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Making business sense of climate change

Energy Efficiency in Plastics Processing

Technical Update 2:

Cooling water

PMMDA

Energy efficient process cooling water supply in plastics processing

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1 Introduction

Plastics processing uses large amounts of energy to heat raw materials and to form these into products. In every case there is also a need to remove this heat from the process to solidify the plastic and complete the process. This means that the provision of a reliable and consistent source of cooling water is essential for fast and repeatable process times in all sectors of the plastics processing industry. Whilst there is a great deal of emphasis in the plastics industry on energy efficient heating and processing of the plastic, there is much less emphasis on energy efficient cooling – a process that uses as much, if not more, energy and a process with huge opportunities for energy efficiency improvements. Energy consumption in the general plastics industry could be reduced by between 10 and 15% but the potential for savings in area of cooling are even greater and it is estimated that energy savings of 25% are easily achievable without any technical risk. Cooling and refrigeration plant uses approximately 11% of all the energy consumed in manufacturing in the UK. Implementing good practice and proven technology could significantly reduce this expenditure.

This Technology Update is designed as a primer to a range of no cost low cost actions and measures that can easily be taken to reduce energy usage in providing cooling process water for plastics processing.

Measures of performance

Energy Efficiency Ratios

COP is the ratio of the cooling capacity to the absorbed power of a compressor.

CSOP is the ratio of the cooling capacity to the absorbed power of the complete system. This includes the effect of the power consumption of fans and pumps as well as the compressor.

COP and CSOP can be used to indicate the relative energy efficiency of the chiller or the system and to compare systems with one another.

The measurement of COP and CSOP are dependent on the conditions used to asses them and should only be used for comparison when identical conditions are used.

Good practice tips

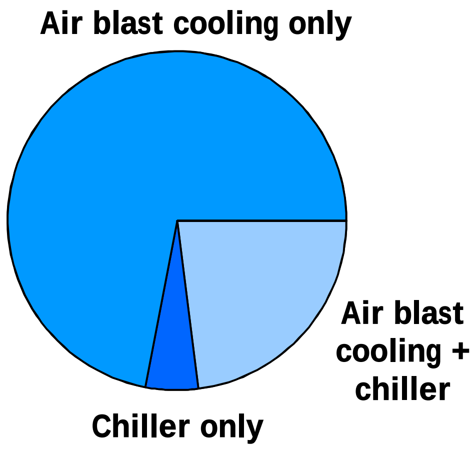
- Cooling plant efficiency can be improved by a multitude of measures; the main task is to decide between the competing measures.
- Cooling plant is generally reliable and tends to be ignored unless there is a problem. Regular analysis of performance data is recommended to enable any loss of efficiency to be detected before complete loss of service.

2 Air Blast Cooling

Standard chilled water system installations do not take full advantage of cold ambient weather conditions and constantly use energy to provide the cooling. It is, however, possible to use low ambient temperatures to pre-cool the return water from the process and to considerably reduce the chiller load and usage.

Low ambient temperatures are experienced for a large part of the year in the UK and the ambient temperature is below 15°C for almost 75% of the year (see chart at right). During these periods air blast cooling can be used to considerably reduce energy costs.

Air blast cooling is particularly suitable for use in the plastics processing industry in the UK because the ambient and flow temperatures involved in plastics processing are relatively similar and air blast cooling can be used to its best advantage.



Percentage of year that air blast cooling is active

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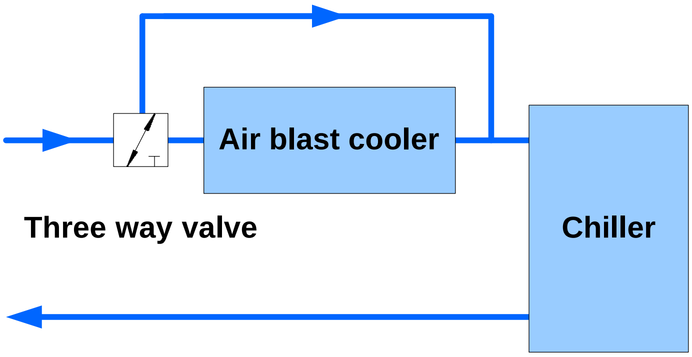
Installation of an air blast cooler as a free cooler into the cooling system can produce significant energy savings for minimal additional capital costs.

Air blast cooling in practice

The installation and operation of air blast coolers as a pre-cooling or total cooling system is straightforward and a typical installation of an air blast cooler is shown at right.

If the ambient temperature falls to 1°C or more below the return water temperature then air blast cooling can become effective and the automatic 3-way valve operates to divert the return water through the air blast cooler section. This pre-cools the water, reducing the load on the main chiller and therefore reduces the energy use and cost[1].



Schematic of air blast cooling installation

The lower the ambient temperature falls below the return water temperature, the greater the air blast cooling effect. When the ambient temperature is as little as 3°C below the return water temperature the pre-cooling achieved is sufficient to switch the main chiller off completely and the chiller load is reduced to zero. The only energy consumed at this stage is that used to drive the fan motors of the air blast cooler.

The physical layout of an air blast cooler consists of a finned copper tube, an aluminium fin matrix and a 3 way valve with electronic microprocessor control that follows the external ambient temperature to control the switching of the return water to the air blast cooler when ambient conditions allow it to be effective. Varying the fan speed or progressively cycling the fans according to the ambient temperature controls the amount of cooling achieved by an air blast cooler.

Air blast cooling provides extremely low cost cooling of process water and the energy savings generated by reducing or eliminating chiller usage have a typical payback period less than 2 years and can be as little as 12 months in many cases. Installation of an air blast cooler increases the potential life of the main chiller unit by reducing the usage and acting as a standby for the main chiller system.

Typical air blast cooling installation

Air blast coolers can supplied as standard equipment for new chiller installations or they can be retrofitted as an additional cooling loop to existing cooling systems to improve their energy efficiency. For new systems, air blast cooling is generally available as a factory fitted option and for space saving it can be incorporated within a conventional air-cooled chiller. In this case, the air-cooled chiller contains two coils. The first inner coil is the conventional condenser and the second outer coil is the air blast cooler. For retrofitting the air blast cooler is simply fitted to the return water flow to provide low cost pre-cooling for the existing chiller system.

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[1] Note: In the case of a retro-fit installation it should be established that the existing chiller can run at part load in order to achieve the full benefits of air blast cooling.

Whether new or retrofitted the air blast cooler only operates when the ambient conditions are right and it then provides low cost pre-cooling to enable reductions in chiller operating costs.

Adiabatic Cooling

If lower temperatures are required it is possible to fit an air blast cooler with a water mist system to provide additional cooling capacity. The spray system is only activated for the very limited time when ambient temperatures are at a maximum and the operation uses minimal water to provide the additional cooling reserve.

Good practice tips

- Chillers with air blast cooling circuits can show large reductions in operating costs.
- Chillers with air blast cooling circuits have reduced compressor running times, maintenance costs and extend the life of the chiller.
- Air blast coolers are available for capacities as low as 5 kW with no effective upper limit as units can be linked together to provide greater cooling capacity.
- Chillers with heat exchangers can transfer recovered heat to other areas of the factory.
- The size of the overall chiller package should be capable of providing the total cooling load to cope with the short periods when air blast cooling is not operational.

A Case Study on the use of Air Blast Cooling at Anson Packaging is available as a separate publication.

3 Chiller Cooling

Many plastics processing plants have conventional chillers installations to provide cooling water and in these installations the biggest energy user is the chiller unit itself. Every chiller is basically a compressor that is pumping refrigerant and for every 100kW of cooling capacity a chiller will consume approximately 30kWh of electricity. Even a small plastics processing site can need a 200 kW chiller and the operating cost of this can easily exceed £16,000 per year, larger sites will need proportionately greater chillers and the costs will also be proportionately greater – these are not trivial amounts of money, especially when they can easily be reduced.

Despite the fact that chillers use large amounts of energy they tend to be ignored as simply providing a ‘service’ to the factory. The energy efficiency of existing installations can easily be significantly improved through simple maintenance and process improvements.

As with many energy intensive systems, the total cost of ownership is far greater than the initial purchase cost. For a typical water chiller operating full time then over a 10-year life cycle the energy costs will be 90% of the total cost and the initial capital cost will be only 9% of the total cost.

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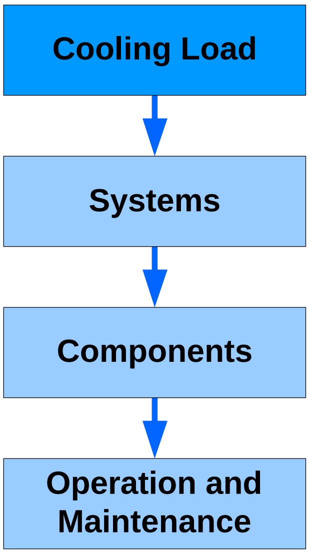
Good practice tips

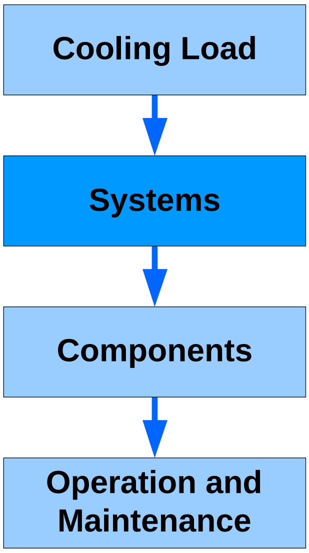
Cooling Load



Eliminating or reducing the cooling load on the system will have a significant impact on the running costs of any cooling installation and identifying the loads and reducing these is critical to improving energy efficiency. Areas for improvement are:

- The provision of cooled water to areas where it is not needed adds unnecessarily to the cooling load. Only supply cooling to areas that need it.
- The correct and *maximum* temperature of cooling water should be used. Every 1°C temperature rise in the output supply temperature from the chiller will reduce the energy required for cooling by approximately 3%. Overcooling is a large factor in excessive energy use. Simply setting the cooling temperature to the maximum appropriate to the process will reduce the energy consumed.
- Parasitic loads (cooling the room and other pipe work) should be minimised by maximising the use of pipe and other component insulation. This is particularly relevant where cooling water pipes are located in or go through ‘service blocks’ that contain boilers and hot water pipes but heat gains can occur on any long runs of piping where the pipe is inadequately insulated.

Systems



A minimised cooling load allows a realistic assessment of the cooling system design, particularly in the way the system responds to part load operations. Areas for improvement are:

- Optimisation of the existing chiller system is a key to reducing energy use and in many cases changes have taken place in the system since it was first installed. Systems should use the most suitable refrigerant and also be optimised for high part-load and winter efficiency. This is particularly important where additional chillers have been added to the system to provide multi-chiller capacity.
- Pumps and the chillers should be balanced and carefully matched to the normal load with controls available to match a variable load with multi-chiller capacity.
- Changes in the system often mean that pipe work has been extended or deleted without considering the resulting change in the load and efficiency of the pumps at the increased or decreased pressures. The pipe work and pumps need to be sized for the current demands and pipe work needs to be well insulated to minimize parasitic loads for efficient operation.
- Chillers generate large amounts of heat and heat recovery, using de superheaters and heat recovery condensers, should be investigated to recover this heat for use in other areas of the factory.
  Warm air discharged from the chiller at about 10°C above ambient can be ducted off for space heating and contains about 130% of the heat removed from the process.
  Heat can also be recovered from the super heated high-pressure refrigerant exiting the chiller’s compressors by using de super heaters with no affect on the compressor performance. Approximately 15% of the load can be recovered as hot water for use in preheating boiler feed water, process heating, or feeding a space heater.
- Even if heat recovery systems are to be used, it is important that chillers are well ventilated to provide good airflow over condensers.

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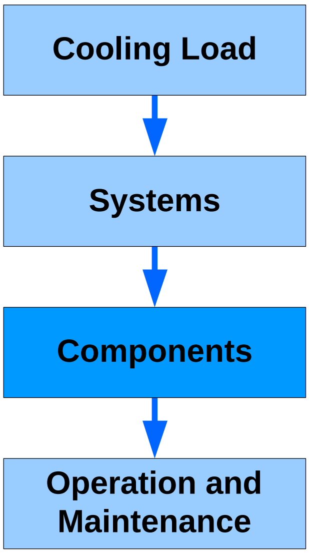
- Utilise a retrofitted air blast cooling system (see below) to use the low ambient temperature conditions for cooling.

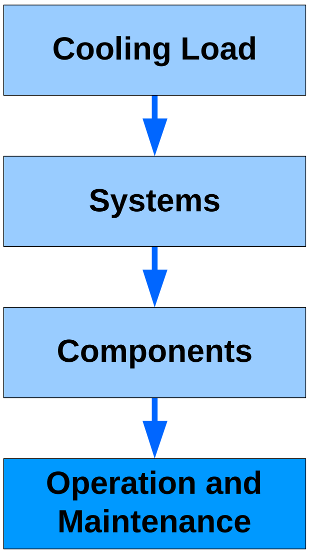
Components



Component selection is a key to energy efficient operations and areas for improvement are:

- New technology chillers feature more efficient scroll and screw compressors and refrigerant gases. These are significantly more energy efficient than older chillers and can be considered as direct replacements for existing chillers if cooling load and systems investigations find this to be appropriate (see the Box on 'Measures of performance' to reliably compare competing systems). When sizing the compressor to match the cooling load avoid running the compressor at low load to maximise efficient operation.
- Where part loads are a realistic requirement, e.g. when using air blast cooling, then multicompressor chillers which perform better under part loads should be considered.
- The majority of pumps and fans in cooling applications UK are oversized for the actual demand and are fixed speed motors. This increases energy consumption unnecessarily because the pump speed cannot be matched to the demand. A 20% reduction in pump speed gives a 50% reduction in energy consumed. Always use variable speed drives (VSDs) and high efficiency motors for circulating pumps and fans to save energy and to match the power requirements to the process demands.
- The selection of energy efficient products can be assisted by referring to the ETL list which is used to assess the suitability of a product for Enhance Capital Allowances.

Operation and Maintenance



It is common for cooling systems to be operating at well below their potential efficiency due to neglect in carrying out routine maintenance tasks. Simple operation and maintenance procedures to improve energy efficiency include:

- Records should be kept of plant conditions (to identify trends) and regular servicing (such as purging of condensers) should be carried out to maintain efficient operation.
- Regular checks on flow and return temperatures and system flow rates should be carried out to verify that these are maintained at the correct and optimum settings. This can act as an early warning of possible degradation in compressor efficiency.
- Systems should be gas tight and have the correct charge of the correct refrigerant. New refrigerants (to replace older refrigerants that are now prohibited) are more efficient and can reduce chiller operating costs by between 12 and 30%. Whichever refrigerant is being used the refrigerant loss should be monitored and any leaks repaired. Under EU Regulations it is required that all refrigeration equipment containing more than 3 kg of gas must be leak tested at least annually.
- Dirty evaporators, air blast coolers or heat exchanger surfaces are less efficient and these should be cleaned regularly to maintain high efficiency.
- It is not logical to provide cooling that is inefficient at the point of use (the mould or extrusion cooling bath). Moulds and cooling baths or spray tanks should be designed to provide good heat transfer from the plastic to the cooling water. For moulds, hot runners should only be used where necessary because 80% of the energy input to hot runner systems must eventually be removed by the cooling system. This must be

balanced against a possible need for hot runners to obtain a practical moulding and the increase in cycle time and cost of cooling the sprue and runner.

- Water pumps and all systems components should be automatically turned off when not in use. The most cost effective way of saving energy with cooling systems is to not use them when they are not needed.

Contributing companies:

Produced with the assistance of member companies of the PMMDA:

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Golding Machinery

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