Energy and Sustainability Topics – Energy Saving Tips of the month

TANGRAM TECHNOLOGY Consulting Engineers

Tangram Technology Ltd.

33 Gaping Lane, Hitchin, Herts., SG5 2DF

Phone: 01462 437 686

E-mail: sales@tangram.co.uk

Web Pages: www.tangram.co.uk

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Contents:

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Introduction

From May 2009 until October 2019, we produced a series of Energy Saving Tips of the Month in Plastics Engineering. Internally these were termed the ‘Recipe Cards’ as the concept was to produce a series of very short cards on the basics of energy management.

These are reproduced here to allow readers to have a short introduction to the main topics of energy management in plastics processing.

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1. Getting started - Energy Management Systems

There will be no progress in managing energy use unless it is on the Management Agenda. If energy use is not visible and measured then there will be no improvement.

Every site needs an ‘Energy Policy’ - a statement of commitment on energy use. This should include improvement targets for the short, medium and long terms. The policy should be widely distributed to encourage awareness of the costs and benefits of energy management.

Energy management should be the clear responsibility of Production because they control most of the energy use. An ‘Energy Manager’ can only act as the scorekeeper and the process should be driven by Production. Funds and time should be allocated to carry out energy management projects.

Monitoring and targeting (M&T) are fundamental for energy management. A lot of data is probably already being collected but energy management is not about data, it is about providing information to target improvements. Targeting is the key action - what gets measured gets done!

Action:

- Create and distribute a formal site Energy Policy.
- Assign clear responsibilities for energy management.
- Gather initial data and convert this into information to manage site energy use.
- Use the performance information to target improvements.
- Publish performance information widely.

2. Integrating energy into the accounts

One of the quickest ways to start to control energy use is to integrate the reporting into the accounts package (along with all the other vital business numbers). Energy use and management is not a ‘technology fix’, it is a vital business measurement and tool and some of the most effective energy management efforts can come directly from the accounting function.

Accountants are familiar with calculating the total costs for a site from the fixed and variable components, where: Total cost = (Production volume x unit variable cost) + Fixed costs. The use of a similar approach for energy management will hold no surprises for most accountants. This allows energy management to be treated as with any other cost element.

The aim is to achieve cost-effective energy management. Integration of energy reporting into the accounting function allows energy to take its place on the management agenda as a part of the normal management of the site.

Action:

- Get the accountants involved in recording, verifying and publishing the numbers for energy use.
- Get the accountants to treat energy use as a variable cost that can be allocated directly to the process and area involved.
- Energy costs can affect product profitability - make sure they are allocated correctly.
- Get the accountants involved in project assessment - they can help with the numbers.

3. Site surveys

Carrying out a full site survey is a specialist task but a mini-survey or walk-around will quickly and easily identify many actions to reduce energy use. Naturally, the focus will be on using that essential tool called the 'OFF switch' but this can have remarkable rewards very quickly.

Look for:

- Equipment that is not in production but has motors, heaters or downstream equipment running.
- 'Accepted' practices that are wasting energy and that can be modified at no cost.
- Simple maintenance measures that can be introduced to reduce energy use.
- Simple methods to stop machinery operating when it is not being productive.
- Simple methods to change the way the site works.

A survey is useless unless action is taken as a result of the findings. A clear and concise report must give the findings, possible projects and, above all else, drive action.

This is not about finding projects but about completing them.

Action:

- Carry out a mini-survey NOW.
- Make notes, take photographs and gather evidence.
- Produce 'Non-Conformance Reports' (as for your Quality system) that must be actioned.

4. The electricity bills

Many sites simply get the energy bill from the supplier and pay this some days later by direct transfer from their bank. The bill is not examined for accuracy or for potential areas to reduce costs and sometimes the Production people don't even see a copy of the bill - even though they are responsible for using most of the energy. Can you think of a better way to waste money?

Sites need to understand the essential information that the energy bill contains. This is real money that we are spending here.

Bills will have a combination of variable charges (for the actual kWh used and sometimes for reactive power used) and fixed charges (for meters, available capacity).

Action:

- Always examine the bill. Billing errors are not uncommon!
- Find out if the supplier can provide energy data (1/2 or 1/4 hourly data) in a spreadsheet. Get this and learn how to analyse this for patterns over time, especially when no production is taking place.
- Manually read the meters each month or get the data from the supplier.
- Set up an internal spreadsheet to check all charges on the bill (fixed and variable) and use this to calculate the bill from the meter readings or from the supplier data.
- Look at the fixed charges for possible cost reductions (Maximum Demand reduction is a quick win).
- Look for improvements in the Power Factor (PF) to reduce reactive power charges (if applied).

5. Assessing performance - electricity

In most plastics processing electricity is the main energy source. Electricity use is not, as is sometimes thought, fixed and uncontrollable, it is variable and controllable. For most sites the electricity use will be directly related to the production volume in a given time period.

It is possible to show this by plotting electricity use against production volume (processed amount of plastic) in the month or week as a scatter chart and finding the linear line of best-fit to the data. The equation of the line-of-best fit is the Performance Characteristic Line (PCL) for the site. This gives an insight into how the site functions and can be used for monitoring and targeting as well as for budgeting purposes. The PCL is the 'energy fingerprint' of the site and varies with every site. It gives important information on how the site functions.

Action:

- Plot electricity use against production volume (processed amount of plastic) in the month as a scatter chart. Use the spreadsheet to find the equation of the linear line of best-fit.
- The intersection of the line of best-fit with the electricity use axis is the 'base load'. This is the energy use when no effective production is taking place but machinery and services are available. This should be approximately 30% of the total load.
- The slope of the linear line of best-fit is the 'process load' for the site and shows the average energy being used to produce each kilogram of polymer. The process load is process specific and varies with the process.

6. The gas bill

Most plastics processing sites use gas simply for space heating but some processes use gas as part of the process, e.g., rotational moulding.

Where gas is used for hot water then this is generally relatively constant over the year. For space heating the gas use load will be related to the weather conditions (how cold it is) and the weather is then a ‘condition’ driver for gas use.

Where gas use is part of the process then use will be driven by both the activity (production) and the condition (weather). The two drivers will need to be separated either by sub-metering or by statistical analysis - but sub-metering is preferable.

Action:

- Plot gas use against time. If it is used for space heating only then you should see peaks in winter and troughs in summer.
- Plot gas use against the ’heating degree-days’ in the month as a scatter chart. ‘Heating degree days’ is a measure of how cold it is in a specific area. There should be a linear relationship, the Performance Characteristic Line (PCL) for the heating system - if not then find out why.
- Use the PCL to assess heating system performance.
- If gas use is part of the process, then recording meters allow gas use to be related to production volume via a PCL - as with electricity use (see last month).

7. Injection moulding 1

Injection moulding is one of the most common plastics forming processes and has made many technical advances in recent years. Injection moulding machines have 'base' and 'process' loads and an idling machine is not 'free', it is costing large amounts of money.

Injection moulding machines use energy even when idling; the amount varies with the machine but can range from between 52% and 97.5% of the full moulding energy consumption. For idle periods of greater than 20 to 45 minutes it can be cheaper to switch off and restart. At the very least, the system should switch off unneeded services and functions, i.e., the main hydraulic motor.

Action:

- Check that all jobs are on the smallest machine possible - small jobs on large machines waste energy.
- Plan and control the start-up sequence to limit the Maximum Demand.
- Fit a warning device to sound or flash when the Maximum Demand approaches the allowable limit.
- Measure start-up energy use, idling energy use and operating energy use to find the relative costs.
- Define an 'idling' mode for all machines - heaters reduced, hydraulics off and compressed air off.
- Stop supplying services (compressed air and cooling water) to idle machines.
- Switch off barrel heaters and cooling fans between runs.
- Design handling systems to operate 'on–demand' only.

Energy and Sustainability Topics – Energy Saving Tips of the month

8. Injection moulding 2

Simple process energy measurement and analysis quickly and easily shows that machine selection and operation can dramatically affect energy use and profitability of injection moulding.

Barrel heating efficiency can be improved by using insulation and by making sure there is good contact between heater bands and the barrel.

Action:

- Monitor machine energy use to identify changes in the machine condition.
- Good maintenance can give significant energy savings. Look at areas such as temperature controllers, hydraulic valves, hydraulic oil viscosity and screw wear.
- Investigate process settings and look for areas where changes can be made. Look for areas such as barrel temperatures set too high, back pressure set too high, clamp force set too high, hold pressure too high, hold time too long, cooling time too long.
- Heater bands should be ‘bedded-in’ by repeatedly tightening and loosening the heater band to get a good seating and by using a conductive metal compound between the heater band and the IMM barrel to maximize the heat transfer.
- Integrally insulated barrel heating bands reduce energy consumption used in heating by up to 17%, depending on the machine and application. Check the heater bands being used and calculate the costs/benefits of replacing these with insulated heater bands.

9. Injection moulding 3

All-electric machines are more energy efficient than hydraulic machines in both controlled trials and from industry operational data.

For some existing machines the installation of retro-fitted Variable Frequency Drives (VFDs) can be used to control the motors and provide a pay-back of less than 18 months.

Mould temperature controllers are not free. They cost money to operate and should be used only when really necessary. Flow and return piping should be insulated where possible to keep the heat where it is needed.

Energy efficiency in mould design is rarely considered but cooling, the size of sprues and runners and how the part is ejected all have energy use implications that should be considered at the design stage.

Action:

- Check the economics of all-electric machines. The pay-back may make it economic to invest in new technology.
- Check the economics of retro-fitted VFDs. For large machines with high operating hours and long cycle times the pay-back may make it economic to invest in this technology.
- Check that mould temperature controllers are being used wisely and that all piping is insulated.
- Make sure that mould designers are aware of the need to consider energy use at the design stage.

10. Extrusion 1

Extrusion uses less energy per kilogram of material processed than injection moulding but extruders should not be complacent, there is still much that can be done.

Extruders run most efficiently (not only in energy terms) when operating at the design conditions and the extruder should be set to run at the maximum design speed. Operating extruders below the design speed, e.g., large extruders and small profiles, makes the process less efficient.

Extruder motors run at high speeds and are geared down. When the gear ratios are not correct, the motor will be operating below the optimum speed and the torque generated will be below the permissible levels. Changing the drive ratio can be a simple project to optimize motor use.

Action:

- Investigate the option to retro-fit existing DC motors with VFD controlled AC motors. The energy savings are not large but replacement motors cost a lot less and maintenance is often less.
- If purchasing new extruders then the option for VFD controlled AC motors is highly recommended.
- Check that the extruder is right for the job and is operating close to the design speed.
- Check the loading on extruder motors and modify the gear ratios to optimize motor performance. If pulleys are used this can be as simple as using pulleys of different diameter.
- If belt drives are used then optimize the belts. Belt types vary greatly in efficiency and toothed belts are the most efficient.

11. Extrusion 2

Extruders do not generally benefit from insulation in the barrel area (the need is often for cooling) but most areas downstream of the screw tips (where there is little shear heating) can be insulated to greatly reduce energy use. This includes areas such as breaker plates, adapters, transfer piping for co-extruders and die areas. If the heater band is constantly pulling power, then it will almost certainly benefit from insulation.

Calibration and cooling of the extrudate (profile, sheet or film) are all areas where energy savings measures can be implemented. This is particularly in the area of services, i.e., vacuum pumps for profiles which operate excessively and with little control, excessive use of cooling water for profiles, poor control of cooling air for film, poor control of compressed air used for air knives and poor control of compressed air for product handling. Simple controls and the installation of VFD drives can reduce energy use considerably.

Action:

- Check that heating and cooling (fan blowers) are adequately controlled and are not operating at the same time.
- Investigate all heater bands downstream from the screw tips and fit insulation as required.
- Investigate all services provided for cooling, drying and handling and reduce the use to the minimum necessary to maintain quality and extruder output.
- If using ventilation fans above extruders then use controls to stop these when the extruder stops.

12. Extrusion blow moulding (EBM)

Product cooling time strongly dictates the cycle time in EBM and minimizing the extrudate temperature (just enough to get the parison to form properly) will minimize the cooling time and the load on the cooling system.

The compressed air used for the blowing process should be at the minimum pressure needed to fully form the parison in the cycle. Excessive compressed air pressures simply waste energy. In many cases the demand is for volume rather than pressure and accumulators can be effective in reducing the compressed air pressure.

Tops and tails are accepted as ‘part of the process’ for EBM and some are necessary for the process but excessive amounts of tops and tails wastes the energy used to form them. Even if the material is recycled the energy is lost forever and it takes additional energy to recycle the material. Top and tails must be minimized to reduce energy use and improve productivity.

Action:

- Minimize the melt temperature to improve cycle times and minimize the load on the cooling system.
- Minimize the compressed air pressure used for blowing and investigate using accumulators to provide the transient volume needed.
- Tops and tails (by weight) should not exceed the industry average of 30%. Setting sheets for EBM must include specification of the allowable amount of tops and tails and this should be monitored on a regular basis - measure the parison and tops and tails weight and control using SPC.

13. Injection blow moulding (IBM)

The use of barrel insulation is very effective in most IBM operations and insulation similar to that used for injection moulding machines is very effective in reducing energy use and in preventing Health and Safety issues with hot barrels.

Where IBM is being used to process PET then any recycled scrap can easily be reground for reuse but the material will generally need to undergo recrystallization before it can be used again. PET also needs drying before processing. These two energy intensive processes can be combined by the use of infrared drying to considerably reduce the energy required for the drying/recrystallization process.

IBM tends to use a very high compressed air pressure for the final blowing step and can require compressed air as high as 30-40 bar (430-580 psi). This is much more costly than conventional low pressure compressed air at 6-8 bar (87-116 psi). Sites need to allocate compressed air costs correctly if IBM is being carried out at sites where there are other processes. The IBM process must bear the costs of the high pressure compressed air generation for accurate cost allocation.

Action:

- Barrel insulation of IBM machines is strongly recommended.
- New drying technologies can combine both the drying and recrystallisation of PET scrap into one process and greatly reduce energy use.
- Ensure that services used for IBM/ISBM of PET, e.g., compressed air and drying are adequately allocated in the accounting process to give correct costings.

14. Thermoforming

Where thermoforming uses cold roll stock, it is often run through a pre-warming cabinet to warm the sheet prior to entering the full heater banks. These cabinets are often poorly insulated and have large entrance and exit slots that are not sized to the sheet being warmed. This leads to high heat losses and excessive energy costs.

The entrances, exits and sides of the main heater banks are often poorly sealed and this allows a continuous and considerable loss of heat. If using clamshell heaters, the tops, sides and bottoms of the heater banks can be insulated to not only reduce heat losses but also to remove any Health and Safety concerns with hot surfaces.

Action:

- Reduce input and output slots on pre-warming cabinets to the minimum needed for free movement of the sheet. Excessive gaps simply allow heat to escape and waste energy.
- Improve the sealing and insulation of pre-warming cabinets to reduce energy use. This also includes maintenance of gaskets on access doors.
- Reduce input and output slots on main heating banks to the minimum needed for free movement of the sheet. Excessive gaps simply allow heat to escape and waste energy.
- Improve the sealing and insulation of main heating banks to reduce energy use.
- Investigate the costs and benefits of improving insulation levels around clamshell heater banks.

15. Rotational moulding

Rotational moulding uses gas-fired ovens and gas burner efficiency is important in reducing gas use. Burners get old and need adjustment. Keeping burners in good condition is a key to efficient processing.

After the burners have produced the hot gas, it makes no sense to lose this heat, it should be kept where it is needed, i.e., near the mould. Unfortunately, many ovens are both poorly sealed and poorly insulated. Maintenance and improvement of the insulation and sealing of the oven will have a quick pay-back.

Ovens also use many fans for exhaust and recirculation of the hot gases and for cooling of the hot mould. These are ideal candidates for VFDs.

Action:

- Burner efficiency should be monitored and controlled to ensure that full combustion is taking place.
- Thermographic inspection and burn marks around the oven will show where panels and internal insulation have failed and where seals are old or inadequate. Movement of panels and failure of insulation can lead to large heat losses and seals will become brittle with age.
- Improve the oven insulation with additional retrofitted insulation.
- Improve the sealing of the oven with additional seals, e.g., where the shaft enters the oven and inspection hatches.
- Investigate fans (exhaust, recirculation and cooling) and pumps for opportunities to install VFDs.

16. Start-up and shut-down

Most sites have start-up processes but this rarely includes any consideration of energy efficiency. Everything is simply switched on at the same time and then everybody waits around while the machine warms up. Start-up procedures are needed to bring energy demands on-line at the best/latest possible time.

Shut down of machines should also be carried out properly to reduce energy use. The use of shut-down procedures should be assisted by clearly marked and visible isolation switches that allow complete isolation of the machine services (electricity, compressed air and chilled air) from one simple area with simple on-off valves/switches. Preferably, link downstream equipment to the main machine controls so that when the machine stops then all downstream equipment (conveyors etc.) stops.

Action:

- Manage start-ups effectively to reduce unproductive energy consumption.
- Ensure there is a final check of all settings by the setter before the machine is given to Production.
- Set up a 'shut-down' area to shut down all unnecessary energy use. Automation will assist here if management is not strong enough.
- Set up the procedures to minimize energy use when no production is temporarily taking place.
- Document the procedures, and ensure that setters and operators use them. These are not 'office' documents but must be used in real life. This is real money.

17. Compressed air pressure

The energy cost of running a compressor works by a “square rule” so that compressing air to twice the pressure uses 4 times as much energy and costs 4 times as much. In most plastics processing sites, the compressors are set on a delivery pressure of around 7 bar (100 psi).

Most processing machinery doesn’t need the compressed air pressure this high and many machines have a pressure reducing valve at the machine inlet that takes the pressure down to 4 bar (58 psi) or less. Simply reducing the compressed air generation pressure can save an enormous amount of energy with no effect on production.

Reducing the set point from 7 bar (100 psi) to 4 bar (58 psi) will reduce the cost of compressor operation by approximately 66%.

Action:

- Check the compressed air generation pressure.
- Reduce it by 1 psi but don’t tell anybody otherwise everything will be blamed on the reduced pressure.
- Check for any problems with machines or processes and solve any problems.
- Wait 1 week.
- Reduce the set point by 1 psi again.
- Continue until the set point is minimized.

18. Compressed air leakage

Compressed air losses cost most sites significant amounts of energy and money every year. Most sites have no internal compressed air leakage detection programme and in most of these there will be significant air leaks. The general industry leakage rate for a site without an active management program is in the region of 20-40%. A very good site will have a leakage rate in the region of 10%-15% and an excellent site will have a leakage rate in the region of 5%. Leakage above 10% can be considered to be excessive.

This is not an identification program - this is a rectification program. Don't just find them, seal them! Compressed air leakage control is not a single task that can ever be completed; it is a continuous rolling program of leak detection and sealing that never ends. This program should include refurbishment of existing pipes, hoses and fixtures (replace worm drive and plastic snap fittings with proper crimped fittings where possible).

Eliminating leaks will not only save energy, it will also make the factory quieter.

Action:

- Purchase an ultrasonic leak detector. These allow leaks to be detected even in noisy factories and at up to 6 m away. The leaks are costing money now - why wait for a shut-down to find them?
- Carry out regular internal surveys of selected areas and seal leaks promptly. Note: Leaks will often occur in the same places. Record the location to target areas for further improvements.
- Isolate and seal any unused spurs at the site to prevent leakage in areas with no production.

19. Compressed air use

Compressed air is very expensive to produce. It is not free despite the fact that we treat it as such in the plastics processing industry.

Compressed air is the most expensive form of motive, drying and cooling power available. At the point of application, compressed air costs approximately 10 times (per kWh) that of using direct electric power. Compressed air is used wastefully for product movement, drying, assembly and blow guns at most plastics processing sites.

Action:

- Make a 'Compressed Air Map' for the site. This is a list of all areas where compressed air is used. Do not concentrate on areas where compressed air operates closed cylinders but look very carefully for areas where compressed air is discharged to atmosphere. The Compressed Air Map is the basis for targeting of efforts to reduce compressed air use.
- Carry out an engineering evaluation of the cost of each of these applications by estimating use and cost. Use should be reduced where possible and other methods of motive power or process should be devised by re-engineering the process. This is particularly relevant in assembly areas.
- Investigate the costs of re-engineering the process to reduce the use of compressed air.
- Replace all open flow air guns with energy efficient low-pressure guns.
- Investigate any bowl feeders using compressed air and minimize the use.

20. Compressed air generation

Compressed air is needed for most plastics processing but they are hidden away in the plant room and are not seen as a potential area to reduce costs.

Most older compressors use fixed speed AC motors. These can be running 'on-load' (generating compressed air), running 'off-load' (not generating compressed air but still using energy) or fully stopped (not generating compressed air or using energy). An 'off-load' compressor will continue to use energy at 50 - 75% of the 'on-load' energy use.

Most compressor manufacturers offer the option of a Variable Speed Drive (VSD) compressor. This is a compressor where the motor speed can be varied to match the amount of compressed air produced with the actual amount of compressed air used. VSD compressors are much more economical to run than fixed speed compressors and payback times can be under 1 year.

For sites with multiple compressors, the control system used to set which compressor is run is a critical item. Even systems with a VSD compressor need a good control system to minimize energy use costs.

Action:

- Strongly consider buying a VSD compressor. Most sites will need only 1 VSD compressor. Fixed speed compressors for the base load and a suitable VSD compressor for the variable load.

For sites with multiple compressors, examine and, if necessary, upgrade the control system to rotate compressor use and turn compressors off if they are not needed.

21. Compressed air treatment and distribution

Treatment and distribution of compressed air offer a range of opportunities to reduce pressure, improve flow and reduce costs. Compressed air is a fluid and like any other fluid will suffer from pressure drops as it flows along piping. Minimizing pressure drops means that the system pressure can be set lower and still deliver the same pressure at the point of use.

Action:

- Isolate and seal off all redundant spurs or areas of compressed air piping.
- Ensure that the distribution system is a ring system rather than a spur system.
- Use the right materials for the piping, stainless steel or aluminium piping have lower pressure losses than iron or steel piping.
- Fit the largest diameter piping possible - this will reduce pressure losses and also act as a receiver to reduce pressure fluctuations. Many applications need volume and not pressure but if the piping is small then the pressure will have to be high to get the correct volume of air to the process.
- Regularly get receivers for safety - they are pressure vessels and there are regulations for these in most countries. Mark the date of the check on the receiver so that the retest date is clear.
- Treat compressed air to the lowest possible quality that is necessary for the process.
- Test filters regularly to make sure that the pressure is < 0.4 bar - if the pressure drop is > 0.4 bar, replace the filters as the cost to overcome the drop is greater than the cost of a filter.

22. Reduce parasitic heat gains for chilled water

Heat gains from uninsulated chilled water piping (<15°C) will raise the temperature of the chilled water between the chiller and the point of use. These are called ‘parasitic heat gains’ because they are not serving a useful purpose, i.e., they are not removing heat from the actual process but simply removing heat from the surrounding air.

Good insulation on chilled water piping allows the chiller set-point to be increased and yet still deliver the same water temperature at the point of use. Increasing the set-point of a chiller by 1°C will decrease the chiller energy use by ≈ 3%. Insulation for chilled water piping and other areas will generally have a payback of less than 1 year.

Insulation is not normally necessary on cooling water piping (>15°C) because the parasitic heat gains will be small and the payback time will be long.

Action:

- Use a thermal camera (rent or buy) to examine chilled water pipes/hoses and tooling for areas where a lack of insulation or inadequate insulation is causing parasitic heat gains.
- Check chilled water pipes/hoes and tooling for condensation in warm weather - condensation is a sure sign of high parasitic heat gains.
- Insulate cold areas on pipes/hoses and tooling to reduce parasitic heat gains.
- Increase the chiller set-point to deliver the same water temperature to the process.

23. Increase cooling water temperatures

Many sites use chilled water temperatures that are far lower than are actually needed by the process but they have never actually investigated increasing the set-point. They simply assume that a very low set-point is good. This has a direct effect on the cost of chilled water. The chillers will run much harder to keep to a low set-point. Increasing the set-point of a chiller by 1°C will decrease the chiller energy use by ≈ 3%. Simply increasing the chiller set-point can have a dramatic effect on chiller operating costs.

Where multiple chillers are used, it is common to find that these have different set points and water temperatures. In this case, the first action is to get the chilled water temperatures consistent across the site. As a first step, choose the highest reliable temperature setting and synchronize all other settings with this.

Action:

- If multiple chillers are being used, then set all the chillers to the same (highest) set point.
- Increase the set point on all the chillers by 0.1°C and note the results in production.
- Check for any problems with machines or processes.
- Investigate and solve the problems.
- Wait 1 week and then increase the set point by 0.1°C on all the chillers again.
- Increase set points again until a consistent set point of at least 15°C is reached or the setting is maximized.

24. Reduce cooling costs

After the chilled water is set to the correct temperature it is possible to investigate methods of reducing cooling costs. When the ambient temperature is less than the chilled water flow temperature then it is possible to use ‘free cooling’ as either pre-cooling or as a total cooling system (this is another reason to get the flow temperatures up, it makes free cooling applicable for longer periods of the year).

Free cooling is very suitable for plastics processing because ambient temperatures in many parts of the world are similar to chilled water flow temperatures and free cooling can be used to its best advantage.

The lower the ambient temperature, the greater the effect of free cooling. If the ambient temperature is ≈ 3˚C less than the chilled water flow water temperature then the free cooling is generally enough to provide all the cooling load and the chiller can be switched off. The only energy then used is that used to drive the fans of the free cooler.

Action:

- Increase chilled water flow temperatures to the maximum to increase the benefit of free cooling.
- Get advice from a specialist cooling company about the possibility of free cooling as a pre-cooler in your area. A specialist cooling company will also be able to provide energy saving and payback calculations.
- Install as appropriate.

25. Reduce cooling water distribution costs

Most chilled and cooling water pumps to the process will be fixed speed pumps and most sites will have multiple pumps with some on standby in case of pump failure.

Fitting pumps with Variable Speed Drives (VSD, also known as Variable Frequency Drives or Inverters) allows the speed of the pump to be tuned to the process demand rather than simply running the pump at full speed all the time. A VSD will also reduce temperature variations in the chilled and cooling water circuits by taking a signal from the return piping before the sump.

For sites with multiple pumps a VSD is generally only needed on 1 pump. The fixed speed pumps provide the base load and the VSD controlled pump provides the variable load. A suitable control system can be used to control the number of fixed speed pumps running according to the demand. A second control point may be needed to maintain adequate system pressure (generally ≈ 4 bar).

Action:

- Examine the control system of chilled and cooling water process pumps (if any).
- Calculate if a VSD will reduce energy use.
- Obtain quotations for VSD purchase, installation and commissioning.
- Calculate the payback period.
- Install a VSD using the chilled or cooling water return temperature as the control parameter.

26. Motor management

Motors are one of the largest energy users in plastics processing (66% of the energy costs are in motors) and simple decisions about motor purchase and maintenance will have a large effect on future energy use. Over the typical life of an AC motor the cost of the energy used will be far higher than the capital cost of the motor so it pays to get the right motors in the first place.

Standard AC motors are very reliable but 'motor management' is about deciding what happens when they fail before they fail. Develop, implement and enforce a motor management policy to reduce costs over the long term. High efficiency motors (the scale varies around the world) will reduce energy costs by up to 3% for little additional capital expenditure and conversion to HEMs will gradually reduce energy use as inefficient motors are replaced with HEMs.

Action:

- Create a motor management policy for the purchase and operation of motors.
- Create a 'motor register' of all the important motors on the site.
- Specify the purchase of high efficiency motors for all new or replacement motors.
- Specify that motors are to be rewound only in exceptional cases. Rewinding decreases motor efficiency by 1% for every rewind - it is cheaper to purchase a new HEM in most cases.
- Define a repair and replacement policy based on the 'whole life cost' of the motor where all the purchase, maintenance, repair and operating costs are considered.

27. Turn off motors

Turning motors off by improving controls is one of the most effective and profitable ways of reducing energy use. Use the ‘motor register’ to identify any motor >5 kW and check the control system.

Any motor where the only control is the ‘on/off’ switch is a candidate for improved control. These motors will generally be always ‘on’ and using energy. The control system can be by timers, condition sensors, sequenced operation and will vary with the application. For equipment that is downstream of the main processing machine, e.g., conveyors, printers, regrinders, blowers, transport devices, pullers and cutters, look at what happens when the main processing machine stops operating. If the main machine is not producing product, then stop the downstream equipment. In most cases a simple control signal can be taken from the main machine, e.g., if the platens are not moving on an injection moulding machine, then why are the conveyors running?

The payback on most projects involved with turning off motors will be less than 1 year.

Action:

- Use the ‘motor register’ to identify motors that can be turned off when not performing useful work. Look particularly for motors in services, ancillary equipment and buildings.

- Determine and cost the best method for turning off the motor when it is not needed, i.e., timers, condition sensors, sequenced operation, linking to upstream main equipment.

- Implement a control system to turn off any motor when it is not performing useful work.

28. Reduce the load on motors

If it is not possible to turn a motor off then reducing the load will also reduce energy use and costs. Many motor loads are excessively high simply because of poor maintenance or initial system settings, e.g., a blocked filter will increase the load on a fan motor moving air through the filter, dirty and dusty fan blades will increase the load on the fan motor. Reducing the load at source can also involve eliminating the load at source or reducing transmission losses.

Most of the work in motor load reduction is actually simple 'good maintenance practice' and this will not only decrease energy use but also increase machine life and reliability.

Action:

- Identify areas where the load can be eliminated at source, e.g., use natural ventilation instead of motor driven fans.
- Identify areas where the load can be reduced, e.g., cleaning of exhaust fans, air filters and chiller surfaces, high system pressures for air or cooling water.
- Identify areas where transmission losses are high and can be reduced, e.g., using V-belts instead of toothed belts for cooling tower fans and extruder drives (toothed belts are ≈ 2% more efficient), incorrect or low lubrication of gearboxes, chain drives or bearings, excessive wear or play in gearboxes.
- Improve maintenance to reduce all motor loads at source.

29. Get the correct motor size

Using a large motor for a small load will decrease the efficiency of the motor and increase energy use for no improvement in operations.

Motors will only operate at their best efficiency when they are sized correctly for the specific application. Many motors are too large for the actual application because they have been specified by engineers who either have no idea of the operating costs or are unconcerned about them (they are only concerned with installing the system not the operating costs). This is particularly true in services (pumps, fans etc.) where motors will often be increased in size several times during the specification process to provide additional 'safety factors'. It is often the case that when a motor fails (for whatever reason) then it is replaced with a larger motor 'just to be safe' – these decisions build in cost for the lifetime of the larger motor.

The replacement of over-sized motors with the correct size can normally be financially justified in less than 1 year. Motors come in discrete sizes, i.e., they are only available in 11 kW, 15 kW, 18.5 kW etc. so there will sometimes be cases where a larger than necessary motor is the only suitable motor.

Action:

- Examine the sizes of all motors using the motor register.
- Identify potentially over-sized motors.
- Calculate the correct size motor.
- Replace with correctly sized motors.

30. Improve the motor efficiency

All motors are not equally energy efficient and there are various national motor rating schemes for motor energy efficiency. These rating schemes identify and rate which motors can be classified as High Efficiency Motors (HEMs). HEMs offer significant long-term energy savings and generally the additional capital cost is small. Purchasing the highest efficiency motor available will lead to long-term savings.

Saving small amounts on the capital cost by buying an inefficient motor will inevitably cost more in the long-term. Most AC motors have a service life of > 10 years so purchasing motors that are not energy efficient will embed energy inefficiency into the site for a long time. HEMs can have an efficiency of up to 3% higher than standard motors and over a 10-year motor lifetime can save significant amounts of money (this is especially true for motors that are ‘always on’ where the cost of energy used will exceed the capital cost of the motor after only 40 days of operation).

Action:

- The specification/purchase of HEMs for all new motors should be part of the motor management policy. Use a single supplier for motors and ensure that they only supply HEMs.
- Always purchase HEMs when replacing failed motors (after checking that the motor is the correct size for the application).
- It is rarely economic to replace a good operating motor with a HEM motor but there can be situations where this will make financial sense.

31. Slow the motor down - VFDs

VSDs are one of the most important tools available to plastics processors to reduce energy use and costs. Standard AC motors are fixed speed and operate at full speed irrespective of the demand. Variable Speed Drives (VSDs, also known as Variable Frequency Drives or Inverters) allow motors to be slowed down to match the demand. They give both energy savings and improved process control.

Simply slowing a motor down to 80% of the previous fixed speed with a VSD reduces the motor energy use by 49%. If the motor can be slowed down to 70% of the previous fixed speed with a VSD then the motor energy use is reduced by 66%.

VSD projects can have paybacks of less than 6 months (depending on the application) and are also some of the easiest projects to identify, carry out and prove the savings. VSDs are also suitable for main plastics processing equipment and can be used on hydraulic injection moulding machines (new or retro-fitted) and extruders (new or retro-fitted).

Action:

- Use the motor register to find and identify pumps and fans suitable for the application of VSDs - if a pump or fan operates at fixed speed or is simply damped then VSDs offer significant advantages.
- Prepare an ‘Action List’ for investigating VSD applications.
- Start a program to install VSDs on pumps and fans using appropriate sensors for control.
- Implement a site policy to specify VSDs for any suitable new pumps or fans.

32. Lighting

Site lighting is also often poorly controlled and it is not uncommon for lighting switches to have been lost during renovations. It is difficult to turn it off if nobody knows where the switch is!

Although lighting is only about 5% of the total energy cost, it is a visible sign of a commitment to energy management. Lighting projects will not save the company but will send the right message to staff.

It is important to recognize the difference between the two types of lighting levels required. 'Ambient' lighting is needed for safe general movement and 'task' lighting is needed for specific tasks such as inspection or machine setting. Most sites will have a mix of the two but providing 'task' lighting levels throughout a site is a waste of energy. Do not confuse the two!

A first step is to try to understand the site lighting and a 'site lighting map' should be prepared to show the position and size of all the lighting and controls. This is the basis and map for a full lighting program.

Action:

- Always carry out some lighting projects even if the return is not as good as other projects.
- Learn to view lighting levels in terms of 'ambient' and 'task' lighting.
- Create a 'site lighting map' showing the type of lighting, controls (if you can find them) etc.
- Survey and inspect all areas to set the lighting need but be aware of Health and Safety issues.
- Establish 'Action Lists' for improvements.

Energy and Sustainability Topics – Energy Saving Tips of the month

33. Drying the right materials

Hygroscopic polymers absorb moisture from the air to an equilibrium level that will vary with the local humidity. This moisture will be bonded to the polymer - this is not a surface effect and there may not be any obvious moisture on the surface. Typical hygroscopic materials are PET, PA and PC. Drying of hygroscopic materials is essential.

Non-hygroscopic materials do not absorb water but adsorb water onto the surface by condensation (particularly if the materials handling is not good and cold materials are brought into a warm production area). These should not need drying but poor handling may mean that they can carry surface moisture that must be removed before processing. Typical hygroscopic materials are non-polar polymers such as PE, PP, and PVC.

Action:

- Define the materials that it is to dry and dry to the absolute minimum.
- Hygroscopic polymers will absorb less water in hot, dry weather and drying times can be reduced.
- Supplier's data for drying times and temperatures materials will be based on the 'worst case'.
- Drying of non-hygroscopic materials is a waste of energy unless they have picked up moisture due to poor materials handling. However, in some cases, a non-hygroscopic base polymer (PP or PE) may need drying to remove moisture absorbed by the filler (talc) or colorant (carbon black).
- Over-drying can result in volatile additives being driven out of the material.

34. Storing materials for drying

Hygroscopic polymers will absorb moisture during storage and minimizing this will reduce the drying needed. Non-hygroscopic polymers may become wet if poorly stored and suffer from surface condensation if poorly handled.

If material is poorly stored and moisture levels are high, it will take additional energy to achieve the desired moisture content. Storing materials in a warm, dry environment will reduce the moisture content before drying and the drying load.

Small investments in proper storage and handling can lead to big energy savings at the dryer if drying is based on the real moisture content of the material and not simply on the times given by the supplier.

Action:

- Ensure that all materials are stored in warm, dry areas.
- Investigate warming materials storage areas using waste heat rejected by compressors and chillers. These can provide large quantities of warm dry air that has already been paid for. Keep these areas as warm as possible to reduce the possibility of condensation.
- If material is stored in external silos, then transfer it to internal 'day bins' before processing.
- Opened bags or containers should be promptly (and effectively) resealed after use.
- Check the materials handling system for air leaks to prevent dried materials reabsorbing moisture.

35. Dryer control systems and insulation

Drying has always been difficult to control and controls are mostly based on time or on the dew-point of the process air, i.e., not on measurement of the actual moisture content of the material. New developments allow direct measurement of the moisture content of the material.

Improved controls reduce energy use, avoid over-drying and allow drying to a moisture level rather than to a temperature/time specification. Control systems that monitor moisture content will save energy and reduce costs by optimizing the process to eliminate over or under-drying.

After a material has been dried, the dryer should be put into a 'set-back' condition to simply keep the material stable and 'ready-to-use'.

Most drying systems have fixed speed blowers and fans with damping as the control method. These are prime candidates for VSDs (see #31).

Dryers are designed to be hot and will lose heat if there are leaks or poor insulation. This will increase energy use and costs.

Action:

- Improved controls in drying can have rapid payback.
- Establish controls to ensure that the system is operating at the correct temperature and is able to maintain the temperature and dew point accurately.
- Use controls to put dryers into a 'set-back' condition when drying is complete.
- Blower and fan motors are very suitable for VSDs.
- Check all dryers for leaks and insulation breakdowns and seal/rectify these
- Insulate air inlet and air delivery hoses to reduce heat losses but do not insulate return air hoses from the top of the hopper to the desiccant bed (it is more efficient for the process if these hoses lose heat).

36. Desiccant drying

Desiccant drying is the most widely used drying method and works by passing moisture-laden air through a canister containing desiccant. The hygroscopic desiccant adsorbs moisture from the feed air to produce dry air, which is heated and passed through the plastic granules. The warm dry air removes moisture from the granules and is recycled for further drying and use. The desiccant canister is regularly removed from the drying stream for regeneration to remove adsorped moisture.

Conventional desiccant dryers use canisters packed with desiccant to dry the air. These have a large thermal mass and regeneration demands large amounts of energy. Carousel dryers are based on a wheel which has desiccant crystals impregnated and grown on a fiberglass substrate. This lightweight wheel has a high surface area to air flow ratio and has a much smaller thermal mass than the conventional canister.

Action:

- Dryers with automatic desiccant regeneration controlled by dew point sensors or by material moisture content are best.
- Overloading the desiccant will reduce process efficiency.
- The lower the dew point of the air supplied the quicker the drying time.
- The smaller the plastic granule the quicker the drying time due to the shorter diffusion path through the granule.
- High desiccant reactivation temperatures improve desiccant reactivation and adsorption in use cooling but may use more energy.
- Desiccant systems need to be correctly sized for the demand.
- Well insulated materials hoppers, desiccant beds and piping can reduce heat losses from the process.

37. New drying methods

New technologies are being developed in response to the need to reduce energy consumption in drying.

Compressed air drying uses conventional compressed air and allows this to expand to reduce the dew point and dry the polymer. These dryers have no moving parts, no desiccant, and have low maintenance. If additional drying capacity is required then it is possible to upgrade compressed air dryers with a moisture removal membrane to further dry the polymer. The process can be very effective for relatively low volume throughput.

Low pressure drying (LPD) uses a vacuum applied to a dryer cabinet to accelerate the drying process. Using vacuum as a driving force reduces the drying time by up to 80% and reduces the direct energy use (including the energy for the vacuum) by 50-80%. LPD is suitable for small to medium volume throughput

Infrared drying (IRD) uses the energy from IR radiation to directly heat the bulk material of the polymer granule/flake. IRD is particularly suited to the drying of reprocessed PET as it combines recrystallisation and drying in one pass. IRD can also be used with a vacuum to further increase the process efficiency and reduce energy use. IRD is suitable for high volume throughput.

Action:

- Processors should examine the new technologies to determine if these are suitable for their operations.
- If considering compressed air dryers then make sure that the cost of generating the compressed air is used in the costing of the drying process.
- If considering compressed air dryers then make sure that the site has adequate compressed air generating capacity.

38. Regranulation

Regranulation of internally generated scrap reuses the material but the energy used in processing the material is lost forever. Energy-efficient regranulator operation is essential but it is even more essential to regranulate as little material as possible.

Regranulation is expensive and even a small machine can cost over $10,000/year to operate but most sites have no controls on regranulator use - regranulators running in the background are like compressed air leaks, they are ‘part of the environment’.

Gaining control of regranulators can be a very rewarding exercise and both automation and management controls can be effective. Automation can be used to start regranulators based on photocells which detect feeding of the regranulator and to stop regranulators based on monitoring the vibration or current drawn. Strong management and good staff training can have equally effective results.

Action:

- Train staff to recognize that regranulator use is not ‘free’ and give them the techniques and tools to minimize energy use in regranulators.
- Use soft-start and other motor controllers to prevent high starting currents.
- Sharp blades are needed for good regranulation. Sharpen blades regularly to reduce energy, noise and fines.
- Do not overfeed regranulators. Overfeeding will increase current spikes and can jam the regranulator.
- Check the drive mechanism. If it uses V-belts then consider replacing these with alternative belts.
- If the regranulator is not automatically emptied then check that the collection bin is regularly emptied. Full collection bins will back up and the regranulator will eventually fail.
- Automatic feeding will control peaks in regranulator use and avoid overloading.

39. Vacuum systems

Vacuum tends to be treated as a 'free' resource but high flow rates and high vacuum levels will result in high energy costs. Vacuum, like compressed air, is not free. Vacuum can be generated various methods and these have different operating characteristics:

- Vacuum pumps provide high vacuum levels at moderate volume flow rates - these are used for applications such as drying, degassing, extrusion calibration and vacuum forming.
- Vacuum blowers provide low vacuum levels at a high-volume flow rate - these are used for applications such as granule and powder transport.
- Ejectors use compressed air to provide high vacuum levels at relatively low volume flow rates - these are used for applications such as robot grippers and packaging.

Whichever method is used, the system settings will have a large effect on the operating cost of the system and these need to be critically examined.

Action:

- Check the application demand and set the system to deliver this and no more.
- Establish a regular vacuum checking programme to locate and seal leaks in the system. Vacuum leaks do not have the 'ssssssss' noise of compressed air leaks and can be difficult to detect.
- Open vacuum ports are effectively a leak in the system and increase energy use.
- Vacuum pumps are often over-sized. Investigate motor sizing on all vacuum pumps.
- Fit vacuum blowers with VSDs to ensure that the blower is only generating the required level of vacuum.
- Materials transport systems often have small leaks and should be included in the vacuum checking programme.
- Investigate the cost of using a central system for vacuum.

40. Hydraulics systems

The energy losses in a hydraulic system are a function of the flow rate and the magnitude of the pressure drop through which the flow occurs. Minimize energy losses by minimizing:

- Large numbers of fittings.
- Small inside diameters of any fittings.
- Flow-through relief valves.
- Excessive flow controls.
- Small directional control valves.
- Leakage at cylinder seals.

As with any system, operating the hydraulics system when it is not loaded is a total waste of energy. Systems should be fitted with timers to automatically switch them off when they are not required or after excessive periods of no-load operation.

For many systems, the application of VSDs can be very effective (see #31). This is particularly true for large injection moulding machines where a VSD can be used to slow the hydraulic pump down during the hold and cooling stages. This is a specialist application of VSDs and should be undertaken with care.

Action:

- Maintenance does matter. Simple preventative maintenance will maintain energy-efficient operation. Good maintenance is the major factor in energy savings for hydraulic systems.
- Hydraulic fluid quality should be regularly checked for cleanliness and replaced at regular intervals with the specified hydraulic fluid. Excessive internal leakage reduces the system efficiency and cause hydraulic fluid deterioration through heat generation.
- De–aerate hydraulic oil on a regular basis to improve the efficiency of the hydraulic system.
- Many problems with hydraulics systems are the result of dirty or old hydraulic oil and inefficient or ineffective filtering of the hydraulic oil. Good filters will reduce oil contamination and breakdown times.

41. Tool changeover

Tool changeover may not appear directly related to energy but most changeover take place while machines are live and using energy. The changeover cost must therefore include the cost of the energy used and reducing the time automatically reduces the energy used.

Set-up time reduction works by accepting that some operations can take place while the machine is running (‘external’ set-up operations) and others need the machine to be stopped (‘internal’ set-up operations). The aim is to carry out all the external actions before the machine has stooped the current run, stop the machine, carry out the internal actions and start the machine again. This greatly reduces the down time from good product to good product.

The sequence for set-up time reduction is:

- Establish a ‘set-up time reduction team’. Video the current process and use the video to highlight areas for set-up time reduction. Watch for all the times where people and machines are doing nothing.
- Analyse the existing set-up times. Put these on a chalkboard to show the employees what is important.
- Divide the total set-up time into external and internal set-up operations.
- Reduce external set-up operations by actions such as providing dedicated tool kits for each tool, standardizing all screws, bolts and fixtures, pre-kiting all gauges and inspection, using standard base plates and connectors etc.
- Reduce internal set-up operations by actions such as quick-change tooling/connections, standard base plates, combining handed tooling, set-up sheets for all variables etc.
- Where possible convert internal operations to external operations to reduce the time the machine needs to be stopped.
- Start again.

Action:

- Start reducing set-up times now to improve overall factory effectiveness and reduce energy use.

42. Employee training

Staff can only assist in reducing energy use if they know the effect and costs of their actions. This can only be achieved by training. Nobody wants to explain to their children why they waste energy at work but they will be proud to explain how they are reducing energy use and CO_2 emissions.

The main types of training are:

- Awareness - This is not technical but emotion based. All staff know about climate change and recognize the need to reduce energy use. They almost certainly take action to reduce energy use at home and this should be linked to their actions at work. Awareness training should be approximately 40 minutes long.

- Policy and financial - This is primarily a 'Management Briefing' and should focus on the financial benefits. It should be designed to get senior management support.

- Tools training – This is process/product specific and is developed by the process manager. It should focus on the specific process and where energy is used.

Action:

- Create a general awareness training programme and use this as part of normal staff training process. A free downloadable energy awareness training booklet is available from www.tangram.co.uk/energy.

- Include a 'go-see' exercise in the training where staff go to a production area (not their own) and identify 5 actions to reduce energy use.

- A 'go-see' exercise will identify a lot of common areas (lighting will always be on the list). Record the ideas and take action to reduce energy costs.

- Report the savings to the staff.

- If reporting financial savings in $-terms is an issue then report energy savings in terms of CO_2 emissions.

43. Small power equipment

Small power equipment covers all of the small machinery and energy sinks that are around in any site. It includes all the ancillary equipment used for separating, packing, printing and treating the product before it dispatched. Everything that uses energy is a potential subject for improvement and sites must look critically at every aspect of the process to find poor use of energy and potential actions for energy reduction.

This type of equipment will account for ≈ 5% of the energy use and is very diverse. Some will be 'home-made' to solve a specific concern and this is rarely energy efficient because energy was never considered by the 'designer'. In other cases, the equipment will be purchased for a specific need but will be used incorrectly or insufficiently controlled.

Typical small power equipment is heaters, coolers, sorters, flamers, packaging equipment, conveyors and lifters. All of this equipment will generally suffer from symptoms such as poor or non-existent controls, poor insulation against heat leaks, large openings for heats leaks, poor insulation for cold leaks, excessive operation times and a variety of other energy losses that have nothing to do with the actual process.

Action:

- Look around, feel the air for heat, feel the area for draughts, smell the area for burning and question everything.
- The opportunities are everywhere but are rarely found, i.e., 'there are none so blind as those who will not see'.
- Small power equipment covers a multitude of machinery and energy sinks around a site.
- Look for the small power equipment and save money and energy.

Energy and Sustainability Topics – Energy Saving Tips of the month

44. Process control

Process control in every industry has improved dramatically in the last 10 years and processors using inefficient process control systems are not only failing to manage their energy consumption but also failing to manage many other aspects of their business.

Process control can be either through on/off controls or through proportional controls:

- On/off controls sense the presence or absence of a control signal and take action based on this. This is the simplest type of control system as there is no proportionality between the detected signal and the action. The control system simply determines whether the signal is present or not and takes the appropriate action.

- Proportional controls measure the value of a control signal to regulate the process. This is a more complex control system and there is either direct or inverse proportionality between the detected signal and the action. The control system determines the size of the signal and calculates the size of the resulting action.

Process control systems change the system rather than attempting to change the people. They do not require initial or continued operator training, operator intervention or management of the process. They can be low-technology but after implementation are automatic and need only maintenance to continue to deliver cost savings.

Action:

- Train staff in basic process control techniques.
- Look for opportunities to improve process control through on/off or proportional control systems.
- Improve process control to reduce operator input reduce energy use and improve quality.
- Start to use energy use (kWh/kg) as a process control signal.

45. Site heating

Heating is generally a low cost for plastics site because of rejected process heat. However, this is uncontrolled, costly and is uncomfortable in summer. Insulating the process and heating the building using purpose designed and controlled systems is far cheaper.

Heating should make working areas comfortable and acceptable to staff – very low heating levels will not be productive.

The best and cheapest way to reduce energy use in heating is to improve the controls of the existing heating system. Most systems will have thermostat controls but simple timer controls can save money - every extra hour of heating a building adds at least 4% to the heating costs.

Action:

- Reducing the heating temperature by 1°C will reduce the heating cost by about 8%.
- Check that all controls are operating and set correctly.
- Where cooling is also used for a building then interlocked controls should be fitted to prevent heating and cooling operating at the same time.
- Raise staff awareness of the cost of heating and encourage their involvement in solving heating issues.
- Install tamper-proof thermostats and controllers to stop staff changing them.
- Review temperature settings annually and ensure that controls reflect the seasons, i.e., summer control settings should differ from winter control settings.
- Pumps and fans should only operate when the system is active.
- Do not heat lightly occupied areas when all that is required is humidity control.
- Heating system servicing is a specialist task. Be sure to comply with local regulations for servicing.

46. Hot water

Energy for the production of hot water is a relatively low energy user in most plastics processing sites. It is primarily used for hygiene and personal washing. However hot water is used at every site and energy savings are easily possible.

Action:

- Fit time controllers to all hot water boilers.
- Condensing boilers are the best option for new or replacement small hot water systems.
- Check the water storage temperature if the storage is some distance from the point of use. The storage temperature should be 60-65°C but no higher otherwise heat losses will be higher.
- Check that all hot water storage tanks and pipe work are adequately and fully insulated. Fit lagging to all local hot water storage tanks if insulation is not present.
- Ensure that no hot water taps are leaking and preferably fit automatic sensor-controlled taps.
- Check tap water temperature regularly. This should be the minimum temperature consistent with Legionella control (if applicable). The tap temperature should be 55-60°C but no higher otherwise heat losses will be higher.
- Consider fitting local 'on-demand' hot water heaters to avoid long pipe runs. These can reduce energy use considerably, especially in summer when other demands on a centralized system are low.

47. Air conditioning

Air conditioning is more expensive than heating and can use more energy. It is important to recognize the difference between air conditioning and simple ventilation - natural ventilation is cheaper and when properly controlled can greatly reduce air conditioning loads.

Air conditioning is a chiller by another name and all air conditioning therefore has a compressor of some type in the unit. Some air conditioning units have free cooling coils that operate in the same way as free cooling for chillers (see #24) and these can reduce the cost of air conditioning considerably.

Poorly controlled air conditioning can double the energy costs of even a small office and one of the key issues is to avoid having the heating and air conditioning competing with one another. In temperate climates there is no reason for air conditioning of production areas.

Even when well controlled, air conditioning will make up approximately 35% of the energy demand of the average office. Poorly controlled air conditioning will use much more energy and can be over 50% of the energy use.

Action:

- Investigate free cooling for A/C units.
- Keeping windows closed is just as important for air conditioning as it is for heating.
- Turning thermostats down does not cool the building quicker. An air conditioner has a fixed output and cannot cool faster than this.
- Cooling levels should be adjusted to the outside temperature.
- Reducing the delivered air volumes can reduce costs.
- Leaving air conditioning on overnight does not save energy. Use controls to turn air conditioning off overnight.

48. Building fabric

General building fabric improvements have greatly reduced heat losses and gains in buildings but older buildings have considerable opportunities for improvements. A well-insulated and sealed building will not only lose less heat in cold weather but will also gain less heat in hot weather and reduce cooling costs.

The issues for industrial buildings are similar to those for domestic buildings and the things that can be done in your own home to reduce energy use can be replicated in industrial buildings. It is simply that the costs and benefits are larger.

Action:

- Check that insulation thickness meets best practice.
- Use controls to operate ventilation only when needed and fit VSDs any fans.
- Draught proof doors and windows. It is cheap but effective. Even a small gap will cause draughts and heat losses. You would not accept it at home so why accept it at work?
- Permanently seal unused doors and windows.
- Keep windows and doors closed to reduce draughts - adjust the controls instead.
- Do not heat areas when you have windows or outside doors open.
- Fit automatic closers on all doors and do not block them open, especially if adjacent areas are at different temperatures.
- For vehicle doors, automatic fast-acting roller shutters are more effective than plastic strip doors.
- Interlock temperature controls with large vehicle doors so that ‘door open = heating/cooling off’.
- When adding new buildings look at energy-efficient designs with energy efficient windows, improved insulation, passive solar heating, passive ventilation, added thermal mass, and natural lighting systems.

49. Carbon footprinting - the basics

A carbon footprint can refer to either a site or to a product and these are very different. A site carbon footprint does not include the embodied energy in raw materials. It relates only to emissions resulting from site activities. A product carbon footprint covers the complete carbon emissions resulting from the production of the product. The site footprint will only be part of the product carbon footprint.

Carbon footprinting requires data on all the carbon emissions and there is a 3-part classification for emissions:

- Scope 1: Direct emissions - this covers emissions that a site directly causes or from controlled assets.

- Scope 2: Indirect emissions from imported utilities - this covers emissions from purchased electricity or other imported utilities, e.g., heat or steam.

- Scope 3: Indirect emissions - this covers emissions that a site causes to occur but where it does not control the asset.

One area of confusion is whether to allocate an emission into Scope 1 or Scope 3. The key issue is whether the site has control of the asset and actual ownership is less important than control.

For a very basic carbon footprint not all Scopes are calculated.

Action:

- Find out how to prepare a carbon footprint.

- Prepare an initial carbon footprint. You will need it sooner than you think. Carbon footprinting will become an issue for customers as they attempt to reduce their own carbon footprint.

- Start to record carbon emissions regularly.

- After a site has prepared an initial carbon footprint, the data collection should become part of the normal operations.

50. Carbon footprinting - Scope 1

These are the direct emissions at a site, i.e., the emissions that a site directly causes and controls through assets. Typical emission sources are:

- Gas and other fossil fuels (heating and process).
- Gas (fork lift trucks).
- Owned cars - This includes all cars provided for use by employees (leased or owned). If the site has control of the vehicle, then it is counted here.
- Owned trucks or vehicles - This includes all leased or owned vehicles.
- Refrigerant emissions - Chillers, compressed air dryers and A/C units all contain greenhouse gases (refrigerants) and suffer from gas leakage.

All the calculations will need values for the relevant 'driver', i.e., for gas you need the amount of gas used (litres, kWh or other measure) and the emission factor (amount of CO_2e/driver) for the emissions source. There are a variety of sources of emission factors but the most reliable and comprehensive set of data is that published by the UK government (http://www.ukconversionfactorscarbonsmart.co.uk).

Action:

- Quantify the relevant emissions in terms of their drivers.
- Use the emission factors to calculate the amount of CO_2e for each emission source.

51. Carbon footprinting - Scope 2

These are the emissions resulting from electricity use and the size of these emissions depends on the method of generation. Nuclear, thermal or hydro generation result in low CO_2e emissions whereas coal, gas and other fossil fuels result in high CO_2e emissions.

The driver is the total number of kWh used in the year and the relevant emission factor for the supply.

The best source of emission factors is direct from the supplier because this will reflect their specific generation profile (most suppliers should be able to supply this on request). If the supplier cannot supply the emission factor, then it is possible to use the country emission factor. In the USA, the diversity of generation capacity means that a single value is not relevant for most of the country. It is possible to use the eGRID data produced by the EPA but try to get supplier data before using eGRID.

Action:

- Quantify the electricity used in terms of kWh.
- Use the emission factor for the supply to calculate the amount of CO_2e.
- Always use the emission factor for the consumption and not for generation.
- If getting data from suppliers then check that it is total CO_2e data and not simply CO_2 data.
- Always use the latest emission factor to reflect changes in generation profiles with time.

52. Carbon footprinting - Scope 3

Scope 3 covers the direct emissions from assets that a site uses but does not control, i.e., when an employee flies in a plane, the site takes a share of the emissions. Typical emission sources are:

- Employee business travel:
    - Private car use.
    - Flights (short-haul and long-haul).
    - Rental cars and taxis.
    - Employee commuting.
- Product transport to the customer by contract transport (not collection).
- Water use and waste disposal.

All calculations need values for the relevant 'driver' and the emission factor for the emissions source. The recommended data set is that published by the UK government (http://www.ukconversionfactorscarbonsmart.co.uk).

Action:

- Quantify the relevant emissions in terms of their drivers.
- Use the emission factors to calculate the amount of CO_2e for each emission source.
- Scope 3 emissions may be difficult to calculate but for most plastics sites Scope 3 will be < 10% of the total and even large estimation errors will not affect the total greatly.

53. Internal site benchmarking

#5 (October 2009) introduced the concept of the Performance Characteristic Line (PCL) for a site. This is found by plotting a scatter chart of 12 months of monthly electricity use against 12 months of production volume (amount of plastic processed). The PCL is the linear line of best fit to this data. The equation for the PCL is generally of the form: kWh = A x Production volume + B (where A and B are constants from the line of best fit).

The PCL can be used to set targets and assess energy use. If the PCL for the site is: kWh = 1.5551 x Production volume + 48,106 and the production volume for the month is 70,000 kg, then the predicted energy use will be: kWh = 1.5551 x 70,000 + 48,106 or 156,963 kWh. This predicted energy use value is the target for the month and can be compared to the actual energy use.

The PCL allows internal benchmarking based on previous site performance.

Action:

- Plot 12 months of electricity use against production volume. Find the line of best fit.
- Establish the amount of material processed in a month and calculate the predicted energy use.
- Determine the actual energy use for the month and compare this to the predicted energy use.
- If the energy used is less than predicted then the site performed better than target.
- If the energy used is more than predicted then the site performed worse than target.

Energy and Sustainability Topics – Energy Saving Tips of the month

54. Budgeting for the future

One of the most valuable uses of the PCL (see #53) is in forecasting future energy costs for budgeting.

Many plastics companies have no procedure to predict energy use or energy costs but knowing the PCL makes this easy:

- Convert the sales forecast into a monthly production volume (in kg or lb of plastic).
- Convert the forecast production volume into a forecast energy use (kWh) using the PCL relationship between production volume (kg) and energy use (kWh).
- Convert the energy use into the energy cost using the current (or future) energy cost.

This method of energy budgeting shows that energy costs are is directly related to production volume. Energy costs that were previously seen as simply a fixed and uncontrollable cost are now seen as a variable cost. This will result in finance involvement in the control and management of energy costs. It also allows rapid recalculation of the energy cost to the site with changes in production volume.

The information from this method also allows the Finance function to forecast the energy costs in absolute terms and as a % of sales revenue – to highlight the importance of energy management in overall cost management.

Action:

- Find the PCL for the site (see #5 and #53)
- Use the sales forecast to find the forecast production volume.
- Use the PCL to convert the production volume forecast into an energy use and energy cost forecast.

55. Setting targets

Internal benchmarking (see #53) is the start of setting targets for energy use based on the actual plastics throughput of the site.

The Performance Characteristic Line (PCL) shows you how much energy you should be using. If your actual use is higher (worse) than predicted or lower (better) than predicted then you can quickly see this.

Control charts (similar to those used in SPC charts) can be used to show when if deviation from the PCL is significant but the best tool for setting targets is the CUmulative SUM (CUSUM) chart. This looks at the CUSUM of the deviations from the standard and is sort of like looking at your bank balance - if it heading in the wrong direction then you have to do something!

CUSUM charts can be used to set a 'challenging but achievable' target based on the best previous actual performance.

Action:

- Look for a period of sustained good performance and create a PCL based only on this period. You know this is 'achievable' because the site has done it in the past.
- Challenge the site to perform consistently to the best level they have previously achieved and not to the average of what they have previously achieved.
- Avoid simple targets such as 'Reduce energy use by 15%'. These are not related to production volume and may not be challenging enough to bring out the best performance.

56. Reporting energy costs and use

After targets are set it is essential to report the energy costs and use so that site managers can see the results of their actions. Setting targets is no use if the results are not reported. If no reports are made then it is useless setting targets.

Every process has a different energy intensity, i.e., injection moulding uses more energy than extrusion and reporting needs to take the process into account. The site or area PCL is essential to the reporting process.

Reporting should be vary with the target audience but the data should be consistent across the site. Operational managers will be interested in relating energy use to the amount of plastic they have processed; accountants and general managers will be interested in the financial aspects and all staff will be interested in carbon savings as a result of energy efficiency actions.

Reports should show the benefits of operational decisions and energy efficiency projects. If you have installed a new chilled water system then the report should look at the actual performance of the system. Good reports can provide the justification for additional investment in energy saving technologies.

Action:

- Report energy costs and use widely to show that you care. Reporting is not only for the accountants; it is for the operational managers and all staff.
- Make sure that the reports get to the right people.
- Divide energy costs into processing areas/types so that each area manager knows that they are being monitored.
- Use reports to provoke action. Reporting is only useful the result is action, otherwise reports are simply wasted paper.

57. kWh/kg as a monthly measurement metric

Many novice sites use kWh/kg as a monthly measurement metric and wonder why it varies uncontrollably and by so much. They will generally be forced to use kWh/kg by 'Head Office' or by an accountant who does not understand the process.

Using kWh/kg as a monthly measurement metric to assess performance in plastics processing is a fatally flawed concept and only works when production volume is constant each month. The moment production volume varies then kWh/kg will vary with the production volume. As a metric it is only suitable for use by people who think that everything can be measured by a single number and can only hold one number in their head at a time. Real manufacturing is a little bit more complicated than that.

At most plastics processing sites with a reasonable base load, increasing the production volume will decrease the kWh/kg and decreasing the production volume will increase the kWh/kg. This is the result of amortizing the fixed base load into an increasing or decreasing variable process load. It has nothing to do with increasing or decreasing energy efficiency. It is simple mathematics.

Action:

- Never, ever use kWh/kg as a monthly measurement metric. It is affected by production volume and will vary with production volume.
- If you must use kWh/kg (and I strongly recommend that you don't) then at least take a rolling average over a minimum of 6 months. This is still flawed but less flawed than a monthly measure because the effect of changing production volume will be reduced.
- Try plotting kWh/kg on the same graph as production volume, in most cases you will find they are a mirror image of one another.

58. External site benchmarking

No matter how good your internal benchmarking results and how much progress you are making internally, the key question is 'How do we compare to other plastics processors?' You need to know if you are better or worse than the competition to see if you are making the progress that you need to be making to stay in the market.

External benchmarking of plastics processing is difficult because energy efficiency is strongly related to the volume throughput. Some people give a 'benchmark' for a plastics forming process based simply on a Specific Energy Consumption (SEC in kWh/kg) - this is not only wrong but can actually send you in the wrong direction. Benchmarking data for plastics processing must take into account both the process and the volume throughput rate.

Never try to apply an 'average' SEC for a plastics forming process to your site.

Unfortunately, the only real-world benchmarking data available is Tangram Technology data. However, we have published this widely and a Web search should allow you to find the relevant graphs and equations for your site.

Action:

- Find the Tangram Technology site benchmarking curves for your process. They are out there but you may have to look.
- If you want the full data for site benchmarking of most plastics processes then these are available in our book on Energy Management.
- Use the data to externally benchmark your site and understand how competitive you are in terms of energy.
- Take action to improve your operations.

59. Machine monitoring

At some time in the energy management process, you will want to measure the real energy use of individual machines. It is not difficult to measure current using a simple clamp meter and to convert this into the power drawn and the energy used (by knowing the voltage and the power factor).

The problem in plastics processing (and particularly in injection moulding) is that the current and power vary rapidly with time and it will be almost impossible to get an accurate value for the current because it changes so rapidly. Fortunately, plastics processors are not alone here and there are many instruments available to measure current at specific intervals and then to use software to convert these readings into power drawn and energy used.

I use the Elcomponent 'SPC Mini' for quick jobs and their 'SPC Pro' for full 3-phase monitoring with factor calculation and reference voltage recording to give more accuracy (www.elcomponent.co.uk). There are other manufacturers but I like the Elcomponent software for data handling.

Whichever meter you choose, it is also important to check that the data handling software is also user-friendly. Try it before you buy it!

Action:

- Buy a logging clamp meter. This will record the current at intervals and they generally have software supplied to convert this into the power and energy used during the process cycle.
- Use machine monitoring to 'look inside the cycle' in injection moulding.
- Use machine monitoring to look at energy use in compressors and see that an idling compressor is still using energy even if it is producing no compressed air.
- Machine monitoring can be fun but electricity is dangerous (especially 3-phase). Follow good Health and Safety practice and stay safe.

60. Energy mapping

Before starting to try to reduce energy use at any site you need to know where you are using energy. This is so that you do not spend time on the small things but concentrate on where you will get the 'biggest bang for your buck'. For example, people get fascinated by the lights but lighting uses less than 5% of the energy at most plastics processing sites - if you want to reduce your energy bill by 30% then this is not the place to start!

Energy mapping is a technique that we developed to quickly assess how much energy a site is using in each area (services, machines and site). Energy mapping uses a simple spreadsheet approach and a sample energy map for an injection moulding site is available at www.tangram.co.uk/energy. This can obviously be modified for other processes/machines.

Energy mapping focuses attention on the big energy users and makes the priorities for action clearer. A reasonable energy map will take about 4 hours to produce but gives clarity in decision making. You may be surprised with the results, especially the cost of services.

Action:

- Start building an energy map.
- Count the motors (and their sizes), count the lights, estimate the actual duty load, the operational hours and start to put values on the energy used/year.
- If machine monitoring data is available then this should be used to improve the accuracy of the energy map.
- Use the actual energy bills for a year as a final 'reality check' for the total energy used.
- Start to use the energy map to quantify the potential savings and prioritize actions.

61. Interval data

Interval data is one of the most powerful tools available yet very few plastics processing sites actually get it or know what to do with it. Not only does it give you time-based information on your energy use but it is generally free.

Your energy supplier will be collecting data on how much energy you use every 10, 15 or 30 minutes (you can see this if you go to the main meter and look for the connection). They do not collect this for your benefit, they collect it so that they can bill you for energy use.

However, this data is very valuable to plastics processors. It allows you to look at your energy use every interval and to see when you are using energy. This is particularly important for looking at start-up, shut-down and holiday use or use at any time when the site is not fully operational.

This data is even more valuable when a site has several meter points. The interval data then becomes almost sub-metering for free!

Action:

- Get the interval data from your supplier. They are already collecting it and they will send you a large spreadsheet file.
- The data will be in spreadsheet format (generally CSV). Convert this to your preferred format and start looking at the data. Add up daily use, look at daily profiles and look at times when the site is not fully operational.
- Look especially at start-up times, shut-down times and energy use over holidays. Using interval data will allow you to see when the machines were turned on or off.
- Above all use the free data.

62. Sub-metering

Interval data (see #61) is valuable but sub-metering is even better. The only problem is that sub-metering costs money whereas interval data is generally free.

Sub-metering allows you to look at energy use by area, machine or any other activity that you want to meter. This means that you can see what an area, machine or service is using in real-time and how efficient you are. You can look at patterns, rogue events and all of the other things the interval data does but with more accuracy. Good sub-metering systems (and there are many) will allow you to set alarms to warn you if the maximum demand approaches a penalty limit, will record all your energy use by area or machine and give you the ability to look at small changes in demand for exception reporting.

Action:

- As a general rule a reasonable sub-metering system for a plastics processor will cost approximately 2% of the annual electricity bill but it will pay for itself very quickly. The savings achieved can be up to 20% of the electricity bill.
- Sub-metering generates lots of data very quickly. Check that any system has good data handling controls.
- Go for area-level measurement first and only extend this to machine-level measurement when you have experience with data handling. As a general rule, any area, service or process using more than $75,000 of energy per year should be sub-metered (energy mapping will quickly give you a good idea of these areas).
- Look for good web access so that you can look at the data remotely.
- Look for good displays so that you can communicate energy use to the staff.

63. Injection moulding - base loads

Modern injection moulding machines are much more energy efficient than older hydraulic machines but there are a lot of older machines in use and these use a lot of energy.

The biggest energy user in an older hydraulic machine is the hydraulic motor itself and one of the main reasons for this is the base load of these machines. In many machines, the base load from energy losses in the hydraulics is far higher than the actual energy used for the process. In fact, for all but the most recent machines, the base load is an average of 75% of the total load. This means that 75% of the energy goes in operating the machine and only 25% of the energy is used in producing the part.

It is essential that you make sure that the machine is not using energy when it is not producing parts. This means switching the main motor(s) off as soon as the machine stops productive work.

Action:

- Check the base load for older hydraulic machines by monitoring the energy used with the main motor running but with the platens not moving - be prepared for a big surprise.
- For older hydraulic machines turning off the hydraulic motor the moment the platens stop moving is one of the effective things you can do.
- Fit controls to turn off the motor, e.g., the EATON Easy Series. Do not try to change the people - they will always forget and cost you money.
- Fit controls to turn off the downstream equipment, e.g., conveyors, regranulators and blowers as soon as the main machine stops producing product.

64. Injection moulding - get the right machine

Getting the correct machine size is critical in injection moulding but many sites do not realize that selecting a machine that is too large for the job has very definite implications for energy use. Last month (see #63) we talked about the base load for hydraulic machines and for older hydraulic machines this is an average of 75% of the total load.

Choosing a machine that is too large for the moulding can have a dramatic effect on the base load. If the machine is too large for the moulding, then the base load rises as a proportion of the total load. In the worst case that we have measured the base load was 93% of the average load. This means that 93% of the energy was being used simply to operate the machine and only 7% was being used to produce the part - this is a recipe for disaster.

If you must use a larger machine than necessary (because of scheduling issues) then it is even more important to get the main motor switched off as soon as possible.

Action:

- Get the right machine for the job. Choosing a large machine (with a high base load) can increase energy costs so much that the job actually becomes uneconomic.
- Measure the base load for all old hydraulic machines and calculate the idling cost of these machines. The financials will act as an incentive for further action.

65. Injection moulding - get it set right

Machine setting is crucial to getting the best part out of an injection moulding machine but it is also crucial in minimizing the energy use of the machine. Good moulding settings are needed for reproducible part production and this also minimizes the energy used in production.

Optimizing the process through setting will minimize energy use by minimizing cycle times and the cooling required but also by increasing the productive output of the machine. The material in rejected parts may be recovered but the energy used in producing them is lost forever.

Machine energy monitoring (see #59) can also reveal machines that are incorrectly set. If the cycle is unclear when monitored then it is likely that the machine is not set correctly and is using excess energy. Look at settings such as barrel temperatures, back pressure, clamp forces, cooling times and other variables that can increase the cycle time without improving the quality or reproducibility of the part.

Action:

- Get injection moulding machines set correctly by using 'scientific moulding' at the start of the job, record the settings and make sure they are always used.
- Good setting techniques not only optimize the cycle and give more reproducible results but also reduce the energy costs of operating the machine.
- Use SPC to control the process and the product.

66. Injection moulding - get the right motor

The motor (or motors) of hydraulic injection moulding machines are the largest energy user in the complete system and progress in controlling these has been rapid over the last 20 years. These developments are mainly concerned with slowing the motor down when hydraulic oil is not needed or reducing the need for oil by other methods. In some cases, this means that new hydraulic machines are not far away from achieving all-electric standards of energy use.

However, there are still many older machines in service that use old technology (fixed speed pump/fixed volume pump) and these have very high energy demands. Fortunately, motor and control system developers have produced a wide range of solutions using variable speed motors, variable volume pumps and now servo motors with fixed speed pumps. These are available for many older machines and can dramatically reduce energy use if retrofitted to older machines.

Action:

- Examine all the motors used in the injection moulding machines.
- Produce a list of the motor/pump types used and find out what the options are for retrofitting new motors and control systems to reduce energy use.
- Consider retrofitting older machines with electric screw drives (if available) to reduce the peak power needed and downgrading the main motor (if possible).
- Consider retrofitting older machines with servomotor pumps/fixed speed pumps.

67. Injection moulding - variable speed drives (VSDs)

For larger hydraulic machines with high operational hours one of the best methods to reduce energy use is the variable speed drive (also called variable frequency drive or inverter). As with pumps and fans, slowing the motor with a VSD will reduce energy use significantly but the savings are not generally as high as can be achieved with pumps and fans.

VSDs get the best savings during hold or packing when the pump does not deliver much hydraulic fluid and is simply holding the pressure and slightly packing the plastic. The VSD slows the motor down to keep the required pressure but not the constant volume that is normally supplied. In other phases of the cycle, a VSD will match the supply of fluid to the demand but the savings are not as great.

This is a technology that is excellent for machines with variable displacement vane or gear pumps and very good for machines with variable volume pumps (although the savings may not be as great).

Action:

- If the supplier offers the option of a pre-fitted VSD then this is a worthwhile option for new machines with large motors that are going to be operational for more than 6,000 hours/year.

- For existing hydraulic machines with large motors that are operational for more than 6,000 hours/year then it is worthwhile looking at retro-fitting a VSD. This is a specialist task and it is not as simple as fitting a VSD to a pump or fan. Take care in choosing you supplier and make sure that they have experience in this area.

68. Injection moulding - electric machines

Electric machines are without a doubt the most energy efficient type of injection moulding machine. Our industry monitoring shows that electric machines have the potential to reduce energy use by between 30 and 60% (depending on the moulding and machine being used). This monitoring shows that energy is saved during most phases of the moulding cycle because there are no hydraulic system losses. Electric machines can also reduce the cooling needs because there is no need for oil cooling.

Additional benefits include:

- Electric machines can also often reduce cycle times (up to 30%) because it is possible to carry out operations in parallel because there is no need to worry about the peak flow requirement of the hydraulic system.
- No hydraulic systems to maintain.
- No hydraulic oil to contaminate the site.
- Quicker to start-up.
- Improved process control and a process that is easier to set up, is easier to adjust and calibrate and is more stable in series production.
- Reduced maintenance load (no hydraulics to maintain).

Despite these benefits, electric machines have not yet achieved the market penetration in the USA and Europe that they have in Asia. Do they know something that we don't? Are they equipping for the future whereas we are equipping for the past?

Action:

- Investigate all-electric (or hybrid) machines now to re-equip for the future.

69. Injection moulding - heating and insulation

The barrel heaters on an injection moulding machine uses between 15-40% of the energy input to the machine (it is actually higher for all-electric machines because the motor use is lower). Getting the heating right is a key issue in reducing energy use.

The first thing to do is to make sure that the heater bands are effectively transferring their heat to the barrel by ensuring good thermal contact between the heater and the barrel.

Heat losses from barrel heaters are significant. This is why if you need safety guarding as a minimum but guarding does not reduce heat losses. To do this you need barrel insulation. This is a proven method of reducing energy losses, producing a more stable process, reducing start-up time and removing Health and Safety risks from hot barrels.

Barrel insulation reduces energy use in heating by up to 50% and the overall energy use of a machine by between 10-25% (depending on the type of machine and the original proportion of the load that was due to heating). Barrel insulation has a payback of ≈ 1 year depending on local costs.

Action:

- Bed heater bands in by repeatedly tightening and loosening them to get good seating.
- Use conductive metal compound between the heater band and the barrel to maximize the heat transfer.
- Get quotations and fit barrel insulation.
- Maintain the insulation and check the insulation condition and fitting as part of the set-up process.

70. Injection moulding - mould temperature control

Mould temperature controllers (MTCs) are often used for heating moulds or providing extra cooling if the mould temperature needed is less than that of the site-wide chilled water setting. These are not 'free' when used for either heating or cooling but their use is often sporadic and they are rarely controlled effectively.

Some sites use no mould temperature controllers (MTC) and similar sites producing similar parts use them extensively. There appears to be no consistent decision-making in the process. Sites can be using large amounts of energy on MTCs when the benefits are doubtful.

MTCs rarely have any substantial insulation on any of the piping/tubing connecting the MTC and the tool. These can be substantial runs of piping and are always subject to parasitic heat gain when cooling or heat loss when heating the tool.

Action:

- Check the MTCs to understand how much energy they are using (use monitoring or energy mapping).
- Check if MTCs are really necessary and if they are performing a useful function.
- If MTCs don't save you time/money then turn them off!
- Piping between MTCs and the mould should be insulated when there is heat loss or parasitic heat gain. The temperatures involved in mould heating are generally relatively low and high temperature insulation is rarely needed. You insulate hot water piping in your house, why not at the site?

71. Injection moulding - mould design

Energy has not been regarded as important by many mould designers in the past but their decisions can have a large effect on energy use. Mould design, even using good software, does not explicitly incorporate energy use as part of the design criteria.

Reducing wall thickness not only reduces material use and cycle time but also reduces energy use.

Cooling effectively determines the cycle time and the energy use and the two key variables are cooling channel location and the mould material. Cooling channels should be located as close to the surface of the mould as possible to minimize the amount of energy used to cool the mould and to maximize the amount of energy used to cool the part. The spacing of the cooling channels in the mould is also important but less important than the distance from the surface.

Action:

- Cool the part and not the mould.
- Get the cooling channels close to the surface to maximize cooling efficiency.
- Look at new cooling techniques such as conformal, pulsed and evaporative cooling.
- Check cooling channel effectiveness by measuring the pressure drop across the mould. Increasing pressure drops will indicate possible blockage of the cooling channels and ineffective cooling.
- Minimize the size of sprues and runners. The material can be recycled but the energy is lost forever.
- Reduce the use of compressed air in part ejection.
- Insulate the mould from the machine (it is a heat sink) to keep the heat (or the cold) where it does real work.

72. Extrusion - motors

Extruder motors use ≈ 66% of the power input and it is essential to get the choice right. Traditionally a DC motor was used to give the variable speed needed for extrusion but this is being superseded by AC motors + Variable Speed Drives (see #31).

VSD controlled AC motors can vary the extruder speed so that it runs at the lowest possible speed (within the allowable torque values) and reduces energy use. Many manufacturers offer AC motors + VSD drives and it is relatively easy to retro-fit AC motors + VSD drives.

Energy savings vary depending on the machine type, speed and application but savings of 5-30% are widely reported. Using AC motors + VSDs also greatly reduces the maintenance load for motors.

The newest development in extruder motors is direct drive technology. This uses permanent magnet synchronous motors and connects the motor directly to the screw with no gearbox. As well as being more energy efficient, these systems are quieter, smaller and less complex.

Action:

- Always ask for the AC motor + VSD option in new extruders. Motors should be IE3/IE4 rated (or NEMA equivalent).
- Investigate retro-fitting AC motors + VSD for existing DC motors. Motors should be IE3/IE4 rated (or NEMA equivalent). Payback should be ≈ 1-2 years.
- If a belt drive is used, replace the standard V-belts with more efficient belts and optimize the belts.
- If a gearbox is used then do not exceed the maximum torque allowance of the gearbox, use the correct oil and make sure it is at the correct temperature.

73. Extrusion - heating and insulation

Most of the heating in extrusion comes from frictional or shear heating as the plastic is being moved along the barrel by the screw. In most cases the barrel heaters are used at a very low level and the energy used is much less than for injection moulding machines. Shear heating is also more efficient than external barrel heating which only acts on the outer layer of the material at the barrel interface.

Insulation can be effective on extruder barrels but not in all sections or for all applications. If the shear heating is low then insulation will reduce the energy needed from barrel heaters. If shear heating is high then insulating the extruder barrel can lead to a ‘runaway process’.

Downstream from the extruder screw tips there is very little shear heating because the flow is mainly through channels with low shearing. In these areas, almost all the heating is provided by band heaters and insulation is vital to reduce energy use and for Health and Safety.

Action:

- Check extruder controls to make sure that the heating and cooling are working efficiently together and not competing with one another.
- Check the barrel heater ammeters. If the heaters are constantly 'on' then shear heating is not providing all the heating required and insulation could well be beneficial.
- Extrusion dies, transfer pipes, screen changers/melt filters and almost everything downstream of the extruder screw tips can be insulated with either flexible or with board type insulation.

74. Extrusion - profile calibration and cooling

Extrusion calibration and cooling take place at the same time. For simple profiles, calibration may be a single metal plate calibrator followed by a chilled water bath but for complex window profiles the calibration is usually with multiple metal calibrators (full or plate) in a full chilled water or spray bath.

The rate of heat removal from the extrudate is often the limiting factor in the line speed, i.e., the extrudate must be solid enough to have fixed dimensions and cool enough to handle at the end of the water bath. Despite this, the control methods used are generally poor; chilled water use is highly variable, temperatures, pressures, filtration standards and flow rates depend on the site's experience and there is little guidance on how to achieve good cooling.

Action:

- Check that the chilled water flow is stopped when the machine stops and that chilled water is not circulating on idle machines.
- Check that there is good contact between the profile and the calibrators - this helps calibration and improves heat transfer.
- Check that there is turbulent water flow around the profile and that no bubbles form on the extrudate.
- Check that chilled water is treated, chilled and distributed efficiently.
- Find the maximum acceptable extrudate temperature after cooling and set the chilled water temperature to achieve this. Do not overcool the product.
- Insulate calibration baths to prevent parasitic heat gain to the chilled water.
- Use VSDs to control pumps to produce a constant pressure or flow rate. Use thermostatic controls to vary the flow rate based on the cooling demand rather than the pump's fixed output.

75. Extrusion - vacuum

For profile extrusion with calibration in a water bath, air bubbles on the extrudate greatly reduce the cooling rate and process output. Many cooling baths are sealed (nominally) and fitted with vacuum pumps to provide a reduced pressure. This encourages air removal and can be used to improve contact between the extrudate and the calibrators.

The total energy used in these vacuum pumps can easily approach that of the main extruder motor and they are rarely visible or considered. These pumps are expensive to operate, are generally larger than needed and often the cooling baths do not have good seals to prevent air ingress, i.e., the vacuum pumps are being overworked.

Action:

- Check that the vacuum supply is generated and distributed efficiently. Extrusion often uses a number of small vacuum pumps near the point of use, rather than a central utility. In most cases the motors are oversized, run lightly loaded and are inefficient.
- Check that the vacuum supply is switched off when it is not needed.
- If vacuum pumps are being used to remove air from the cooling bath, then ensure that the tanks are sealed correctly and that the seals are in good condition and do not allow air ingress. Check them regularly, they will age.
- Use VSDs on vacuum pumps to control the vacuum achieved to the minimum actually required. Vacuum control systems can cut energy use by up to 80%.

76. Energy dashboards

Previous tips have discussed reporting energy costs (#57) and the problems with SEC (kWh/kg) as a performance measure (#58). These focused on management reporting but there is a need in every company for a simple 'energy dashboard' to provide everybody with an overview of energy performance.

This should not be a management report with many numbers but should be a visual report to allow staff to instantly see trends and the action being taken. A well-designed dashboard will drive continual improvement, give everybody the same information and maintain enthusiasm for progress in energy management.

Energy dashboards should display:

- Energy use (target and actual).
- Deviation from target energy use.
- Cumulative energy use performance.
- Projects and savings delivered to date (if you are unhappy about reporting financial details then report in terms of CO_2 saved).

There is always a temptation to include the monthly SEC (kWh/kg) on a dashboard but the monthly SEC depends on production volume and is not a reliable indicator of any underlying changes in energy management. Do not include this on the energy dashboard. If you must include an SEC value then use a 'rolling average' over at least 6 months.

Reporting is an essential part of monitoring and targeting and what gets reported gets done. The energy dashboard is an essential part of this.

Action:

- Energy dashboards should be visual, attractive and communicate progress - there are many resources available on the internet to show you how to do this.
- Make the dashboard easy to update. A complex dashboard will fall into disuse. The Energy Manager should be able to update the dashboard by simply inputting a few numbers or, even better, it should happen automatically from the operational results.
- Distribute and display the energy dashboard widely.

309 Words

77. Project assessment

A failing with many projects is the lack of a final assessment to check that the project actually delivered the promised benefits that were the basis of approving the project. Unfortunately, this is true not only for energy reduction projects but for all types of projects. For energy projects, assessment is generally regarded as more difficult because you are not measuring an effect but are measuring the absence of something, i.e., you are trying to measure a reduction in energy consumption.

Fortunately, plastics processors are not alone in this and there is a well-developed methodology available for assessing the benefits of energy projects. This is the International Performance Measurement and Verification Protocol (IPMVP) developed by the Efficiency Valuation Organization (EVO). This can be used to assess project savings by comparing measured consumption or demand before and after implementation of an energy project and adjusting these for any changes in conditions. This is summarized by:

Savings = (Baseline Period Energy – Reporting Period Energy) ± Adjustments

Obviously, it is more complicated than this but IPMVP is a recognized framework for energy project assessment that can be used by processors, investment analysts and for performance contract assessment. The full documents were originally released in 3 large volumes but, since 2014, EVO has a produced a shorter ‘Core Concepts’ document that is available free from https://evo-world.org. This provides an outline of how savings can be calculated for options ranging from isolating retro-fit performance to measuring whole site performance.

Action:

- Get, read and understand the basics of project assessment for energy projects.
- Select the appropriate technique for each individual project.
- Use the selected technique to validate project savings.
- Use the savings to develop and pay for more projects.

78. Capital expenditure and energy

Many energy projects are low-cost and are classified as expenditure but some projects need capital investment and there is always a choice between competing products for capital equipment. At many sites, the option is to always go for the lowest capital cost because that is easiest to get approved. This ignores the fact that for most capital equipment, the cost of energy used during the life-cycle of the investment will be many times greater than the initial capital cost even for energy-efficient equipment. The energy cost will be even more for machines that are not energy-efficient and energy-efficient equipment will save money in the long term.

In the long-term, and that is what capital expenditure is all about, it is cheaper to specify and purchase energy-efficient equipment at the investment stage than to continuously pay for energy inefficiency throughout the life of the equipment. The initial purchase cost should not dominate the decision-making process. The 'whole life' cost of the equipment (initial cost + operating costs) is the important cost for any plastics processor who wants to continue operating in the long term.

Action:

- Energy efficiency must be part of the capital expenditure process. If there is no energy use assessment, then a capital expenditure proposal should not be approved.
- Be prepared to pay slightly more in initial purchase cost for long-term energy efficiency cost savings.
- Beware of simple payback calculations which do not include an assessment of energy costs.
- Look at the sensitivity of the costs to potential energy price increases.

79. Available capacity

Every plastics processing site will be connected to the electricity supply grid and will need an available capacity. This is the agreed maximum power (recorded in kW or kVA) that a site can draw from the supply network. If the maximum demand of the site exceeds the agreed available capacity, then the supplier may apply penalty charges and, in extreme cases, the site could be disconnected from the system by fuses or switchgear. If this happens then there will be a long interruption while the supplier resets the switchgear and there will be a substantial charge for this.

Depending on the location, available capacity may appear on the bill as a fixed monthly charge. In the UK it is charged at ≈ £1/kVA/month and for a site with an available capacity of 2,000 kVA this will mean a fixed charge of £2,000/month.

The available capacity is normally set when the site is first connected to the supply and the supplier sets this based on the relevant distribution cables, transformers, substations and switchgear for the site. This may bear little relation to what the site actually needs. Over time, the available capacity to the site may be changed by occupiers depending on their needs and the capacity availability in the area. The result is that the charged available capacity may bear little relation to the actual site need and the site can be paying too much for available capacity that they are not using.

Action:

- Check the bill for the value of the available capacity.
- Discuss the available capacity before moving to a new property. If the current available capacity is insufficient then upgrading work will be expensive and time consuming.
- Available capacity can generally be changed through consultation with the supplier.

80. Maximum demand

The maximum demand, in kVA, but sometimes in kW, is the actual maximum load that a site draws from the supply in the measurement period. The maximum demand is measured by the supplier for every billing period, e.g., every 10 minutes, 15 minutes or 30 minutes, and at the end of each period is reset to zero. The highest value for the month is the maximum demand that will be recorded on the bill. Often the time of the maximum demand is also given and this can provide information on how to reduce the maximum demand, it is usually during start-up and managing start-ups can reduce the maximum demand.

The maximum demand is simply the maximum power demanded by the site over the month. It doesn't matter if the demand is very low for most of the month. A single period of high demand is what counts.

The maximum demand should be less than the available capacity in any given month or penalty charges may apply.

Action:

- Record the maximum demand for each month and plot this against the available capacity.
- If there is a significant difference then the site can adjust the available capacity to match the maximum demand. Simple available capacity reductions can reduce fixed charges and be a quick win.
- To get an idea of the available capacity needed, find the average ($\overline{X}$) and standard deviation (σ) of the maximum demand over 12 months and calculate $\overline{X} \pm 3\sigma$. This will include 99.73% of the possible results and give an estimate of the available capacity needed.

81. Power factor

The power factor is a measure of the effectiveness of the power delivered to a site. In an ideal world where every electrical load was from a heater the power factor would be 1 but where a site has many motors there will be a difference between the apparent power (which you are charged for) and the useful power (which actually does work). For most plastics processing sites there will be a lagging power factor, i.e., PF < 1. In most countries, the PF is recorded on the bill by giving a 'cos φ' value. The value of cos φ is the proportion of apparent power that is actually doing useful work.

The power factor is a measure of how effectively a site uses the delivered electrical power. A poor power factor not only affects the site (it needs a higher available capacity) but also uses a lot of network capacity and some suppliers penalize sites with a power factor of < 0.90 with surcharges.

The effect of a low power factor can either be seen on the bill as a direct charge for 'reactive power' (measured on kVAr) or it can implicitly charged by the supplier in the charge for each kWh used (the supplier has your full record from the meter and knows the historical power factor). Whether you can see it or not, all suppliers charge more for a poor PF.

Action:

- Record the average power factor for each month (it is shown on the bill either as Power Factor, PF or cos φ) and plot this on a monthly basis.
- If the power factor is significantly less than 0.95 on a regular basis then check any installed power factor correction equipment for correct operation or obtain quotations for the installation of additional power factor correction equipment.

82. Power factor correction equipment

Improving the power factor needs power factor correction equipment (PFC) and this is primarily a set of capacitors. Installing PFC equipment will increase the PF closer to 1. This will reduce reactive power charges (either explicit or implicit) and will bring the apparent power closer to the useful power. This will reduce the maximum demand and can lead to reductions in the need for high available capacity.

Most modern PFC equipment will have several banks of capacitors that are automatically controlled to activate as the demand changes and is relatively low maintenance.

However, PFC equipment can still malfunction and it is essential to have the equipment serviced regularly. This is a simple yearly check as part of the preventative maintenance schedule but will almost always require external contractors. Despite this, some sites have had power factor correction equipment installed but never had it serviced.

A simple record of the power factor on a monthly basis will quickly show if the PFC equipment is adequate and working correctly.

Action:

- There are many calculators available on the Internet to calculate the size of PFC equipment needed and to quantify the cost benefits of improving PF using PFC equipment. Use one of these to assess your site requirements and check this against what you have installed.
- Check that any installed PFC equipment has been serviced recently.
- Establish future servicing dates and mark these dates on the PFC equipment cabinets for easy reference.

Note: PFC equipment is capacitive and will retain high charges for a long time even after being isolated. Use extreme care when near this type of equipment.

83. Transformers

All transformers suffer from energy losses, this is why they get hot and need ventilation. Transformer losses can be either no-load losses (iron losses) or load losses (copper losses). No-load losses are due to hysteresis losses in the magnetizing current and eddy currents in the transformer core. These are effectively constant at all loads. Load losses are losses in the transformer windings and are proportional to the square of the current.

Energy losses are why electricity use is metered on the supply side of the transformer. That way the customer pays for the transformer losses.

Reducing energy losses in the transformer directly reduces costs with no effect on operations at all. Energy losses at the transformer are simply wasted to create heat and often need to be ventilated away at extra cost.

Not all transformers are the same and they do not have the same performance. This is particularly true for older style transformers made from cold rolled grain-oriented silicon steel (CRGO) which have higher losses than new style amorphous alloy low loss transformers. These new transformers use a variety of techniques to reduce both the no-load and load losses. Low loss transformers are slightly more expensive than conventional transformers but can reduce energy costs by 1-2% and have a payback of ≈ 2 years.

Some modern transformers also have integral voltage regulation to reduce the supply voltage and improve voltage stability.

Action:

- Check the age and status of all transformers.
- Search for ‘low loss transformers’ to find a range of suppliers.
- Obtain a quotation on the cost and payback for the installation of a low-loss transformer.
- Install if payback meets internal criteria.

84. Voltage management

The supply voltage after the transformers varies across the world but in the EU, this will be in the range 360-440 V for 3-phase. All equipment sold in the EU must have a CE Mark to show that it will work in this voltage range. In other areas of the world, the variation is not as large but there is always a tolerance in the supply voltage in the region of ± 6%.

Voltage management is only effective for 'voltage dependent' loads. Typical voltage dependent loads are old style mains frequency fluorescent, discharge, tungsten halogen and LED lighting (although there will be a reduction in light output), standard AC induction motors (to a variable extent) and some equipment with secondary transformers installed. For this type of load a 1% decrease in voltage will result in a 2% decrease in power drawn and energy used.

Voltage management is not effective for 'voltage independent loads' – Typical voltage independent loads are heating loads (which will use less power and but run longer to produce the same amount of heat), pumps or fans used to deliver a fixed volume (they will simply run longer to deliver the fixed volume), VSD controlled motors (which will use the same power and draw more current) and modern high-frequency lighting.

The savings achieved at any site will vary with the proportion of the voltage independent and voltage independent loads. This is not a simple 'quick-fix' and needs a detailed survey to assess the benefits and savings.

Action:

- Check that transformer tappings are the lowest recommended settings.
- Carry out a 'voltage survey' for at least one week. Single measurements or short timescale logging are not suitable.
- Carry out a load assessment. This is to determine which loads will deliver savings from voltage management.

85. Protect the site against power failure

Power failures can occur anywhere in the world and sites need to be prepared for these. An unscheduled power failure will stop production but the lost production is temporary. The major issue is data loss and/or damage to the machines. These may well be permanent and cost more to rectify than the cost of the lost production.

Uninterruptible Power Supplies (UPS) can provide continued power for computers and controllers in a power failure. They will not keep a site operating because of their limited energy storage but UPS should be used for all computers (and servers) to prevent data corruption and loss.

The alternative site-wide approach is to use a ‘genset’ which is a diesel engine and an electric generator. Gensets, when suitably sized, can provide enough power to run a plastics processing site but are expensive and are rarely used except for critical applications or in countries with an unreliable grid supply.

Protecting against power failure is effectively an insurance policy against the risk of power failure. There is no financial benefit in providing this protection but are financial implications if it is not provided. Setting up systems to minimize the damage is the first thing that should be done.

Action:

- Set/adjust machines to 'fail to safe' conditions to avoid leaving machines in an unsafe or unstable condition.
- Prepare checklists and procedures for action, e.g., isolate machines, clear conveyors, clear assembly machines, set machines in correct condition for re-start.
- Use UPS to prevent data loss (or corruption) for computers and controls.
- Gracefully shut-down computers and controls. Do not keep working - the UPS will eventually drain.
- Gracefully shut-down machines to prevent machine activation when the supply is restored.
- Back-up, back-up and back-up again. A power failure is a nuisance, data loss can be fatal.

86. Renewables

The growth of renewables and alternative sources of power, e.g., solar, wind, etc. has led many companies to consider these. Renewables may work for a country as a whole or locally in some situations. However, most plastics processing sites will run either 24/5 or 24/7 and the available renewable sources are either not capable of supporting 24-hour operation, e.g., solar, or are variable in their output, e.g., solar and wind.

Plastics processing is very energy intensive and available renewable sources do not have the necessary power density output, e.g., a large solar array on the roof of a typical site would only be capable of supplying sufficient power for the lighting and small services during the day but could not supply sufficient power for the machines. These factors restrict the use of local renewables for most sites.

Many sites have considered the installation of local renewable sources and some have invested in solar or wind installations. These installations may be profitable due to government subsidies and provide a bit of ‘greenwashing’ for the annual report but the available power output from renewables is not sufficient or reliable enough to consider these as a grid replacement.

Sites may want to consider the installation of renewables if the site is suitable, i.e., if there is sufficient land/roof area or if located in a high wind area. However, these installations should only be considered if they are profitable in their own right rather than as a grid replacement.

Note: Improvements in battery technology will not affect this as most sites will use all the electricity generated in real time and have none left over for storage.

Action:

- Investigate the potential for solar or wind power as a stand-alone project only and not as a grid replacement.

87. Going off-the-grid

Renewables are not likely to be enough to take a plastics processing site off-the-grid but there are other technologies that have potential. The most promising of these is 'trigeneration' or 'Combined Cooling, Heat and Power' (CCHP). This is an extension of 'cogeneration' or 'Combined Heat and Power' (CHP). CHP is a proven technology for sites which have a need for electricity and heat but plastics processing sites rarely need heat and almost always need process cooling. With CCHP the heat generated in a gas turbine is used to provide chilled water for cooling via an absorption chiller. This can remove the need for grid electricity and replace it with lower cost gas to operate the CCHP plant. CCHP plant also removes the need for separate chillers.

CCHP can effectively take a plastics processing plant off the electricity grid but does need a good gas supply. When the weather is cold, a CCHP plant can provide power for the machines and heat for site heating with chilled water for the process being provided by air-blast cooling. When the weather is warm, a CCHP plant can provide power for the machines and chilled water for the process.

CCHP does not have to take the complete site off-grid. A CCHP unit can be scaled to provide sufficient chilled water so that conventional chillers are not required (except as back-up) and any power or heat generated simply adds to the financial viability of the project.

Trigeneration is not a new technology, simply an extension of existing proven technology. The financials for operating CCHP plants are very good but they do have a high capital cost.

Action:

- Investigate the potential for CCCP as a replacement for grid supply.
- Search for 'trigeneration' to find a range of suppliers.
- Obtain a quotation on the cost and payback for the installation of a CCHP plant.
- Install if payback meets internal criteria.

88. Hydraulics – the lifeblood

Hydraulic systems will be the major energy user in many processes, e.g., injection moulding.

Good system design and process control will minimize energy use but processors still need to look after their hydraulic fluid. These are ‘hydraulic fluids’ that we are talking about and not ‘lubricants’. They are both oils but hydraulic fluids do more than lubricate, their main purpose is to transmit power from the hydraulic pump for the machine motions. The cost of hydraulic fluid is typically < 1% of a site’s operating costs but good maintenance and correct selection of the hydraulic fluid will not only protect the system but will also reduce energy use (see #90).

Sites should maintain the fluids that are in use and replace these when the fluid is degraded. Oil analysis should be used to check the fluid and to ensure it is in good condition but also as a diagnostic tool to assess the health of the overall system. Fluids do not last forever and fluid breakdown will occur as a result of high temperatures, high pressures and shear stresses. This will reduce the viscosity and increase costs as well as decreasing the protective properties of the fluid.

Action:

- Most of the major fluid suppliers offer fluid analysis services. Use these to make sure that the hydraulic fluid is in good condition and that systems are operating correctly.
- Regularly monitor fluid condition and replace it when monitoring shows it is necessary – do not rely on ‘hours run’ as an indicator.
- Keep fluids clean through continuous filtration. Look after the fluid and it will look after you.

89. Hydraulics – getting the right fluid

To operate hydraulic machines correctly, hydraulic fluids need to be the correct viscosity. Viscosity is a fluid's resistance to deformation by shear stress and is a measure of the 'thickness' of the fluid, i.e., a high-viscosity fluid is 'thick' and a low-viscosity fluid is 'thin'.

The viscosity of a hydraulic fluid decreases with temperature, i.e., it gets 'thinner'. If the fluid is not at the correct viscosity, then the machine will not operate as set and if the viscosity is not stable then the machine will not be stable. Viscosity index (VI) is a measure of the change in viscosity with temperature. A low VI means a high change in viscosity with temperature and a high VI means a low change in viscosity with temperature.

A constant viscosity is vital for hydraulic machines because decreases in fluid viscosity will decrease pump efficiency and decrease the machine's energy efficiency. A higher viscosity will increase the volumetric efficiency of the pump, increase the volume output and can improve the system response time. For high-speed machines where the system response time is the limiting factor this can also potentially reduce cycle times.

Energy savings from using high VI fluids are typically in the range 4–10% of the energy used by the hydraulic pump but these will vary with the machine, the application and other factors. Sites should verify savings through controlled trials.

Action:

- Sites using hydraulic machines should examine their current hydraulic fluid and change to high VI fluids
- The changeover can be gradual and does not have to be site-wide. It can be a planned maintenance change to improve energy efficiency.
- Do not forget to assess the environmental impact of the hydraulic fluid used. Some of the synthetic fluids can have environmental benefits too.

90. Extrusion blow moulding – motors (all-electric)

The penetration of electric machines in injection moulding is increasing in the West but most new machines in the East are already electric. This change is slower in extrusion blow moulding but electric machines are also the most energy efficient type of extrusion blow moulding machine. As with injection moulding, our industry monitoring shows that electric machines can reduce energy use in blow moulding machines by 30 – 60% (depending on the moulding and machine being used). Energy is saved during most phases of the cycle because there are no hydraulic system losses and motors do not operate unless needed.

Additional benefits include:

- Electric machines can also often reduce cycle times (up to 30%) because there is no need to worry about the peak flow requirement of the hydraulic system and it is possible to carry out operations in parallel.
- No hydraulic systems to maintain and no hydraulic oil to contaminate the site.
- Quicker to start-up.
- Improved process control and a process that is easier to set up, is easier to adjust and calibrate and is more stable in series production.
- Platen movement is more accurate and reproducible.
- Reduced maintenance load (no hydraulics to maintain).
- Reduced cooling loads as there is no need for oil cooling

All–electric blow moulding machines are no longer ‘new’. Most of the machine manufacturers have already made the transition and sell electric machines but the majority of the machines in operation as still hydraulic and raise costs through increased energy use. Extrusion blow moulding companies need to start equipping for the future instead of equipping for the past.

Action:

- Investigate all-electric (or hybrid) machines now to re-equip for the future.

91. Extrusion blow moulding – insulation

Heating

As with conventional extruders, shear heat will be negligible downstream of the screw tips and almost all of the material flow components downstream of the screw tips will benefit from insulation. The area downstream of the screw tips is often crowded and insulation is difficult to fix and retain.

Cooling

Parasitic heat gain in EBMMs is often significant. Cooling water hoses are rarely insulated and will suffer from parasitic heat gain but the major cold surface area is the mould itself.

Moulds are rarely insulated even though they are mainly flat surfaces and can be fitted with simple, flat insulation on the outer faces to dramatically decrease the amount of parasitic heat gain to the cooling water system. The mould will not only gain heat from the atmosphere but also from the main machine if it is not insulated from the rear platen.

Action:

- Only attempt insulation where it is easy and practical to apply.
- Check the thermal isolation of the parison heads from the main machine and improve.
- Insulate cooling water hoses.
- Insulate flat surfaces of the mould block with flat insulation board to reduce parasitic heat gain to the chilled water system.
- Use insulation between the mould and the machine platens to prevent heat transfer between the cold mould and the machine.
- Increase the demoulding temperature until the maximum for good product is reached – with good parison control there will be limited differential shrinkage and de-moulding is possible at higher temperatures.
- It is possible to demould quickly from the main mould and use post-cooling with water-cooled contour clamps in critical areas.

92. Extrusion blow moulding – tops and tails

At most sites, tops and tails are 'part of the process' and dismissed with 'it is all recycled anyway'. This fallacy ignores the facts that:

- It costs money to operate the machine.
- It costs money to heat, process and cool the tops and tails even if they are recycled.
- It costs money to regranulate the material.

The material may be recycled but the energy and production time is lost forever. Tops and tails cost real money even if the material is recycled. Minimizing them will save energy and improve process efficiency.

The industry average for tops and tails is 30–40% (relative to the total extruded weight) but 26% of the industry achieves < 30% tops and tails and some have reduced this to < 10% and a realistic lower limit is 5–10%. Achieving tops and tails of < 10% will increase productivity by around 30% and decrease energy by a similar amount.

Action:

- Measure the weight of tops and tails and product for every machine. Do not be misled by the low volume of the tops and tails. Tops and tails are solid but the product is mainly air.
- Specify the allowable % of tops and tails in setting sheets on the basis of the current minimum achieved.
- Monitor tops and tails as part of process control and control these using SPC.
- Improved parison control is a key to improving and reducing tops and tails. Thinning the parison in the tops and tails areas will reduce waste.
- Link tops and tails processing equipment to the machine so that it stops when the machine does.

93. Injection blow moulding – moulding step

The energy use in the moulding step of injection blow moulding (IBM) can be reduced through many of the same measures used for injection moulding.

As for injection moulding and extrusion blow moulding, the introduction of all-electric injection blow moulding machines (IBMMs) has changed the basis of energy use in IBM. All-electric IBMMs have all the advantages of all-electric IMMs and most manufacturers of IBMMs offer an all-electric option.

Barrel insulation can be used with electric or hydraulic IBMMs to both reduce energy use and improve Health and Safety issues with hot barrels.

For sites using conventional hydraulic IBMMs, the main hydraulic motor will be the largest contributor to the energy use and there will also be a base load that uses up to 72% of the process energy (depending on how well the machine has been chosen for the moulding). Getting the main motor stopped as soon as production has stopped will reduce wasted energy use and choosing the right hydraulic fluid will reduce energy use when the motor is running.

Action:

- Purchase all-electric IBMMs wherever possible and when they are suitable for the product.
- Use barrel insulation for all IBMMs.
- Use a high VI hydraulic fluid to reduce energy use.
- Carry out all the other actions recommended for standard injection moulding.

94. Injection blow moulding – blowing step

The close integration of the IBM process means that the pre-form is blown immediately after injection. This reduces the energy required for the process because the pre-form is still hot from the injection process and does not need a large energy input to heat it up prior to blowing.

To avoid cooling of the part and difficulty in blowing the product, IBM moulds are almost always heated using conventional mould temperature controllers. Typically, these will use oil at around 125°C (250°F) and both the hoses carrying the hot oil to the moulds and the moulds themselves are rarely insulated. This is an obvious area of waste as the heat from the hoses and the moulds is lost to the atmosphere.

Mould temperature controllers are not the only area in IBM where heat is used poorly. Most sites have heating (for the process) and cooling (for the product) in the same area and do not manage the heat well. Insulation and good process control will reduce energy use.

Action:

- Insulate all hot mould temperature controller pipes to reduce the energy use in mould heating.
- Insulate all available surface areas of moulds to reduce heat losses from the mould.
- Thermally isolate moulds from the rotating platen to reduce heat losses from the mould.
- Attempt to separate the heating and cooling in the process (heat management) to avoid using energy to heat and cool in the same area.

95. Injection stretch blow moulding – moulding step

Injection stretch blow moulding is primarily a discontinuous two-step process, i.e., there is no linking of the moulding and blowing steps, although this is being modified by some companies to provide a continuous single step process. The most innovative approach is LiquiForm™, developed by Amcor and Sidel, which removes the use of high–pressure compressed air in the blow step and uses the fill liquid to both blow and fill the bottle at the same time.

Pre–form moulding in ISBM is similar to IM and all the material injection moulded into the pre-form is used for the final product, i.e., no tops and tails are produced.

ISBM sites always have very high services loads and the main contributors to this are the material drying load (when PET is used) and the demand for high–pressure air (see 96). These will typically be much greater than the energy used for the moulding step.

Action:

- Carry out all of the energy use reduction activities for standard injection moulding (see previous Energy Saving Tips of the Month).
- The drying load for PET pre-form production is very high. Good management of the drying process is essential for energy efficient ISBM. Sites should carry out all of the energy use reduction activities for drying (see previous Energy Saving Tips of the Month).
- Dryer operation also sometimes has very short and high power spikes at operating cycle transitions.
- IMMs used for the moulding step will be fitted with hot runners. Sites manage hot runners carefully to minimize energy use.

96. Injection stretch blow moulding – blow step

The blow step is the largest energy user in ISBM as a result heating and the high–pressure air use.

Infrared heating lamps must be matched to the material being processed to reduce energy use. Blowing machines (mainly the lamps) use ≈ 25% of the energy at an ISBM site.

The 30–40 bar compressed air used in the blow step of ISBM is much more costly than conventional low–pressure air because compressed air costs more to generate at higher pressures. High-pressure air compressors use ≈ 30% of the energy at an ISBM site. As for low-pressure systems, it is possible to fit VSDs to high-pressure systems either as original equipment or as retro-fit packs. These slow the compressor match the demand and save energy and money.

Action:

- Dry cycling costs real money. Do not dry cycle machines unless absolutely necessary.
- IR heaters should be optimized for the material. New generation reflector lamps can reduce heating costs by up to 18%.
- Recover high-pressure blow air for use in other areas of the machine as low-pressure air.
- Local receivers at blowing machines will minimize transient pressure fluctuations.
- VSDs and good control systems are needed to minimize energy use and cost in the production of high-pressure compressed air for the blowing step.
- Sites should carry out all of the energy use reduction activities for compressed air (see previous Energy Saving Tips of the Month) to minimize the cost of high-pressure compressed air.
- High-pressure compressed is dangerous, treat it with care.
- The high cost of services used for ISBM means that they must be correctly allocated for accurate costings.