

Company Factsheet:

- £2m a year and employs 26 people
- Operates 5 days a week from 8am-5pm for 50 weeks a year
- Gas
 - For Melting and holding aluminium at temperature
 - Space heating in finishing area, offices and workshops
 - Heating of dies prior to casting
- Electricity
 - Melting and holding aluminium at temperature
 - Lighting in the foundry, offices and workshops
 - Production of compressed air
 - Operation of abrasive wheel, power tools, PCs and other equip.
 - Fume extraction
- Compressed air
 - Produced at 7-8 bar
 - Maintained every 6 months, running for 10 years
 - Most equip runs at 2-3 bar
 - Sand blasting runs at 7 bar
 - 18.5kW on load
 - 5kW off load – FOR ONLY 2 HOURS A DAY
 - System leakage of 47%
- Lighting
 - Poorly maintained 20+ years old
 - 10 hours a day, 5 days a week, 50 weeks a year
 - Grav. Die casting: 20x 95W
 - Finishing area: 12x2 fitting 85W T10
 - Sand Foundry: 4x large sodium lamps 125W
- Furnaces:
 - 12 Electric Bale out furnaces – With submetering
 - 5 Gas furnaces – 2 in Sand Casting – NO DATA
- Casting Process:
 - Holds 250kg
 - 5am temp raised from 600-720 ready for 8am start
 - 5pm-5am temp lowered to 600 for 4 NIGHTS A WEEK
 - Over weekend only 3 furnaces are held in molten state
- Casting energy use:
 - Operates 5 days a week for 50 weeks
 - From cold 177kW 5 times a day
 - 113kW for production
 - Overnight 39kW
 - Over Weekend 134kW

1)

Discuss how Alucasts should go about setting up an energy monitoring and targeting system explaining what issues they need to consider:

Energy monitoring and targeting has long played a part in efficient function of high energy consumers and with a total cost of £139,058 being spent on electric furnaces alone, small improvements in efficient operation have the possibility to make substantial impacts on the cost of energy within the company. The main sources of energy usage identified in the brief are electrical energy and gas energy where the electrical energy usage also cover the compression of air for power tools and other equipment. The key steps of running a well operated monitoring system are as follows (Sustainable Energy Authority, 2019):

- Identifying the separate areas of energy usage
- Being able to record regular readings of the largest areas of energy consumption
- Identify specific subsections that are influencing energy consumption
- Identify areas of excessive consumption
- Estimate baseline energy use for each area
- Set reasonable and achievable targets
- Compare metering to targets and make comparisons in data sets

Based on this my first recommendation would be to ensure the big consumers have a means of metering and measuring energy usage; while there is sub-system level metering in the electric furnaces there is no means of sub-system or even system level metering for the gas furnaces. Installing flow meters for each of the 5 gas powered furnaces will allow for automated data collection of energy usage. Digital gas flow meters can cost anywhere between £100-£800 depending on the flow rate required for the gas lines (RS Hydro, 2020), meaning an estimated £2000 cost to install gas metering in all 5 gas furnaces. Not only will this help understand the energy usage of the furnaces but will also allow for observation into the energy waste of individual furnaces. As an example; if one furnace was using substantially more power than another that one furnace could be observed to see where that power could be lost. In the case of gas furnaces some key areas of energy loss are (Industrial Technologies Program, 2004):

- Worn furnace fabric resulting in heat loss through openings or exposed parts
- Possible excess air usage resulting in a cooling effect
- Heat loss through transported product
- Less heat efficient crucible structure

Not only does metering allow for targeted approach to failure of furnaces but allows for the generation of monitoring based statistics which can give “bigger picture” analysis into energy usage but also are useful to shareholders and stakeholders (who may not understand the technicalities) to get an idea of energy usage at the site. Therefore, my next recommendation would be a monthly or quarterly energy report highlighting the key monitoring statistics and performance indicators i.e. the Monitoring specific consumption which allows for a look into the energy per unit of product produced which is an industry wide statistic allowing for an industry level comparison. One of the issues with specific consumption is that it does not account for the type of business, by its nature melting of metal goods is a very energy intensive process. The use of monitoring energy consumption against a baseline regression means that the energy ‘drivers’ or sources of energy usage are accounted for in the baseload making the process less industry specific. Having a mandated energy report as a part of company policy means the company MUST keep a stronger

record of energy usage in electrical and gas. For a more general overlook having the metering broken down into segmented parts of the factory allows for better day-to-day observation without having to analyse each system individually. I would recommend sector metering for the foundry, the offices and the workshops paired with a strong change in policy for more regular measurements of all available meters and a continuous improvement in energy-related performance. The new monitoring policy should also look at thermal mechanical efficiency of the furnaces more regularly reducing the possibly of wasted energy through unnecessary efficiency loss.

The next area of concern is with respect to the energy used through lighting; the current lighting system consists of 3 main bulb types: 20 x 95W high pressure lamps, 24 x 85W T10 fluorescent tubes and 4 x 125W high pressure sodium lamps., which based on the 9.2p electrical tariff costs just over £1000 a year to run. With the rise in LED usage, they are becoming more cost effective and bright to operate as alternatives to large space lighting. High-pressure sodium lamps (HPS) run at considerable inefficiency, a single 150W HPS bulb was found to operate for 32,000 hours at 16463 lumens, while more expensive, a 150W LED bulb will operate for 50,000 hours at 20,000 lumens. To meet the 16,000 lumens currently generated by the bulbs, an equivalent LED would cost around £60 compared to around £20 for the HPS bulb. It will therefore mean on average LEDs to replace the HPS bulbs will be more expensive. However, the next recommendation would be change in repair strategy; currently the maintenance staff will fix on a run-to-failure basis, while this does ensure optimal usage of a specific bulb, it does not account for the downtime due to possible unsafe working environment. Not only is running to failure dangerous for staff but can halt current operation costing the business large amounts of money in downtime. Creating a log of installed bulbs and operating till almost maximum lifetime will allow for an uninterrupted work environment due to failed bulbs.

The next recommendation is a look into the current heating systems in place. While heat is currently managed by gas powered space heating, monitoring the energy use through heating can provide useful insight into possible improvements. Inducing a convective flow around the offices that are space heated allows for better distribution of heat.

The final recommendation would be a tariff analysis. While gas tariffs do not change significantly hour to hour, electrical tariffs change severely during peak time usage. Having monitoring systems in place to observe electrical tariffs means that during high electrical tariff prices, the electrical users can be used in a standby mode running on gas where available until the electrical tariff price is reduced. With such a high electrical usage, this has the potential to save the business thousands of pounds a year in electrical energy costs.

Summary of recommendations:

- Energy audit to break down current areas of energy use
- Gas monitoring for better understand of individual and system loss
- Change in policy that looks at:
 - Monthly/Quarterly energy report
 - Day to day metering
 - Structural analysis of furnaces and components to ensure minimal energy loss
 - Change in repair policy of lighting
- Moving to LED bulbs to improve lifetime and efficiency
- Monitoring temperature distribution to better place heating systems
- Analysis of tariff costs to put in a 'peak energy cost' strategy

2a)

- Operates 5 days a week for 50 weeks
- From cold 177kW 5 times a day
- 113kW for production
- Overnight 39kW
- Over Weekend 134kW

From cold heating = $177kWh \times 5 \times 6 \times 250 = 1327500kWh$

Production Heating = $113kWh \times 6 \times 250 = 169500kWh$

Weeknight overnight holding = $39kWh \times 4 \times 50 = 7800kWh$

Weekend overnight holding = $134kWh \times 50 = 6700kWh$

Total energy used = $1327500 + 169500 + 7800 + 6700 = 1511500kWh$

2b)

Total Cost = $1511500 \times 0.092 = £139,058$

2c)

Evaluate how the company can reduce their annual energy costs from the electric furnaces:

As mentioned in Q1 having an updated company policy on monitoring is the first step to gaining a more efficient electrical furnace system. This allows possible faults in a single furnace to be identified by electrical usage comparison. Paired with better monitoring, system simulation is another option to heavily improve the energy loss efficiency. Trejo et. Al. have developed a simulation method based on electrical arc furnaces to predict how the energy is distributed throughout the system as shown in Figure 1, showing that the majority of the energy consumed is transferred into thermal energy within the steel, the next biggest consumer of loss is through gasses in the system. Therefore, the next recommendation is to look at the feasibility of a possible flue/off gas heat recovery system for the use of space heating in the building. This will alleviate all current space heating costs making the furnaces more cost effective.

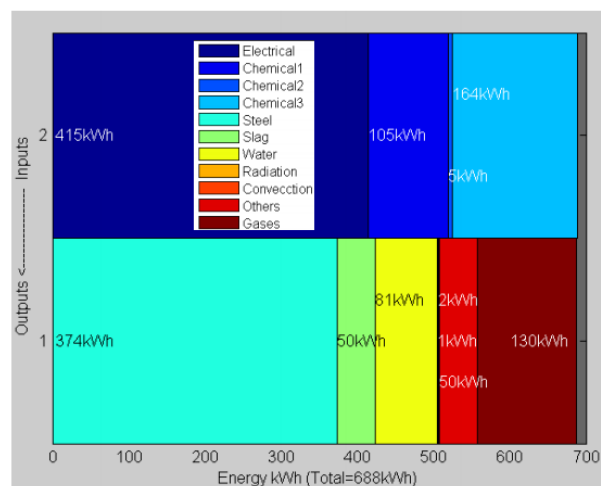


Figure 1 – Model simulation of energy balance in electrical arc furnace

While the implications of a well-managed safety and operation inspection routine are significant there are surprising economical savings to be had also. One such example is the overfilling of furnaces; overfilling can result in loss of energy through the lid of the furnace, but if overfilled too much can also result in the lid not being closed properly which leads to huge energy loss. As

mentioned again in Q1 the times usage of electrical furnaces allows for avoiding peak tariff costs which on scale needed for furnaces is very significant. Having equipment regularly inspected and repaired if required ensures no energy loss due to unacceptable thermal efficiencies, most notably the crucible used to hold the molten metal.

Summary of points:

- More regular monitoring to better target issues
- Specific system simulation to help generate targets
- Possible thermal recovery system from flue/off gasses
- Inspection routine to ensure reasonable thermal efficiency of older parts
- Ensuring the lid is closable and the crucible is not overfilled
- Peak cost management

3a)

- Poorly maintained 20+ years old
- 10 hours a day, 5 days a week, 50 weeks a year
- Grav. Die casting: 20x 95W
- Finishing area: 12x2 fitting 85W T10
- Sand Foundry: 4x large sodium lamps 125W

$$(20 \times 95w) + (12 \times 2 \times 85w) + (4 \times 125w) = 4440w$$

$$\text{Total hours used} = 2500$$

$$\text{Total energy} = 11,100kWh$$

$$\text{Total Cost} = 11,100 \times 0.092 = £1021.2$$

3b)

Evaluate what course of action the company could take to improve the efficiency of the compressed air system.

- Produced at 7-8 bar
- Maintained every 6 months, running for 10 years
- Most equip runs at 2-3 bar
- Sand blasting runs at 7 bar
- 18.5kW on load
- 5kW off load – FOR ONLY 2 HOURS A DAY
- System leakage of 47%

Assuming the air compressors are running for the same timeframe as the remaining equipment i.e. 8 hours a day for 5 days a week for 50 weeks a year the estimated energy cost for the current compressed air system is as follows:

$$\text{Energy on peak per year} = 18.5kW \times 6 \times 250 = 27,750kWh/year$$

$$\text{Energy off peak per year} = 5kW \times 2 \times 250 = 2,500kWh/year$$

$$\text{Total energy cost per year} = 0.092 \times (27,750 + 2500) = £2,783$$

When compared to the total cost of running the furnaces over an annual period, the cost of compressed air seems comparatively insignificant, however £2,783 is not an insignificant sum of money and if ran badly could be resulting in an un-necessary significant economic impact.

The first change to be made to the compressor system would be a change in how the compressed air is generated. The current air compressor generated compressed air at 7-8 bar, but with only one piece of equipment requiring this pressure it is possible that the high system leakage of 47% will be worsened by this high pressure. It would be suggested to isolate the sandblasting air compression stage and keep the current air compressor to operate only when the sand blasting is occurring. Depending on the flow rate required by the remaining equipment it would be recommended that a new air compressor is installed. One that is not oil based due to a reduction in possible air filtering required. A brand new air compressor that runs on a direct drive system for an industrial setting will cost around £400-£500 (Hyundai Power Products, 2020) and will operate at 2.2kW on full load. Even

when assuming a constant full load during working hours, it is clear that this compressor will be perfectly sufficient to meet the needs of the tools and equipment it is powering.

$$\text{Energy per year} = 2.2kW \times 8 \times 250 = 4,400kWh/year$$

$$\text{Cost saving per year} = £2,783 - (0.092 \times 4,400) = £2378.2 \text{ saved per year}$$

When not accounting for the energy that will still be used by the sand blasting process, it is estimated that a new separate air compressor for the low-pressure equipment will save around £2000 per year.

To ensure the longevity of this new compressor system and the tools using it the maintenance routine for the compressors must be completely overhauled; With end usage fixings being the leading cause of compressed air energy loss, an investigation into the current state of all pipe fixings and replacement where necessary will contribute enormously to potential energy savings for compressed air. This degradation may down to erosion by bad filter management. As explained the current compressor is an oil based compressor, which has the possibility of causing erosion of fittings, so along with the new compressor a new filter system should also be installed and importantly, better maintained, mandating a monthly inspection policy into the company will ensure the compressed air stays of high quality and no detriment to any of the equipment using it. To further reduce wasted compressed air the installation of regulator valves may also be recommended; regulator valves means the air pressure can be sectioned off for each workshop or even individual equipment allowing for the equipment to operate at the exact pressure required.

It is also important to recognise that not all equipment may need to use compressed air, it is known that compressed air, even with all the repairs suggested is a very inefficient use of energy. If a piece of equipment can be replaced with electrical energy or even better recovered energy as discussed in previous questions, the electrical usage of that piece of equipment is bound to go down.

Points overview:

- New and separate compressor system for lower pressure equipment
- Fixings and equipment inspected and renewed/replaced
- Better review policy for filters and fittings to increase compressor life
- Pressure regulation to better meet equipment need and reduce leakage
- Review if a piece of equipment actually needs to use compressed air