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1 Introduction

The European plastics processing industry faces intense competition from lower wage economies and alarming rise in energy prices. To remain competitive a business must have an effective energy management process, good market knowledge and an awareness of technology and support mechanisms. This industry comprises more than 27,000 companies more than 80% small to medium enterprises (SME), employing more than one million people, and with total sales of over 100 billion.

If it were possible to reduce energy consumption across the industry by 10%, this would result in an annual reduction in carbon dioxide emissions of more than 3 million tonnes.

Western industry is highly focused on the cost of labour and sees the growth in volume of imported products as being due purely to the lower labour costs of overseas suppliers. The reality is that labour costs are, and always have been, a minor component of the overall cost of most plastics products. Direct labour has shrunk from an average of 25% of manufacturing costs in 1960 to 10% today. The cost of materials and overheads are far more important in the total product cost, but Western industry still focuses overwhelmingly on labour cost even as the overhead and energy costs rise. The main energy usage and cost is in processing machinery and services (92%), lighting, heating, and offices are minor energy costs (8%).

For the majority of plastics processing plants, the cost of energy is in the region of 4% to 8% of sales and for some firms is approximately equal to the profit level. In low margin sectors of plastics processing, such as packaging and automotive parts, the cost of energy can be greater than the profit margin.

The possible savings from good energy management are in the range of 30% of current energy expenditures for most plastics processors. In rare, extreme cases, energy savings of up to 50% have been identified with little difficulty.

These savings are virtually irrespective of the industry sector or process used. One particular plastic process does not waste more energy than another. It is not the process but the management that makes the difference.

The potential for 30% average savings in energy cost is achievable in equal shares through management, maintenance, and investment. Simple recognition that the rules have changed and that managing energy usage with about the same degree of effort that management devotes to managing direct labour can produce savings of up to 10% of energy usage.

Another 10% energy savings is available with simple quick fix actions such as controlling the use of utilities and services (such as compressed air) in both the process and the plant at large. This includes small investments in emerging technologies such as variable-speed drive control of water pumps and air-handling fans. Maintenance investments are defined as those whose expected payback is less than one year, regardless of the amount invested.

The final 10% saving is possible through investment in energy-efficient processing technologies and, just as important, through effective management of these technologies.

The majority of all these savings can be delivered through a balanced combination of no-cost, low-cost, and investment (maintenance or capital) actions. The average payback for all investments in energy management is, generally in the region of six to nine months.

However, in Asia their low labour costs mean that in many cases energy costs are already higher than labour costs [1]. Some of the most energy efficient sites in the world are already in the East. In addition to a labour cost advantage, they are also gaining an energy cost advantage.

Energy costs now represent the third largest variable cost (after materials and direct labour) for most plastics plants, and in some cases energy is the second largest variable cost. This is particularly true for plants that have low direct labour costs.

Energy efficiency is one of the 'hot' topics of the 21st century and plastics processors around the world are trying to come to terms with it. Ten years ago, a column on this subject would have attracted scant management interest. Today, energy management is not just a 'green' issue, or a 'carbon footprint' issue, it is a very real business issue and, in many cases, a matter of survival.

Price increases in energy and the desire to reduce greenhouse gas emissions have raised the profile of energy management in the plastics processing sector. This has pushed many businesses into action, but all too often their efforts have been poorly directed or ineffective. Sadly, this has led some firms to abandon their efforts to improve energy management, even though the basic techniques are essentially very simple and easily applied. Where managers have been well informed and have diligently

2 Heating and Lighting

The general philosophy with both heating and lighting is to 'supply what is required to the point of need', less but consistent light in circulation areas, but more light at the machinery and in quality control areas.

Examine the areas that are being heated or lit and decide if too much or too little light is being supplied. Offices need to be periodically checked to ensure that unused rooms are not being heated to the same temperature as those that are in use. Additionally, interlocks should be fitted to large access doors to ensure heating is switched off when the doors are left open. Poor fitting windows and doors are also a large source of heat loss and routine maintenance of these items will save more money than it costs. Lighting is one of the most important factors in our working environment and optimal levels will provide many advantages:

- Critical work is carried out under the best light conditions
- High productivity is obtained
- Improved safety on the job, especially when moving around
- Increased security and improved well-being

2.1 Light Source Selection and Fixtures

Fluorescent lighting is normally used in production and administration areas. These should be fitted with dimmable high frequency (HF) coils in all production rooms, including those with a high ceiling, allowing penetration of daylight.

2.1.1 *Energy Efficient Electronic Ballasts*

All fluorescent tubes are provided with electronic ballasts to reduce the current through the lamp, but they can also be fitted with high frequency ballasts (HF-coils).

As well as providing energy savings of approximately 25%, the HF-coils also provide quality advantages:

- An increased lifetime of 50% to 70%
- The tubes light up instantly – no flashing
- No flickering or stroboscopic effect
- Variable lighting regulation, e.g., after daylight radiation
- Cut-out of defect tubes

2.1.2 Energy Efficient Lighting Fixtures

Old lighting fixtures are often inefficient. It normally pays to replace these fixtures with HF ballasts, reduce the number of tubes and still obtain better lighting efficiency. As a general rule, fixtures with fewer tubes are more efficient. This can be further improved by fitting fixed or loose reflectors in the tubes.

When designing the lighting system it is important not to over dimension as this can result in a very high maintenance factor. Over dimensioning is normally more expensive than cleaning and maintenance of the system. Therefore, it is important to find easy to clean lighting fixtures and to set up a fixed maintenance procedure.

2.2 Light Regulation

2.2.1 Light Regulation According to Daylight Penetration

Daylight penetration should be considered when designing room and workplace lighting in industrial premises. Building regulations regarding size of the windows normally ensures ample light during normal daylight hours. Equipment for control and regulation of artificial light is being used more often to adjust the lighting to reflect the daylight penetration and the requirements of the various activities. By regulating the artificial light according to the variations in the daylight, large energy savings can be obtained.

3 Cooling

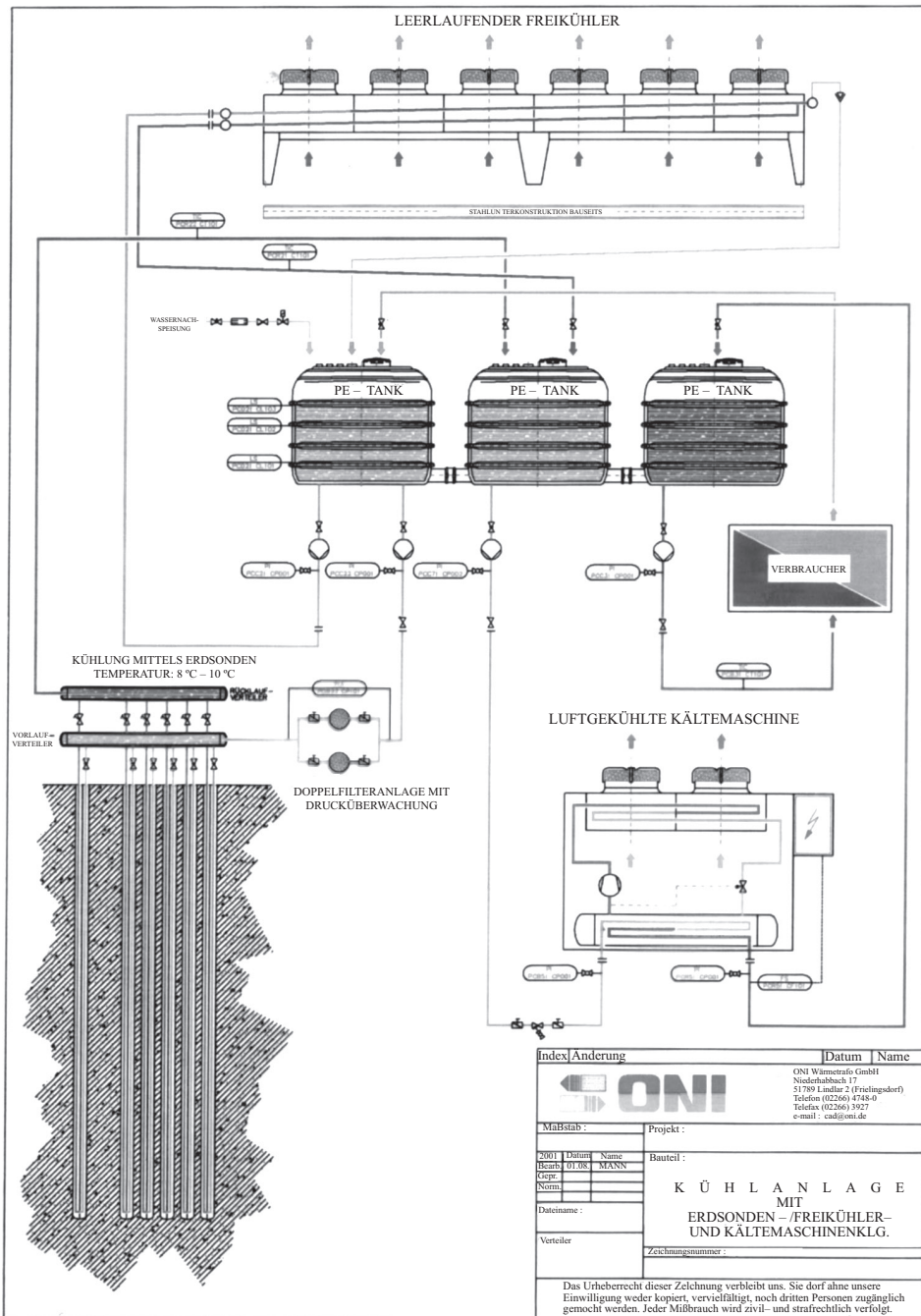
3.1 Refrigeration

The use of modern refrigerators for the production of cold water and oil cooling is energetically very efficient. Therefore, the use of modern and clean cooling media supports optimisation. For cooling the injection moulding tools a water temperature of approximately 12 °C is necessary. Normally, electrical powered refrigerators are used for producing cooling water during the whole year. Here cooling energy supply systems are an attractive alternative (see **Figure 3.1**). During the winter months the water is directly cooled by the available ambient air (see **Figure 3.2**). During transitional months the exterior cooler can be used for the prior refrigeration of water and the refrigerator undertakes the rest of the refrigeration. In this way the energy intensive refrigerator has to be used only during the hot summer months (see **Figure 3.3**). The temperature rise of the cooling water (during the oil cooling) from 30 °C to 35 °C, which is heated up through the waste heat of the machine, can be used for room heating [1].

3.2 Cooling Water

Chillers are used to supply cool water for a variety of process needs including: cooling the injection mould, controlling the temperature of the hydraulic oil, cooling baths and chill-rolls for extrusion processes. All the energy that is put into the polymer during processing must be removed again to produce a finished article at room temperature. Choosing the correct ‘water chiller’ and finding the optimum operating conditions, can significantly reduce the energy requirements. Over a 10 year period, 90% of the chillers’ costs are energy costs, so choose the most efficient and not the cheapest.

Decide what the water temperature should be and raise it by 1 °C. A possible 3% reduction in the chillers’ power can be achieved.



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Figure 3.1 Total scheme of a cooling system. Reproduced with permission from Oni-Wärmetrafo GmbH, Wir setzen Energie Sinnvoll Ein, K-Zeitung, 2005, Number 17. ©2005, Oni-Wärmetrafo GmbH [1]

4 Compressed Air

Compressed air systems [1] are installed in almost 70% of all factories and it is not uncommon that these systems account for more than 20-30% of the company's total electricity consumption. A review of the system and its operational conditions will often result in one or more compressors being closed down or replaced by more operationally economic types, which will definitely improve the efficiency of the whole system.

When trying to optimise the compressed air system it is important to investigate both the entire system as well as the individual components. This means that apart from checking the individual parts of the system, it is necessary also to analyse the system's inlet and discharge side and their interaction. In the optimisation procedures is therefore advisable to consider the following:

- Investigation and documentation of the existing operation conditions including identification of operation parameters
- Clarification of existing and future demands on the performance of the compressed air system based on the company's production plans
- Analysis of operational data including demands to system performance over 24 hours
- Reuse of the energy from the compressors
- Analysis of alternative system installations including improvements
- Outline the technical and economical solutions at component as well as system level
- Implementation of solutions
- Collection of technical data for validation of energy and economical savings. Check payback times and so on
- Continued thorough and systematic supervision and optimisation of the compressed air system means better utilisation, technically as well as economically

- Ensure continued optimal operational conditions and preventive maintenance of the system

4.1 Compressed Air Requirements

4.1.1 Capacity

The capacity of the compressed air system is typically determined by analysing the requirements of the individual components and work procedures which use compressed air. When calculating the compressed air demand it is important to consider the load cycles of the individual processes, so that the measurements are not based on 24 hours' full load. Thus, the total capacity requirement of the plant is determined by adding up the average demand figures of the individual tools and processes. In cases where a high load is required for a limited time it is possible to use stored air from an air receiver. In some system setups it may be optimal to connect more air receivers which are placed close to the sources which require the high capacity. Mostly, a thorough review of the actual capacity demands of the system will show that the overall capacity of the system can be reduced.

A system with oversized compressors will run ineffectively, as the compressors normally use more energy per produced air volume, when running outside their peak load area. It is often more economical to use several smaller compressors, which are sequentially controlled at loads below the peak loads of the plants.

If there are still capacity problems after the optimisation of the system (with additional compressors), there are still alternatives to the use of compressed air, for example, electric tools, which may often be a more efficient and less energy-consuming solution.

4.1.2 Load Profile

It is extremely important to clarify the company's requirements for compressed air – typically defined over one working day, and an accurate load profile of the system is important to be able to design and implement an energy-efficient compressed air system in the company. Companies with a very varying load profile should invest in a system consisting of several sequentially controlled compressors which are running effectively under partial load. Correspondingly, companies with a simpler load profile can do with a system controlled according to simpler principles.

5 Motors

5.1 Introduction

There are millions of motors in use in industry worldwide. The Motor Challenge Programme claims that motor driven systems account for approximately 65% of the energy consumed by European Union (EU) industry. The Motor Challenge Programme is a voluntary programme promoted by the European Commission to help companies improve the energy efficiency of their electric motor driven systems.

Energy efficiency should be a major consideration when purchasing or rewinding a motor. The annual energy cost of running a motor is usually many times greater than its initial purchase price. For example, even at the relatively low energy rate of \$0.04/kWh, a typical 20 horsepower (hp) continuously running motor uses almost \$6,000 worth of electricity annually, about six times its initial purchase price.

The main barriers to achieving energy efficiency with motors are:

- A large number of motors are sold to original equipment manufacturers, whose main concerns are price and delivery time rather than efficiency
- Those departments of a company responsible for buying motors are often under pressure to recover their investments as quickly as possible. They are not responsible for buying energy. Maintenance managers make purchase decisions on replacement and not on energy efficiency
- The majority of motors when they fail are rewound, because repair is usually cheaper than a new motor purchase. Therefore, rewinding reduces the maximum theoretical penetration rate for efficient motors. The penetration rate is estimated to be around 6% per year, based on an average life of 15 years

5.1.1 Compressed Air Systems

Compressed air plays a very large part in the industrial field since it counts for approximately 11% of the current consumption. A survey conducted for five years

with the 6,000 hours operation of an air compressed system shows that energy accounts for 75% of the operating costs.

The output of a compressed air system is only 10% in most cases. Compressed air is an energy carrier which is difficult to control because it is expensive (0.06 to 0.3 per Nm³) and it has a high improvement potential of around 25% of possible energy saving on an average.

5.1.2 Cold Production Systems

Industrial refrigeration represents 4% of the electricity consumption in the industry and almost 7% of the domestic current consumption.

The food processing sector alone uses 57% of the electricity consumption is dedicated to the industrial refrigeration. The energy savings achieved in the industrial refrigeration sector is about 20% of possible savings on average.

5.1.3 Pumping Systems

Pumping systems represent approximately 25% of the worldwide current consumption. Studies have shown that significant energy savings could result from using more efficient equipment and appropriate control systems making it possible to save up to 40% of energy for an average lifetime of 15 to 20 years. The major two pump families are the centrifugal pumps and the displacement pumps. Centrifugal pumps with a 73% market share represent great possibilities of energy savings because it is considered that 75% of the pumping systems are oversized, most of them by 20%.

5.1.4 Ventilation Systems

Ventilation is a tool necessary for the proper operation of an industrial plant, ensuring the quality of production and the individual protection against the emission of pollutants or heat in premises.

The energy consumption of a plant represents on average 10% of the current consumptions of the industrial business. The indirect energy consumption to be considered is still higher when the air has a great energy content due to its conditioning for example heating and cooling.

6 In the Office

Saving energy in the office doesn't need great investment, just for employees to adopt some simple energy saving measures that cost little or nothing in time and money. In this chapter, a list of these measures is included, especially those regarding office equipment (computers, monitors, photocopiers and so on). Also, the suitability of carrying out an energy audit in the office and the implications of this are discussed. Clarification of the different energy rating labels and their meaning is also included in this chapter.

6.1 Energy Audits

Whether one is constructing a new building or remodelling an existing space, a business energy audit is a great way to implement eco-friendly company values. Save energy, cut back on carbon dioxide emissions, and create a more comfortable workplace with this relatively inexpensive procedure.

How to conduct an energy audit:

- Do-it-yourself energy audit: Consider conducting your own business energy audit. Start by checking the list of information commonly requested on audit questionnaires to get an idea of the kinds of data you will have to collect
- Professional energy audits: Alternatively, hire a professional to do the job
- Hire an energy efficiency contract specialist: Once the audit is complete, start improving the energy efficiency of the building

Information commonly requested on audit questionnaires:

- Number of employees (full-time and part-time)
- Primary business activity
- Average number of business hours per day

- Average number of business days per week
- Year building was constructed and occupied
- Average ceiling height
- Total square footage of building and percentage used regularly
- Number of floors in the building
- Percentage of exposed walls, walls shared with other buildings, and walls with windows (and whether windows are single-, double-, or triple-paned and if they have tints or reflective coatings)
- R-values of exterior walls and ceiling/roof (for this you will need to have information about the type of materials used in the building's roof/ceiling and their estimated heat flow resistance values). The R-factor (also known as R-value) indicates the insulating value of a product, or put another way, the product's resistance to heat flow. The higher the R number, the higher its insulating effectiveness
- The kind of energy used in building (natural gas, electricity and so on) and the age, efficiency, and type of system used to cool and heat facility (central air, window air conditioners, hot water, boiler, furnace, unit heaters, baseboard heaters, radiant heaters and so on)
- Average setting on thermostats throughout the building while open and closed and whether thermostats are programmable
- Type and condition of water heating units (including those in pools and hot tubs)
- Number, type, location, age, condition, efficiency, use-patterns, and size of refrigerators and freezers, laundry equipment, microwaves, dishwashers, and stoves/ovens
- Number, type, age, efficiency, use-patterns, and size of all electronic equipment (computers, printers, copiers, monitors, servers and so on)
- Number, type, wattage, and average operational time of indoor and exterior lights
- Number, type, age, and use-patterns of all elevators and escalators
- Information about any equipment used seasonally (dehumidifiers, irrigation systems, special events equipment and so on)

7 Bills and Meter Readings – Understanding and Analysing Data

7.1 Introduction

An electric meter or energy meter is a device that measures the amount of electrical energy consumed by a residence, business, or an electrically powered device. Electric meters are typically calibrated in billing units, the most common one being the kilowatt hour (kWh). Periodic readings of electric meters establish billing cycles and energy used during a cycle. In settings when energy savings during certain periods are desired, meters may measure demand, the maximum use of power in some interval. In some areas, the electric rates are higher during certain times of day, to encourage reduction in use. Also, in some areas meters have relays to turn off non-essential equipment. The first accurate, recording electricity consumption meter was a direct current meter invented by Hermann Aron, who patented it in 1883. Hugo Hirst of the General Electric Company introduced it commercially into Great Britain from 1888. Meters had been used prior to this, but they measured the rate of power consumption at that particular moment. Aron's meter recorded the total energy used over time, and showed it on a series of clock dials. The first specimen of the alternative current (AC) kWh meter produced on the basis of Hungarian Ottó Bláthy's patent and named after him was presented by the Ganz Works at the Frankfurt Fair in the autumn of 1889, and the first induction kWh meter was marketed by the factory at the end of the same year. These were the first AC wattmeters, known by the name of Bláthy-meters.

7.2 Measurement

7.2.1 Measurement Unit

The most common unit of measurement on the electricity meter is the kWh, which is equal to the amount of energy used by a load of one kilowatt (kW) over a period of one hour, or 3,600,000 joules. Some electricity companies use the International System of Units (SI) megajoule instead. Demand is normally measured in watts, but averaged over a period, most often a quarter or half hour.

Reactive power is measured in volt-ampere reactive hours, (varh) in kilovar-hours. By convention, a 'lagging' or inductive load, such as a motor, will have positive reactive power. A 'leading', or capacitive load, will have negative reactive power.

Volt-ampere measures all power passed through a distribution network, including reactive and actual. This is equal to the product of root-mean-square volts and amperes.

Distortion of the electric current by loads is measured in several ways. Power factor is the ratio of resistive (or real power) to volt-ampere. A capacitive load has a leading power factor, and an inductive load has a lagging power factor. A purely resistive load (such as a filament lamp, heater or kettle) exhibits a power factor of 1. Current harmonics are a measure of distortion of the wave form. For example, electronic loads such as computer power supplies draw their current at the voltage peak to fill their internal storage elements. This can lead to a significant voltage drop near the supply voltage peak which shows as a flattening of the voltage waveform. This flattening causes odd harmonics which are not permissible if they exceed specific limits, as they are not only wasteful, but may interfere with the operation of other equipment. Harmonic emissions are mandated by law in European Union (EU) and other countries to fall within specified limits.

7.2.2 Electromechanical Meters

This mechanical electricity meter has every other dial rotating counter-clockwise. The most common type of electricity meter is the Thomson or electromechanical induction watt-hour meter, invented by Elihu Thomson in 1888. The electromechanical induction meter operates by counting the revolutions of an aluminium disc which is made to rotate at a speed proportional to the power. The number of revolutions is thus proportional to the energy usage. It consumes a small amount of power, typically around 2 watts.

Two coils act upon the metallic disc. One coil is connected in such a way that it produces a magnetic flux in proportion to the voltage and the other produces a magnetic flux in proportion to the current. The field of the voltage coil is delayed by 90 degrees by using a lag coil. This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product of the instantaneous current and voltage. A permanent magnet exerts an opposing force proportional to the speed of rotation of the disc. The equilibrium between these two opposing forces results in the disc rotating at a speed proportional to the power being used. The disc drives a register mechanism which integrates the speed of the disc over time by counting revolutions (much like the odometer in a car), to give a measurement