher pressure than a gravity fed system can deliver, it is possible to use mains pressure heat stores, though these are more expensive than their conventional gravity fed counterparts.

The efficiency of solar collectors, especially flat plate, falls as temperature rises, so in the interests of thermal efficiency, the cylinder or part of the cylinder which is being heated by solar power should be as cool as possible. Other energy inputs to the cylinder should be made as late as possible to allow the efficient delivery of solar heat from the collector for as long as possible. This will also optimise fuel savings.

Solar heat is generally delivered to the bottom of the heat store as that tends to be the coolest part, the warmer water stratifying at the top.

In retrofit situations with a pre-existing heat store, the existing store can be replaced and possibly enlarged, or a second cylinder added to preheat water for use in the original store. Where water is heated 'on-demand' with no heat store, a preheat cylinder may still be used in some circumstances, but the on demand heater must be tolerant of the preheated waters temperature and pressure, further raising the water temperature if necessary under thermostatic control. In either case, the required water temperature must be delivered using additional backup heat from a conventional energy source such as oil, gas or electricity when the solar preheated water is below the required temperature.

Not only must the backup heating equipment tolerate the full range of solar heated water temperatures, it must also withstand the available pressure. For example, a standard gravity fed backup hot water cylinder might fail catastrophically if supplied with preheated water at rising main pressure, and a 'combi' on demand gas heater might fail to pass sufficient water to operate if supplied with pre heated water from a low head gravity fed system.

Most dairy water heaters we have seen in the Nottingham area provide heated water at low pressure, some using electrical level switches to sense water level, and solenoid valves to control the ingress of water to be heated. These may provide heat to an entire dairy or have dedicated applications such as tank washing. It seems likely that the majority of these might be fed preheated water, their thermostats reducing other energy inputs automatically.

Case Study

Requirements

The fist part of the design of any system will be to establish the requirements. The calculation below makes assumptions for a typical small to medium size dairy unit based on observations of dairy farms in the Greater Nottingham Partnership area and the procedures specified by the Dairy Hygiene Inspectorate.

Volumes and Temperatures

300 litres 85°C

Power Required

Assuming the delivery of cold water at 10°C

Temperature increase required	= 75°C
Energy to raise 1 litre of water 1°C	= 0.001161 kWh
Energy required to raise 300 litres of water by 75°C	= 26.1 kWh
Heat losses from cylinder	= 3.9 kWh
Total heat requirement	= 30 kWh

Power Available and Collector Area Required

Peak UK insolation is about 700 watts per square meter in summer, but peak insolation only occurs in the middle of the day, and there is virtually no energy input during most mid winter days. The energy input to a square meter of south facing collector is up to 1000 kWh of solar radiation during a year[12]. If we assume that in the middle of summer a square meter of solar collector might be exposed to 4 kWh of heat radiation per day, the heat demand of 30kWh might be met by a collector area of seven or eight square meters if the collectors were 100% efficient *which they are not*.

Available System Designs

Direct and Indirect Systems

There should be little performance difference between direct and indirect systems as long as water hardness does not compromise the equipment in direct systems. This distinction will thus be ignored from the point of view of performance and cost benefit comparisons.

Flat Plate and Evacuated Tube Options

Given that the target system temperature of 85°C is high relative to typical domestic applications, the use of evacuated tube systems should be considered even though these collectors typically cost more than flat plate varieties.

Typical Systems

Selecting a Size

When choosing the size of a system it is worth keeping in mind that any energy contribution has a cash value even if the full daily requirement is not met.

One common approach is to aim to just meet the daily energy requirement on the hottest day in summer. This will typically offer the best solar energy contribution per unit investment, but greater savings are possible by increasing the size of the system to improve the contribution in spring and autumn. As size continues to increase however, returns diminish as harvesting significant power in winter would require massive investment, and most farms have no other use for a large summer hot water surplus.

For the purposes of this case study it will be assumed that the aim is to just exceed the daily energy requirement on the hottest days in summer.

Flat Plate

Flat plate collector efficiency decreases significantly with temperature rise, and although stagnated panel temperatures can exceed 100°C, heat store temperatures above 75°C are seldom seen. Dairy water system temperatures are high so it seems unwise to assume an efficiency of more than 45% using this type of collector over this temperature range. This suggests that an area of about 18m^2 might be appropriate, and even this is likely to struggle to achieve the full temperature rise.

Evacuated Tube

Evacuated tube collector efficiency decreases relatively little with temperature rise, and while initial rates of temperature rise may be a little slower than flat plat, rates of warming should be maintained well as heat store temperature rises. If we assume an efficiency of 65% for these products, this suggests that an area of less than 13m^2 should be adequate, and evacuated tubes should be able to reach the target temperature.

Costs and Outputs

If the solar water heating system is undersized and heats a preheat cylinder, it may be that there will be no net benefit to the use of evacuated tubes as the preheat cylinder will never get warm enough for the efficiency of flat plate collectors to roll off significantly.

Estimated installation costs are estimated based on 2005 prices. Estimates of energy value assume an equal split between off-peak electricity at 2p per kWh and on-peak at 5.2p per kWh.

Flat Plate

An installation cost of £8,900 ex VAT is a fair estimate for installing a flat plate collector system with a surface area of 16.5m^2 delivering approximately 8,250 kWh per year if well sited.

Evacuated Tube

An installation cost of £10,380 ex VAT is a fair estimate for installing an evacuated tube plate collector system with a surface area of 14.45m^2 delivering approximately 9,390 kWh per year if well sited.

Conclusions - Best Fit Solar Technology

System financial payback

The evacuated tube system with the initial investment about 10% higher, should be able to deliver a bigger proportion of the thermal energy required. At current energy prices, the value of the energy from the flat plate collector system is approximately £300 per year, while the evacuated tube system yields about £340. This suggests that the two systems both have 'payback times' of over 30 years.

H*owever, fuel has increased in price rapidly over the last few years, and this trend seem unlikely to reverse in the long term*[11]*, due to both scarcity and carbon taxes*.

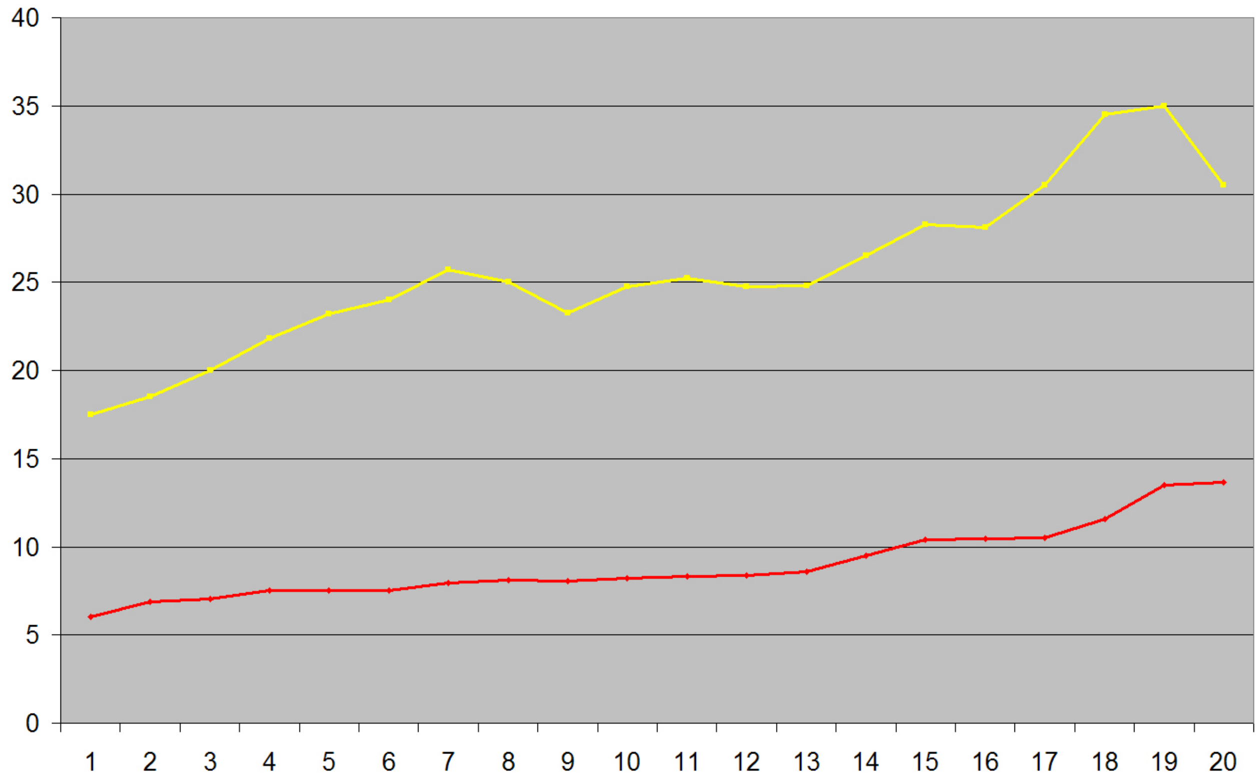
Some agricultural growers have reported price increases of about a factor of two over the last three years taking into account the introduction of the Climate Change Levy and tariff increases. This represents a price increase of about 25% per year

The UK is increasing its imports of natural gas, and it has been predicted that the rate of oil extraction world wide may be about to start its decline[11], while at the same time demand from developing countries is growing significantly.

If this trend continues, energy costs may increase by a factor of as much as eight in a decade.

While this scenario may be extreme, it is worth noting that if energy prices rise by even 10% year on year, the payback time for the systems identified above comes down to about 15 years, and if energy prices rise by 17.5 or 25 percent per year, the payback times come down to around 13 years, and about a decade.

As cost increases among primary fuels are passed to the consumer, solar heating is likely



Above, the twenty months from April 2003 to November 2004, wholesale energy prices in pounds per MWh, gas in red and electricity in yellow.

to become more competitive, possibly paying for itself more than twice over during its anticipated life on sites with high hot water demand.

On the basis of the figures shown, it seems that there may be little to choose between evacuated tube and flat plate systems from a 'return on investment' point of view, and the choice of technology should depend on the extent of their environmental benefits, the amount that can be invested, and future price movements of equipment and installation.

Displaced fuels

On the basis of visits to farms in the GNP area, it seems most of the displaced fuel will be electricity, though LPG and oil are also widely used on remote farms in other areas.

Gas and oil boilers that are used to provide hot water in summer may be prone to 'dry cycle' as the thermal load is small, causing brief periods of combustion and inefficient fuel use. Under these conditions, the cost of gas or oil fuelling may be little better than electricity.

From an environmental perspective the best emissions saving per pound's worth of equipment installed will be made where the existing installation makes inefficient use of primary fossil fuels. As electricity production and distribution are unlikely to deliver more than around 40% of the energy available in their primary fuels to the consumer, the displacement of electrical energy use should be prioritised over the local combustion of oils and gas using modern efficient equipment.

While the displacement of any fossil fuel is desirable, coal and electric water heating should be given the highest priority, followed by oil and gas. There would be little advantage to displacing biofuels if these are used for water heating.

System environmental payback

It is interesting to consider that if the displacement of 450g of carbon dioxide per delivered kWh is achieved, the evacuated tube system described above might prevent the release of over 4,225kg of carbon dioxide per year, and each installed system might reasonably be expected to have a working life of at least twenty five years, saving the emission of in excess of 106 metric tons of carbon dioxide during its design life, as well as other pollutants from the combustion of primary fuels.

Fitting a System

This section is not intended to replace the manufacturers instructions for any particular product, but rather seeks to make some general but important points. The first of these is that a system should be constructed in such a way that it can run for decades with only a minimum of simple maintenance. In particular it is worth making a good job of all work on the roof as the effort and cost of gaining roof access may be significant compared to the effort of small but important repairs.

Access and Putting Up The Panel

The bulk and weight of many flat plat collectors can make installation difficult where access is restricted, for example in the narrow gaps between buildings, or where a boundary, road, or path is close to a building. A winch or crane may be necessary to hoist heavy panels, but care must be taken to keep the centre of gravity well within the footprint of the scaffolding or tower used to gain access. Some panels may be carried up in component form as frame and insulation followed by collector surface, followed by the glass front.

Most evacuated tube systems can be assembled on the roof tube by tube once the manifold is mounted. Manifolds and tubes can generally be lifted by one person and passed up to the roof by hand, but beware products (such as the Nippon Electric Glass DP-4 and DP-6), which are delivered with their tubes soldered into the manifold by the manufacturer, and which must be mounted on a frame before being lifted onto the roof, (see picture top of page 11 and below).

NEG DP-6 collectors mounted on galvanized Dexion angle with straps securing the frames to the roof timbers under the tiles.

Flow Rates, Pipe Sizes and Pumps

The amount of heat to transfer dictates the primary circuit flow rates. A flow rate of about one litre per minute per square meter of panel is generally accepted as optimal. Unless the controller can modulate the pump speed electronically, the lowest possible speed should be selected at the pump, that can move enough water around the primary circuit. This minimises the electricity used by the pump. The flow should then be adjusted down to the one litre per minute per square meter of panel flow rate required, using the ball valve adjuster that is usually built into the flow gauge.

Except in systems that transfer heat by the convection of a fluid which require wide pipes, a low primary circuit thermal capacity is regarded as an advantage as this makes the system more responsive to brief periods of sunshine. There is thus no advantage and some cost penalty to over-sizing pipes or pumps in a pumped system.

Flushing

When systems are commissioned, any residues of flux, wire wool etc should be flushed out of the system to minimise ongoing corrosion and wear of mechanical parts. Many commercial installations we have seen have not been thorough in this respect, and as a result flow gauges can be hard to read, and may give false readings making optimisation of the flow rate difficult.

Insulation

Insulation of the entire solar water heating system is critical to performance, especially the panel, primary circuit pipe-work and cylinder. It should be as thick as you can afford, and will still save money in the long run project despite the higher initial cost.

Note that external insulation must be weather proof and resistant to ultraviolet radiation. Short runs of external insulation may be wrapped in aluminium tape for protection. Longer runs should be wrapped securely in butyl rubber sheet for protection.

Insulation of the pipe-work within two meters of the panel should be able withstand the stagnation temperature of the panel, i.e. the temperature it will reach in bright sunlight with no water flow. This may be several hundred degrees, and foam products may melt and decompose at these temperatures. The use of glass fibre or mineral wool products is necessary despite the expense.

Valves

Gate valves (typically a red hand wheel and brass bodied valve), are not very reliable if operated repeatedly over a number of years. In addition to increasing leakage from the gland over time, they may also cease, becoming impossible to open or close.

As an alternative we suggest the use of good quality ball valves which while marginally more expensive offer significant long term savings of time and effort.

Drain Points

When draining systems, standard drain cocks sold by many plumbers merchants only allow low rates of drainage, and tend to leak from the valve thread as well as the hose tail. We normally recommend wide bore ball valves that allow quick draining of cylinders with a minimum of mess. The time saving is particularly significant on larger cylinders.

Primary Pipe-work and Joints Close to Panel

In recent years plastic hot water pipe has been increasingly used in domestic hot water systems. Because of the extremes of temperatures that may arise during or after stagnation, plastic pipes should not be used in primary circuits under any circumstances.

For the same reason, it is recommended that compression fittings are used within two meters of the panel to eliminate any risk of melting soldered joints.

Planning for a Quality Installation

Even if work is not carried out under the Clear Skies[8] scheme (Clear Skies is a DTI funded renewable energy grant scheme funding the domestic and community sectors), it is instructive to examine the checklist their installers use for solar thermal installations. See Appendix 1. Although these are aimed at the domestic sector, most of the points apply equally to systems on dairy farms. It will be much cheaper and easier in the long run to make a sound installation by good initial design, than to retrofit adaptations to make a poor system function reasonably well.

Note the Clear Skies emphasis on the user retaining the information necessary to maintain the system, as well as fail safe design and good engineering practices.

The Building Research Establishment who administer the Clear Skies scheme have been commissioned by the Energy Saving Trust, to write a ‘best practice guide for solar installations’ which will be based on Clear Skies check list. This is expected to be published in August 2005.

Making a Safe Installation

Farms have statutory duties under the Health and Safety At Work, and other Acts, as well as building regulations. Whoever manages the installation of the system has a duty of care to consider both the process of installation and the safe use of the installed system.

This list is not intended as a substitute for a proper site specific risk assessment.

Working Off the Ground

All work should be carried out in accordance with current regulations. Beware of recent changes due to the 'Use of Work Equipment Directive (dealing with Temporary Work at Heights)'. New UK regulations came into force on 6 April 2005, applying to all work at height where there is a risk of a fall liable to cause personal injury. See http://www.hse.gov.uk/press/2005/c05008.htm for more details.

Electrical Issues

All wiring should be carried out according to Part P of the current Building Regulations.

Most plumbers and heating engineers are not appropriately qualified, and when work is undertaken, it must be clear who is assuming responsibility for ensuring that all wiring associated with the work is safe and complies with all relevant regulations.

In the words of a recent communication from the Health and Safety Executive:

> "It will be taken for granted that the equipment conforms with relevant EN standards for electrical equipment. Because electrical connections are in a wet environment we would generally consider most farmers as not competent to carry out installation work..."

Mechanical Explosion

While it can be convenient to use isolating cocks in some parts of solar water heating systems to facilitate easy maintenance without draining the system, care should be taken to avoid any risk of isolated parts of the system being heated. Severe superheated steam burns and mechanical explosion might result if water is heated under pressure in confined spaces such as an isolated pump or solar collector.

Cylinder Installation Certification

Part L of the building regulations requires water cylinders to be installed by competent persons, and requires the installer to certify the installation they have made. There appears however to be no clear definition of a competent person. It is our understanding that anybody who has a plumbing qualification should be able to make this certification. While we understand that some people working as plumbers have not come into the profession by a path that accredits them, the requirement imposed by Part L remains.

Note that the accreditation required for mains pressure cylinders is more stringent than that for gravity fed systems due to the greater intrinsic hazards of heating water at higher pressures in sealed vessels.

Temperature of Delivered Water

Dairy cleaning processes can require temperatures as high as 96°C, and the bulk of hot washes require water at 85°C, so except for tank washing, there should be little need to reduce peak solar water temperatures.

The temperature at which solar heated water is available depends on the amount of heat delivered to the water cylinder and the amount leaving it. If the insulation of the cylinder is good (and it should be !), and no water is drawn off, the temperature may become very high with even a moderate amount of direct summer sunshine. Evacuated tube solar water heaters are notorious for bringing water up to boiling point, but flat plate collectors may also bring water up to temperatures that might cause discomfort or scald.

While these high temperatures are ideal for dairy cleaning applications, for hand washing, it will be necessary to use a three port thermostatic mixing valve at the sink or other point of use. These combine hot and cold water to give the desired output temperature, and can be preset to meet the temperature requirements of each location.

Legionnaires' Disease (Legionellosis)

This bacterial infection is a risk posed by all hot water storage systems. As far as we are aware, stored potable water in domestic properties in the UK has not to date been responsible for any outbreaks of Legionnaires' Disease, occurrences being attributable to air conditioning systems where water remains warm and stagnant for very long periods. Infection from contaminated water is by fine aerosol water droplets inhaled deep into the lungs.

Attention has been directed towards minimising the number of bacteria in stored water. The *legionella* bacteria is present in all source water at sub-clinical levels, but growth of the bacteria depends on the time spent in store, the store temperature and nutrient availability. Maximum growth rate occurs at about 42°C. At higher temperatures bacterial populations decline until at 60°C, sterilisation occurs within seconds. This has led to the recommendation from some quarters that all hot water stores be maintained at 60°C or above. Although solar water heating system temperatures cannot be accurately controlled, all water used in the dairy should have been taken up to temperatures in excess of 60°C, so legionella should present no risk to dairy staff, cattle or the food chain.

In normal use a dairy hot water system is unlikely to remain stagnant for much more than twelve hours which reduces opportunity for bacterial populations to grow significantly, as does the use of a copper cylinder and pipe work, copper also being toxic to the bacteria. The rising main cold water supply is also generally very low in nutrients, and frequently contains traces of chlorine or other bactericide, though water collected from other local sources may have a higher nutrient content, especially if contaminated with agricultural run off.

Should any hot water system be unused for any length of time, care should be taken to flush or sterilise it to eliminate all risk of infection.

The Water Research Council have revealed that their main concerns regarding *legionella* relate to shower units containing plastic or rubber water pipes. These materials may provide nutrients for growth, which may be significant if water remains stagnant in them for some time. One of the greatest risks is that water might be delivered from a shower head in a form that could be inhaled[10]. A similar issue might arise if droplets of warmed water can be inhaled when cleaning dairy equipment with water from any source that has not been heated sufficiently.

Evacuated Tubes - Handling, Hazards and Disposal

Implosion

Rather like the 'tubes' from old televisions, the primary risk associated with evacuated tubes is implosion. Although an implosion initially causes fragments of glass to move towards the centre of the tube, some material will pass though the collapsing structure or bounce out of it, and many fragments may have enough energy to cause injury, especially to the eyes and any exposed skin.

To some extent this risk must depend on the shape of the tube and the evacuated volume. It may be that smaller diameter double wall vacuum tube 'flask' designs pose less of a threat than other types of evacuated tube, especially than single wall tubes of larger diameter because of their lower evacuated volume.

This risk can be controlled by wearing full-face protection and robust clothing when tubes have to be handled, and also by wrapping the tubes when moving them to contain and restrain any broken glass.

Falling

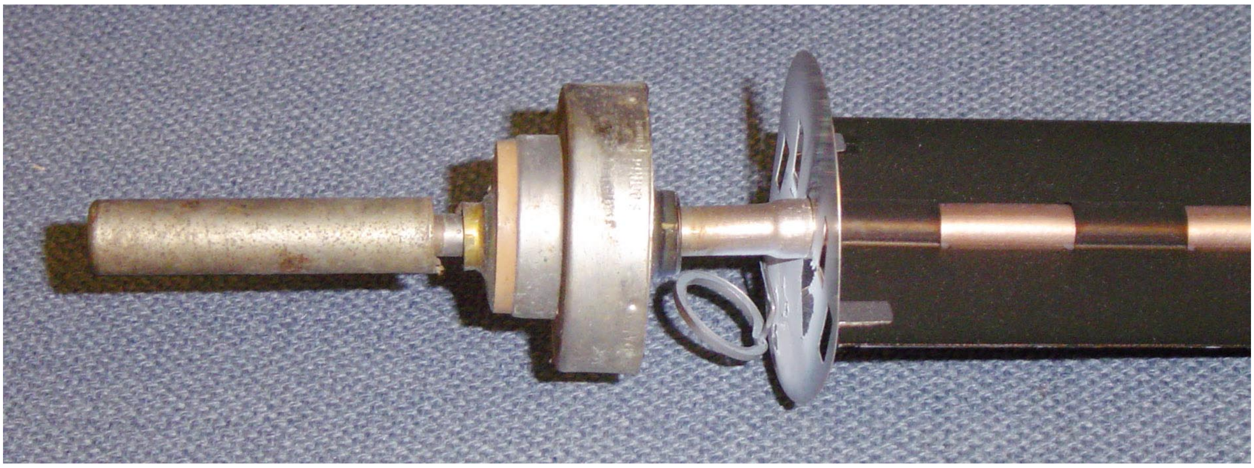
Implosions are noisy. It must be kept in mind that even people of the most confident disposition may be startled into falling by a loud bang close to them, especially if accompanied by flying glass. This should be taken into account when working at height with evacuated tubes.

Getters

When evacuated tube collectors are fabricated, any gasses remaining after most of the air has been pumped out are removed with a getter. A getter is a small, usually circular trough filled with a metal that reacts quickly with the residual gas. Once the tube envelope is evacuated and sealed, the getter is heated to a high temperature (usually by radio frequency induction heating) causing the metal to evaporate, adsorb or react with any residual gas, and deposit a dark metallic mirror like coating on the inside of the tube. The getter continues to absorb any gas molecules that leak into the tube during its working life. If a tube develops a crack in the envelope, this deposit turns white on reaction with the atmosphere.

The hazard here lies in the possible toxicity of the getter material. As an example, one common getter metal is barium which is toxic[3], accumulating in muscle, lungs and bone while having adverse effects on the nervous system, gastrointestinal tract, heart, respiratory and other organs[4]. In general it should be assumed that the metals used in getters are esoteric, reactive and toxic, and if entering the body via cuts from broken glass or inhaled dust, may have high bioavailability. Seek medical advice if exposed to these materials, and keep a sample for analysis.

Below, the getter ring and some of the white residual getter chemical deposit found in an evacuated tube just under the central copper coloured heat pipe.



Heat Pipe Contents

Some evacuated tube collectors use a device called a heat pipe to move heat from the collector plate to a water filled manifold or heat store. These are generally fabricated in copper or steel to withstand significant internal pressure when in use. They are not as they may at first appear solid metal, and although some manufacturers use innocuous materials such as water under reduced pressure as the heat transfer medium in their products, others have used organic compounds such as hydrocarbons or other volatile organic materials. While these products may not have high acute toxicity, the possibility exists that some manufacturers may have used less benign materials, and the manufacturers should be consulted to establish if any special disposal precautions are required.

On no account should heat pipes be disposed of on a fire. Apart from the risk of mechanical explosion due to the superheating of the contents, the contents themselves may be flammable, and some may produce toxic combustion products.

Funding Sources

At the present time we are aware of no sources of grant funding for solar water heating projects specifically for dairy farming.

If the farm has diversified to offer significant community access and the community is being made aware of environmental work on the farm, it may be worth applying for funding under the Clear Skies community scheme, but the justification will have to stem primarily from community experience and learning.

Please contact us for up to date details of any schemes that may have emerged since the initial publication of this document.

Some schemes including Clear Skies requires work to be carried out by accredited installers, which is likely to preclude the funding of DIY installations unless you have become accredited as an installer, can carry out the work to the required standard, and are willing to have it inspected.

In some circumstances some solar thermal equipment may qualify for 0% Energy Efficiency Loans and Enhanced Capital Allowances. Check to see if the products under consideration are approved for these before purchasing.

Performance Monitoring

There is great benefit to monitoring the performance of renewable energy systems and sharing information about them.

As fuel prices rise, information and experience collected by users will have increasing value in supporting decisions about the wider adoption of sustainable energy sources.

T4 will be pleased to suggest approaches to monitoring the performance of any equipment. Some of the techniques now available, especially for temperature recording, are simple, relatively low cost, and may also be applied to the monitoring of stored food, other agricultural processes and the wider environment.

Left (centre), a temperature data logger with programmable sample rate, that is cheap, robust, water proof, food safe, and requires no external connections while in use. It has a wide temperature range and can be used for monitoring solar temperatures. The device is programmed and data accessed when necessary using a standard PC.

Conclusion

As cost increases among primary fuels are passed on to the consumer, solar heating is likely to become more competitive, possibly paying for itself more than twice over during its anticipated life on sites with high hot water demand such as dairies.

Even without subsidy, dairy solar water heating offers an opportunity to benefit from, and gain experience in, the deployment of renewable energy systems, which in the long term are likely to be significant financial assets to the farmer, in both financial and environmental terms, and also offer a broader benefit to society as a whole by the protection of global resources.

Unfortunately these benefits cannot be realised unless the end user is willing and able to invest in them, and if there is significant global benefit, it might also be asked if the farmer should be asked carry this cost alone.

Most farmers contacted take the view that the capital cost is significant, and such investment cannot be a priority in the current agricultural economic climate. Consideration might be given to setting up funding schemes so that the benefits of this opportunity to use renewable energy can be delivered, for both local community and global benefit.

As long as the more cost effective energy conservation measures are already in place, then the increased deployment of renewable energy among SMEs such as farms should be supported to encourage wider uptake in industry, and complement the increase in uptake in the domestic sector.

To date, central government and many local authorities have recognised the benefits of promoting solar water heating in the domestic sector through various funding schemes. By contrast, little has been done in the agricultural sector, despite the fact that the larger and more consistent hot water demand should offer greater financial and environmental benefits per unit investment. Schemes have been a success in other countries however including Australia[16].

References and Acknowledgements

[1] Cloud cover and increased scattering of radiation when the sun is low in the sky exacerbate the short day length, and as a rule of thumb, only 20% as much solar energy is available on a mid winter day as a mid summer day. Cold air further reduces the performance of flat plate collectors in winter, and the water to be heated starts from a lower temperature as both rising main, and water stored in tanks in loft spaces are colder.

[2] Tedlar® polyvinyl fluoride (PVF) is part of the DuPont fluoropolymer family. See http://www.dupont.com/tedlar/ for details.

[3] See http://physchem.ox.ac.uk/MSDS/BA/barium.html and http://www.acialloys.com/msds/ba.html

[4] See http://www.rense.com/general21/tox.htm

[5] See http://www.dti.gov.uk/renewables/publications/pdfs/sp300272.pdf and http://www.dti.gov.uk/NewReview/nr42/html/training.html

[6] Reproduced with thanks to the Nottingham Energy Partnership Sungain scheme.

[7] Reproduced with thanks to Barry Johnson, Managing Director, Solar Twin Limited.

[8] The DTI funded renewable energy grand scheme. See http://www.clear-skies.org/

[9] Farm Energy Centre, NAC Stoneleigh, Dairy Energy Efficiency fact sheet TN27.

[10] Some content and phrasing thanks to the Shine 21 training material.

[11] The book *Hubberts Peak: The Impending World Oil Shortage*, written by a petroleum geologist, has an interesting but accessible analysis of this issue. Author, Kenneth S. Deffeyes, 2001, Princeton University Press. TN 870 .D37 2001.

[12] See http://www.brookes.ac.uk/other/uk-ises/facts.htm
UK ISES, "SOLAR ENERGY - BASIC FACTS".

[13] See http://www.met-office.gov.uk/climate/uk/location/england/sunshine.html to get an idea of the energy availability distribution throughout the year.

[15] Examples include http://www.nyserda.org/wms/docs_program/agguide.pdf from the State of New York, which seeks to promote the use of solar energy in a variety of agricultural applications, and http://www.pcmsolectric.co.nz/page8.html which speaks highly of the reliability and ease of use of a large retrofit dairy solar thermal system, and http://fodok.jku.at/fodok/forschungsprojekt.xsql?FP_ID=335

[16] See http://www.seav.vic.gov.au/renewable_energy/shw/shw_rebate_farms.asp

Appendix 1 - Clear Skies Inspection Checklist for Solar Thermal

Documentation

1) Documentation left with building occupier.
2) Solar system commissioning certificate completed and signed.
3) Cylinder/store commissioning certificate completed and signed (if store replaced).
4) Signatory on solar commission certificate to be noted.
5) User instructions left and indicate safe operation instructions.
6) Transfer fluid type fluid level tolerance and circulation rate tolerance indicated Method and frequency of checking is stated.
7) DHW solar temperature adjustment, DHW drain location and DHW isolation points recorded.
8) System schematic drawing (mechanical and electric).
9) Specialist maintenance tasks, schedule and parts list.
10) User actions to prevent overheating are stated (if required).
11) Manual DHW drain-off method to prevent over-heating is prescribed and safe (If required).
12) Schedule and method of testing safety valves (where fitted).
13) User actions to prevent freeze damage to be stated (if required).
14) De-commissioning method including any hazardous substances to be stated.
15) Confirm previous site visit and that risk assessment was carried out before giving a quote.
16) Evidence of limescale assessment by installer/householder.
17) Expected thermal performance in kWh per year to be stated.
18) Freeze damage protection measures used and lowest safe ambient temperature is stated.
19) Written warning if expansion tank is insufficient and under which conditions.
20) Evidence of legionella risk assessment and suggested method of control.
21) Written warning if there is potential for airlocks or component failure during or after stagnation.
22) All end-user and manufacturer's instructions for all installed solar water heating equipment shown and explained to end-user. Document storage location to be explained.
23) Where required by the Pressure Equipment Directive (pressure has potential to exceed 0.5 bar and temperature over 110 celsius), evidence left on site of compliance with essential safety requirements with CE mark.
24) Manufacturer’s written installation requirement’s to be left on-site for any fitted electrical and mechanical equipment.
25) Product list labelling criteria for store (copy of label provided in documentation): manufacturer, serial no, year of production, country of production, maximum operating secondary pressure, total water volume, weight, dimensions, number of exchangers, maximum operating exchanger pressure, dedicated solar preheat volume, volume of each heat exchanger, area of each heat exchanger, label informing if the system is a direct system, heat exchanger position for solar system.
26) Product store listed as approved by Clear Skies Labelling and type of replacement store to building regulations.
27) Product list labelling criteria for collector (copy of the label provided in

documentation), manufacturer, serial no, year of production, country of production, glazing format, absorber insulation, area, stagnation temperature, maximum operating pressure, volume, weight when empty.

Electrical

1) Low voltage (LV - including 240 VAC) electrics to BS7671.
2) LV isolation switch and fuse protection fitted.
3) Existing equipotential bonding is refitted. Equipotential bonding fitted in locations of increased shock risk referred to in BS7671.
4) Class 1 equipment such as pumps etc is earthed.
5) All wiring supported and routed reasonably and of correct length.
6) Cable to pump is heat resisting flex.
7) All cabling correct current rating, type and suitable for purpose.
8) Cable sheaths taken into enclosures and glands.
9) All connections are enclosed.
10) Extra low voltage (ELV) if fitted to BS 7671
11) Sensor and ELV wiring dissimilar in appearance to higher (LV) voltage wiring
12) Sensor and ELV wiring of Band I sufficiently separated from higher voltage (Band II) wiring.
13) PV installation (greater than 36 volts) if fitted has isolator and labelling that complies with DTI/Pub URN02/788 (publication can be attained tel. 01235-432450).

Roof

1) Collector glazing seals are weather-tight and sound.
2) Collector temperature sensors clamped & insulated from ambient.
3) External pipes insulation to be UV and HT standard.
4) No significant shading across collector.
5) Collector orientation checked with that on application.
6) Any auto air vent if fitted must have an isolation valve.
7) Roof fixings robust and weather tight. Roof penetrations i.e. sarking felt made good.
8) Collector mountings fit for purpose.

Operation

1) Indicator of circulation evident for end-user.
2) Electrical controls and sensors are operating sensibly.
3) Cistern, gauges or other fluid indicators at the commissioned settings.
4) Reverse flow protection identifiable from schematic.
5) If a hot water store does not have an open vent then a combination of thermostatic control device, energy cut-off device and heat dissipation method should be present, (i.e. unvented stores and sealed thermal stores).
6) If a hot water store has an open vent it must have at least a thermostatic control or a temperature relief valve.
7) Is there potential for airlocks or equipment failure after stagnation.

8) All safety devices to operate correctly.
9) Check for excessive pump noise.
10) Check provision of key system functions (circulation, temperatures).
11) Condensation prevention in unheated areas.
12) Store temperature sensor capable of 100°C.
13) New boilers fully pumped with interlock. Existing cylinders to have interlock with thermostat on fully pumped systems.
14) Solar system not to preheat combination boilers or instantaneous water heaters unless the appliance is suitable (confirmation in writing from a manufacturer).
15) Sufficient expansion capability in cisterns and vessels.

General

1) Prevention of water backflow into potable rising main by check valve. Filling loop is disconnected.
2) Sufficient drain points to enable all pipes to be drained.
3) Materials are rated and Water Regulations Advisory Scheme listed at stagnation temperature and pressure.
4) Open vent termination over correct cistern
5) No obstruction before safety valves or vents. Vents and discharge pipes to be correctly graded and exhaust locations are safe – no scald risk to people.
6) Sound engineering practice to be used or evidence left on site of higher conformity according to the Pressure Equipment Directive. All pressure components to be labelled and identifiable.
7) Pipe clips and insulation to be sufficient for stagnation temperatures.
8) All indoor components in unheated areas to be sufficiently protected from freeze damage.
9) Anti scald measures are in place e.g. controller can be set or auto blend valve is fitted.
10) Pressure relief measures will operate before failure risk of most vulnerable component.
11) Appropriate lime scale reduction measures employed for collector loop.
12) Solar control present to be capable of limiting store below 60°C in high hardness area or exchanger cleaning facility to be provided.
13) If replaced, DHW back-up heat source to have time switch.
14) If replaced, DHW back-up heat source to have correctly located thermostat and interlock.
15) On replacement cylinders, all connected pipes to be insulated where practicable.
16) Product list store sufficient and dedicated pre-heat volume for user requirements.
17) Product list store sensor pockets or digital readout.
18) Check auxiliary heat source is capable of heating store to at least 55'C to prevent legionella.
19) All unions,and glands are free from leaks; no leaking evident elsewhere e.g from pipework joints etc.
20) All pipework is adequately clipped, insulated and components are adequately supported.
21) Pipe insulation to be firmly in place and secured at junctions and corners.
22) Penetrations in building made good. Debris removed.

Appendix 2 - Project Support, Training and Accreditation

For farmers wishing to undertake installation work themselves, there are a number of local organisations providing training and support. Please contact us for up to date details.

One nationally recognised course is ‘Shine 21’[5] which also results in a recognised accreditation seen as an indication of competence. We endorse the use of this course and its materials, both for initial training and reference.

The DTI funded Clear Skies renewable energy grant scheme[8] also accredits installers, and this is a strong indicator of demonstrated competence and experience.

Project advice and less formal training may also be available from some national and local groups. The Centre For Alternative Technology runs courses on solar water heating as has Energy 21 and many of its member groups. More locally the Derbyshire Alternative Technology Association has advised farmers to help them assess which systems are most appropriate to their needs.

Centre for Alternative Technology,
Machynlleth,
Powys.
SY20 9AZ
http://www.cat.org.uk/
01654 702782

Energy 21,
The Energy Store,
Estate Yard,
Castle Combe,
Wiltshire.
SN14 7HU
http://www.energy21.org.uk/
info@energy21.org.uk
01249 782000

Derbyshire Alternative Technology Association,
c/o 181 Belper Road,
Stanley Common,
Ilkeston,
Derbyshire.
DE7 6FT
http://www.DerbyshireAta.org.uk
info@DerbyshireAta.org.uk
0115 9448911

Appendix 3 - Project Contacts

This document has been produced for the Nottingham Energy Partnership by T4 Sustainability Limited, and funded by the Greater Nottingham Partnership.

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T4 will be pleased to respond to any technical queries arising from this report re solar energy, or any other renewable energy or energy conservation issues.

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