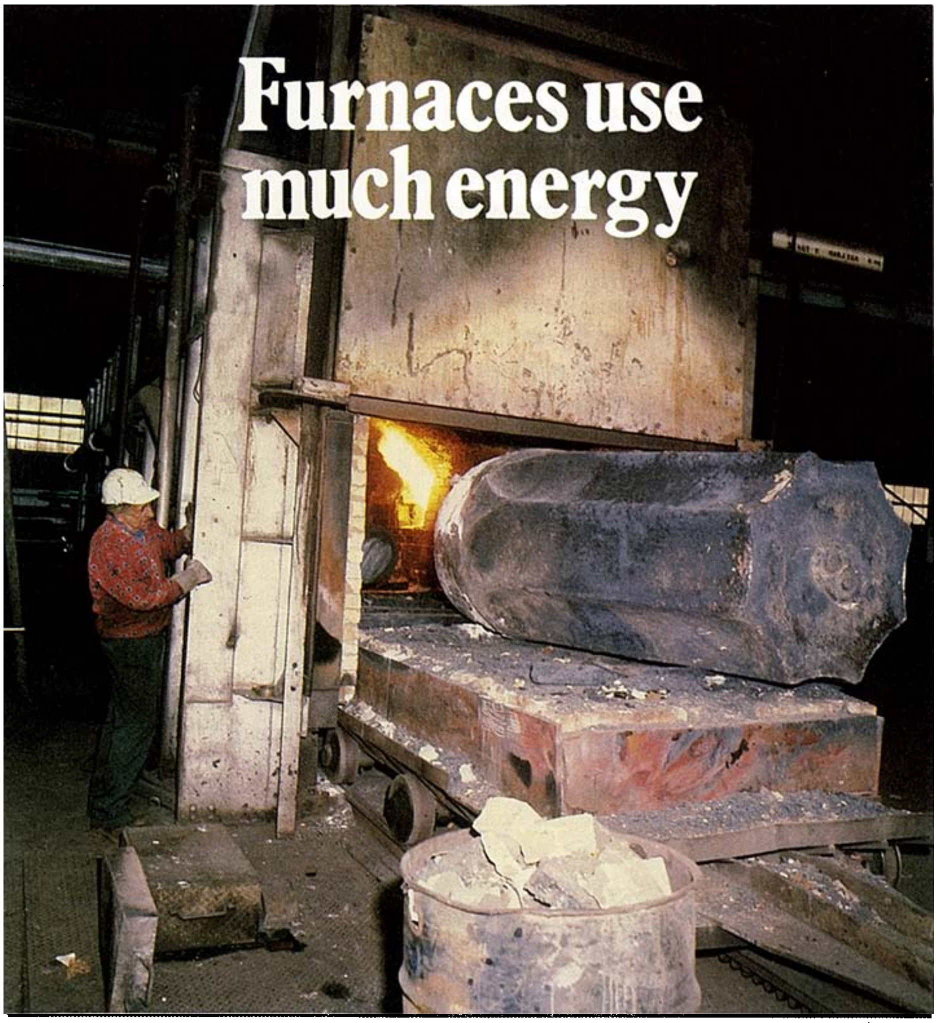
Furnaces use much energy



Metal engineering is the backbone of Australian manufacturing. By forging, sintering, casting, and heat treatment, our modern-day blacksmiths turn out crane hooks weighing many tonnes and finger-sized medical prostheses. In between are turbine blades for jet engines, steering joints and drive shafts for cars, and many other components for the machinery that works for us.

In 1978, the cost of fuel used in making heat-processed metal products was reckoned to be about $550 million. The higher the temperature required for manufacture, the more energy-intensive is the process. High-temperature furnaces have only very low efficiency, from 5 to 15%, and a significant component of the cost of a forged product goes towards covering the energy bill.

Yet, according to the CSIRO Division of Manufacturing Technology, we still lack awareness of, and commitment to, energy-saving measures, probably because energy usage has been a neglected area in the past. The Australian metal engineering industry consists of many small companies, and the need to use very large amounts of energy has seldom been questioned.

Forging still relies heavily on oil-fired furnaces.

In recent years, however, the continual increase in fuel prices has made energy a more substantial component of the cost of many items. As a result, interest in conserving energy has grown in the past few years.

Dr Lee Luong of the Division has conducted a survey to find out the extent of energy consumption in some parts of the metals industry that make use of high-temperature heating. His survey has confirmed that very large quantities of energy are consumed, and pointed to areas where economies can be made.

To test practical means of conserving energy, he has designed a more fuel-efficient furnace, and a heat exchanger that captures waste heat from flue gases and pre-heats incoming air. Examples of both have been built and are working well.

The table shows the results of the survey and reveals that sintering is the process highest on the energy-consuming ladder, with an average demand of 38 megajoules used within the process to produce one kilogram of finished product. This amount of energy is equivalent to 0·8 kg (nearly 1 litre) of diesel oil. Heat treatment comes next (13 MJ per kg), followed by hot forging (12 MJ per kg), and casting (7 MJ per kg).

By comparison, machining of mild steel uses only 0·3 MJ per kg of metal removed, illustrating the dominance of heat-using processes in energy consumption in the metals engineering industry.

In the sintering process, metal powder is compacted to the shape required and, shrouded in a protective atmosphere, heated in a furnace. Many joules are consumed in maintaining the inert atmosphere: perhaps 36–50% of them disappear along with the escaping gas.

Ferrous casting wastes a large quantity of material (36–45%), as metal fills the gates and runners leading to the casting proper. Some non-ferrous foundries were surveyed, but not enough to establish a reliable figure for energy use.

Forging operations still rely heavily on oil-fired furnaces, and in 1979 oil accounted for 77% of the energy consumed in the forging industry. Most of the furnaces were built in-house — leading, in some instances, to poor efficiency.

In open-die forging, where the workpiece can weigh several tonnes, energy consumption varied greatly from plant to plant: from an average of 12 up to 36 MJ per kg in some furnaces. In closed-die forging, where the item is of kilogram size or smaller, a figure of 8–15 MJ per kg is usual.

These values compare unfavourably with a figure of 2 MJ per kg reported by the Japanese iron and steel industry in 1980. Some of Dr Luong's ideas on furnace design and operation could help Australian industry reduce energy consumption in high-temperature processes.

Also, a switchover from oil to natural gas can save money, if not energy. As an example, Dr Luong came across one company using 1165 tonnes of diesel fuel a year at a cost of $280 000. A change to natural gas would reduce the fuel bill to $64 000.

Energy consumption of furnace processes

process	energy required for final product (MJ per kg)
sintering	38
heat treatment	13
hot forging	12
ferrous casting	7

Furnaces use large quantities of energy. If energy used in producing the fuel (in particular, electricity) is considered, the figures are even higher.

What can be done

Before a company attempts to reduce fuel bills, Dr Luong recommends that it carry out an energy audit: a listing of all the places where energy is expended, how much, and in what form. This establishes the basic fuel cost of each activity, and the principal points at which waste or inefficiency occurs.

This information helps identify appropriate remedial steps, and also provides a reference point from which improvements in energy consumption can be measured.

Measuring instruments, such as fuel meters, are often needed in an energy audit. However, these same instruments are needed to monitor a plant's operation to ensure efficient running, and their cost is very small compared with the energy savings they can help achieve. Despite this, Dr Luong has seen many instances of companies spending large sums on fuel, yet little on instruments for measurement and control.

For example, chemical-absorption instruments that detect the level of oxygen and carbon dioxide in the flue gases can be bought for a few hundred dollars. These allow the correct air:fuel ratio to be easily set, ensuring the most efficient furnace operation.

Yet the survey results showed that incorrect combustion conditions were common, and rectifying this fault offered the largest potential for saving fuel. Of 12 furnaces investigated, all could have been improved in fuel efficiency, whether by 4% (the best-run one) or by 90% (the worst).

Other 'good housekeeping' measures can also give significant fuel savings. Dr Luong identified furnace leaks, flame 'sting' (combustion outside the furnace), and poor use of hearth space as easily correctable inefficiencies that are worth overcoming. He calculates that a crack of 0·01 sq. m in a 1300° C furnace, if left open on every single-shift day, gives an annual loss of about 1000 cubic metres of gas or one tonne of oil.

Control of furnace temperature is also important, and Dr Luong recommends thermostatic instruments that provide this automatically. Among the furnaces surveyed, those with manual adjustment often ran at unnecessarily high temperatures, which meant higher fuel consumption, shortened refractory life, and more scale.

Modern refractory materials with low thermal inertia can achieve savings, too. Low-density insulating bricks and ceramic fibres are quicker to heat up than the traditional firebrick, and conduct less heat. Both characteristics lead to lower energy consumption.

Dr Luong used these materials in designing an efficient gas-fired furnace, a project undertaken in co-operation with the Forging Industry Research Committee of the Metal Trades Industry Association. He also paid careful attention to the size and location of burner and flues.

The furnace is now in regular use for producing forged tools, and measurements show it has a fuel consumption of 2·7 MJ per kilogram of material heated — a pleasingly low figure, 65% better than that of other furnaces in operation.

The heat recuperator Dr Luong designed is a heat exchanger for extracting heat from the flue gases for preheating combustion air. A prototype unit has preheated air to more than 600° C from a waste gas temperature of 1300° C. This reduces fuel consumption by 30%.

Dr Luong has also developed a computer model of heat transfer in a furnace, and is using it to study the influence on fuel economy of a number of other factors in furnace operation.

In particular, he is determining the best way of heating large billets (up to several tonnes) to the temperature required, a process that may take a number of hours. By regulating the furnace temperature during this time, fuel can be saved without prolonging heating time.

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More about the topic

Energy technologies for the metals industry. L. H. S. Luong. *Proceedings of the 35th Annual Conference of the Australasian Institute of Metals, Sydney, May 1982.*