# Energy Savings Revealed

## INTRODUCTION

Energy is simply the work done to complete a task. Therefore to get energy savings one simply has to reduce the energy used. Energy cannot be created or destroyed but is transformed from one medium to another, for example in a car chemical energy is transformed into mechanical energy, not all the energy in the chemical is transmitted to the motion as losses exist due to heat, friction, drag, noise, etc.

Energy costs money so reducing the losses makes the car more efficient. However one must remember that the car has to operate on a road and a driver has to follow directions, a wrong turn or a lot of stopping, idling and starting route will increase the energy used and thus make the task less efficient.

This can be done several ways and this document sets out to explain the thinking behind some common energy saving plans and some perhaps not so common. It also tries to let the reader see that there can be unforeseen problems encountered in saving energy and a holistic approach is necessary in order to achieve the goal of energy reduction.

## ENERGY SAVING TECHNIQUES

### Switch it off

If a machine's energy output equals its input it is 100% efficient and thus has no energy loss. This state exists at one state and one state only whatever the machine and that is when it is switched off. It makes sense that if a machine is off it consumes no energy and thus can be saving you money.

There are obvious advantages to this approach namely it does not require complex monitoring equipment in a lot of cases, just people to care and given the right workforce with the correct motivation it can save a company a lot of money. The disadvantages are in the advantages in that it requires people. This does require empowering the workforce with the ability and the will to switch off unwanted machines. Another disadvantage is that in some machines it can take a lot more energy to get the machine back in production-ready state than was saved by switching it off for a short period of time, a good example of this is a fly-wheel application where the energy consumed when up to speed is very minimal and the start-up time is long, where the motor is probably running at maximum power (Power is the rate or energy used [Power= Energy/time]). This approach is probably best applied on more complex machines when technology is applied such as PIR sensors for lighting control or compressor control by monitoring pressure, but a simple "Please Turn Off When Finished" sign can save pounds.

Energy Efficient Machines

As mentioned in the introduction energy is the measure used to determine the work done. Thus if we can get more efficient we can save money.

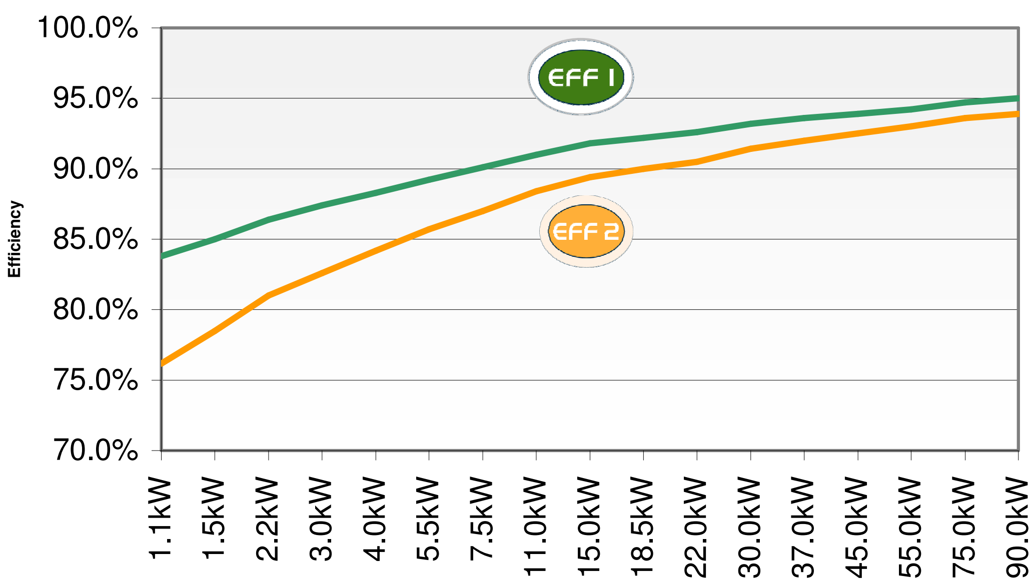
| No Load Losses | Loading Losses | Useful Energy (Output) |
|---|---|---|
| ENERGY USED | | |

Energy Used = Output + Losses
Thus:
Efficiency (%) = Output / Output +Losses

Most machines start with a prime mover, usually an electric motor and then this is connected either directly, or via a geared drive train to the main machine. This type of arrangement gives us plenty of opportunity to make energy savings. We will look at each component in the system and then some simply machines.

Motors – As the majority of electrical energy at a premises will be transformed by an electric motor these have constantly being refined and improved to deliver more and more useful energy and fewer losses and various levels of efficiency exist. As a more accurate build is necessary for a more efficient motor they are more expensive to produce. The difference in cost can sometimes require a payback of 10 years in the case of high kW values, but can be months with the small kW values

**4 Pole Motor Efficiencies**




There are Enhanced Capital Allowances that are reclaimable on capital purchases that reduce energy consumption these are offset against Corporation Tax that will reduce this cost. WYKO can manage this for customers and provide information to enable its customers to claim the allowances.

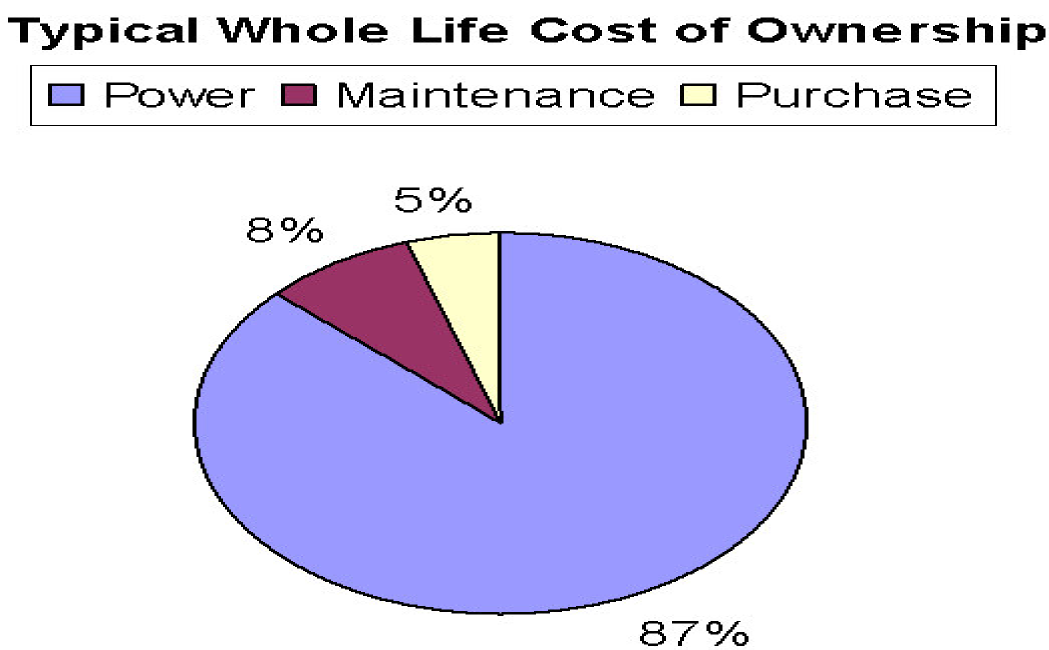
A motor is usually most efficient near its full load; if it operates at low loads it is very inefficient.

| | | |
|---|---|---|
| No Load Losses | Load losses | Useful Energy (Output) |
| ENERGY USED | | |

Therefore one can see that the motor has to be specified to be able to do the job and no more. Sometimes however a motor needs to be large enough to start a machine and therefore runs in the state above (imagine an electric train). Usually though these are large inertia drives and the motors used are pretty specific (DC Traction Motors).

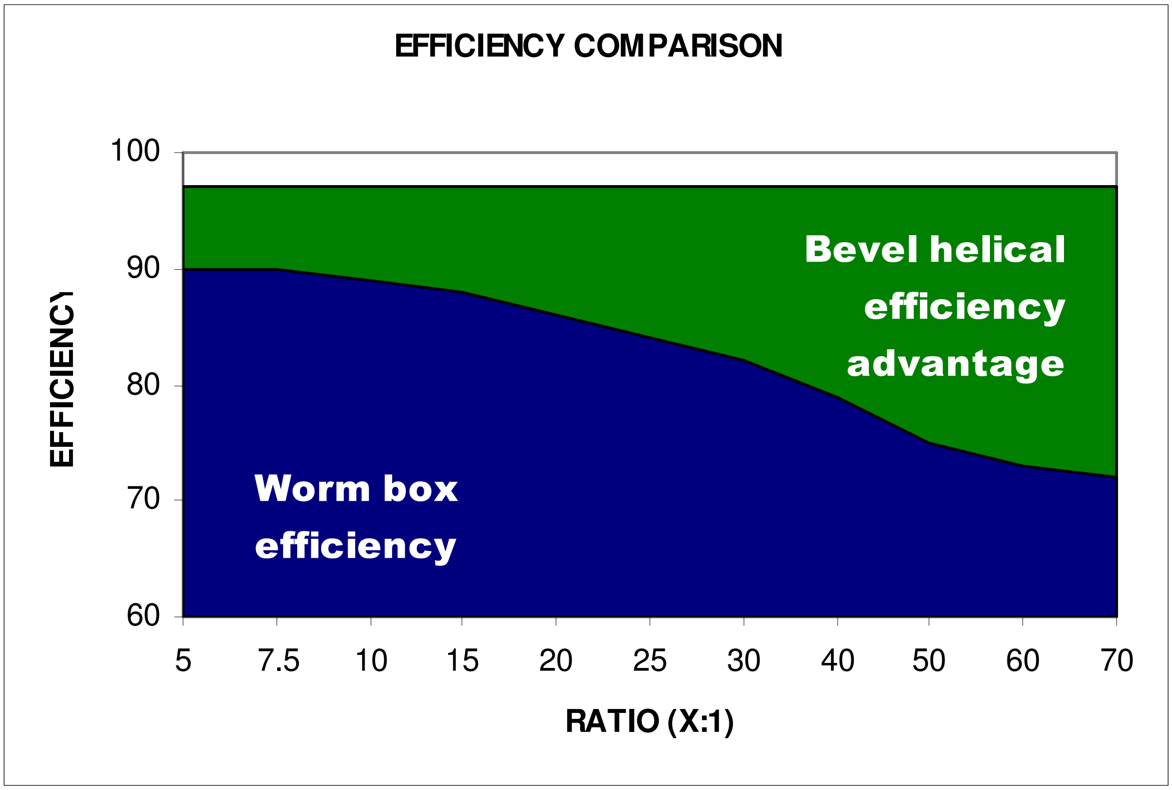
Certain geared motors or pump motors come integral in that the motor cannot be replaced with a standard frame motor. These motors can be extremely. Thus when specifying equipment one must always ask yourself:
What are the initial purchase costs?
What is the efficiency of the machine?
Can the unit be upgraded as technology progresses?
Are you tied into the OEM special motors at their ‘special’ prices?

For example if one is to look at the life cycle costs of a machine one would see a ratio typical to the one shown below.




Once can see that the purchase price is only a small percentage of the total cost of ownership of the machine and any savings that can be made to the energy consumed by the machine will have an impact on the whole cost of the machine. Therefore when one is selecting to purchase a machine one must look at the running and maintenance costs as they have more of a bearing on the true cost of owning that machine.

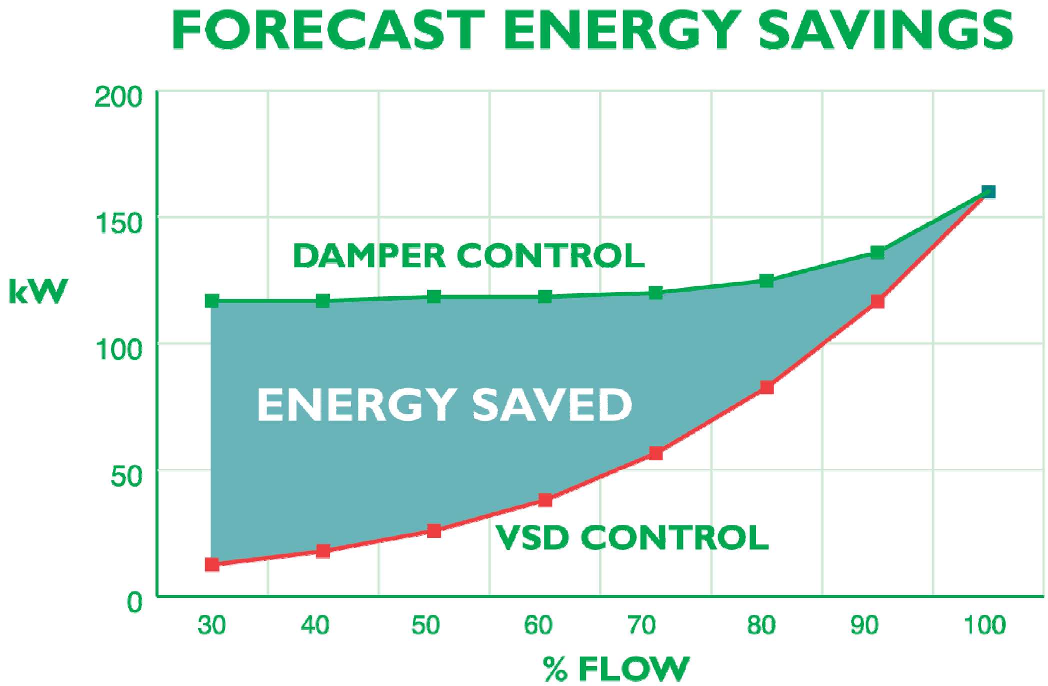
Gearboxes – As we move along the drive train and investigate speed reduction methods the first we arrive at is the gearbox. Many main gearbox drives are still old style worm and wheel gearboxes, massively over engineered and therefore large kW ratings on motor to match.



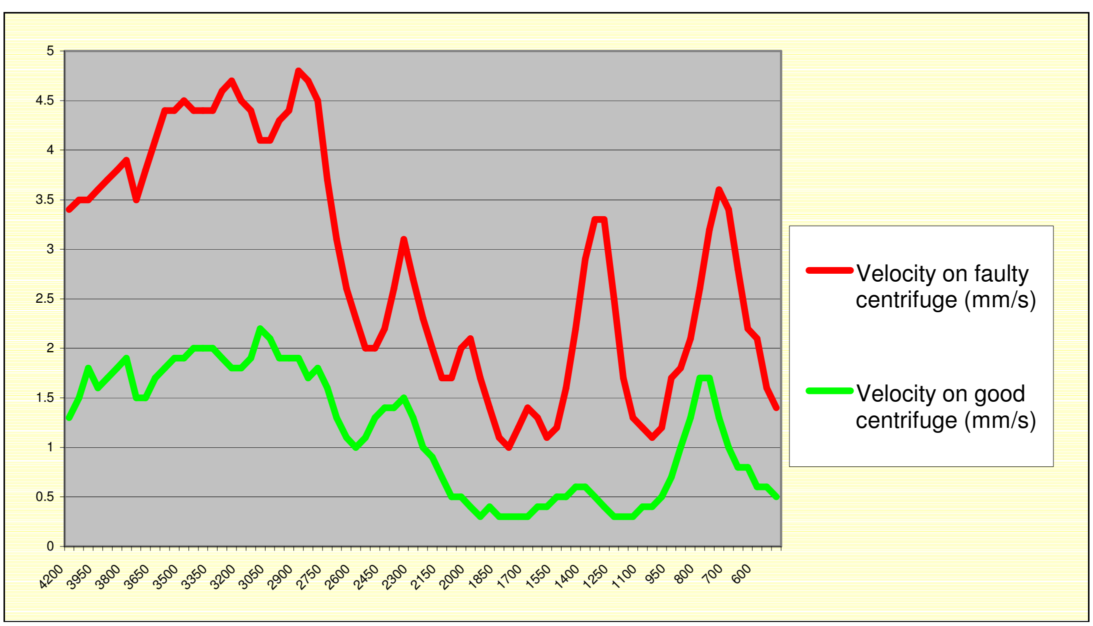

These could be replaced with helical gearboxes that operate at a lot higher efficiency. There is always a drawback with what seems a simple solution, a worm and wheel gearbox has a large surface area in contact at any one time, when compared to the single tooth contact surface of toothed gears. This is one of the reasons why it is less efficient, but this is also its strength, in that it is able to withstand higher starting and stopping loads. It may be possible to withdraw the gearbox in its entirety, lift units are now gearless and utilise modern drives to act as speed controllers.

Simple final drives, fans and pumps – If we are not turning the final machine with a gearbox then the likelihood is that our electric motor is belt driving or coupled to a pump or a fan. Pumps have an efficiency curve and savings can be made if these run at their optimum. Allied to that pumps are often overrated for the duties that they perform or sometimes their duties change but they still continue to pump out the same flow and therefore consume the same energy whether it is needed or not.

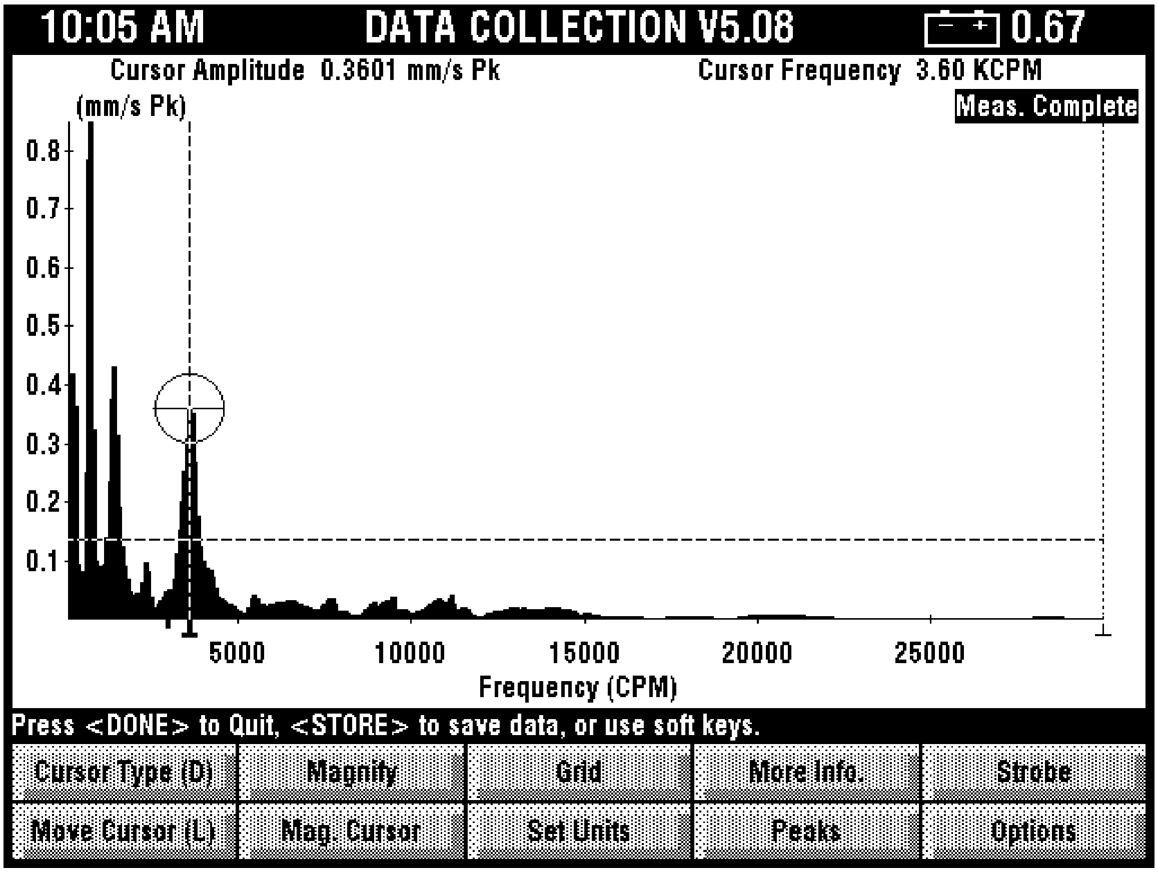
Consider a 75kW fan which cost £15 824 to run last year with energy increases this year it will cost £17 406. However investigations tests etc showed that during some of the production processes the speed could be reduced by up to 30%. Because the energy consumed is propostion to the speed of the fan squared the energy consumed only costs £7503. The cost of the technology to do this is far less than the near £10 000 savings




Imagine if the fan could permanently run at a lower speed, then we just need to buy and fit a new vee-pulley a lot cheaper than an inverter and also with the possibility of lowering the motor kW maximising the useful power and the full energy savings. This has to be a no-lose situation one would think, however one must look at the big picture. Before any speed change takes place one must carry out a run down test to ensure that there are no mechanical resonances in the structure, the following are tests taken out on two centrifuges.



One can see there are responses on one that do not occur on the other.  Another test that can be carried out to determine natural frequencies is bump vibration testing.




MOTOR 06/19/06 10:06:00

This gives the frequencies that the machine could be unstable at.  Another thing to bear in mind is that there could be other machines in the vicinity that could be excited by the new frequencies being generated by the speed change.  These occurrences are rare but one only has to recall the Millennium Bridge in London to see what can occur when the unexpected turns into a reality.

Compressed Air Systems – coming from an electromechanical repair background I do not feel in a position to compare all different types of compressor, reciprocating, screw etc and evaluate the finding, however I would not be surprised if there are efficiencies to be had in selecting the right compressor.  A lot of the above can be applied to the main drive of the unit Eff1 and switching off when not required.  One can also look at the system beyond the compressor.  I used to work as a maintenance electrician and one the jobs that we had to do was turn all the equipment off before a shutdown such as Christmas Eve.  Once we had isolated the plant and removed all machinery noise from the factory, we was left with a hiss of escaping compressed air.  I always used to think that this was the only way to find air-leaks, however that was before I got involved in condition monitoring and picked up an ultrasonic detector.

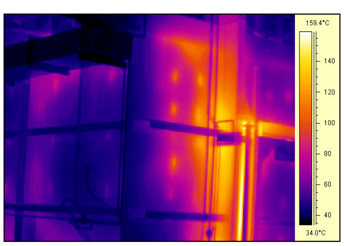
The Ultrasonic handgun senses high frequency sounds produced by operating equipment, leaks and electrical discharges. It electronically translates these signals by “translating” them into the audible range so that a user can hear these sounds through a headset and see them as intensity increments on the meter.

Ultrasonic leak detection is extremely broad based. Sensing ultrasounds generated by a leak, the Ultrasonic handgun can be used to locate leaks in pressurised systems regardless of the type of gas used. This is especially beneficial in areas where there is a saturation of gases or where a wide variety of gases, pressurised vessels and vacuum processes exist.

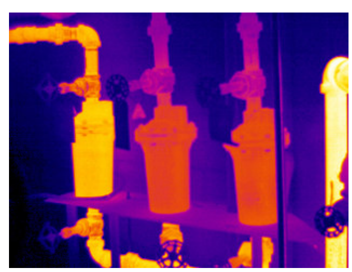
The ultrasonic handgun can also be used to locate the electrical discharge in high-voltage systems. Not as accurate as partial discharge measurement and very subjective, it is a use that cannot be ignored and would provide useful feedback. The handgun can detect problems that standard vibration cannot, such as chain drives, universal couplings ultra-slow moving items, (though vibration technology is catching up with the advent of longer and longer time waveform data) anywhere that mounting a transducer would be problematic. The main use of the handgun remains detecting air leaks, it is simple to use and leaks can be detected above machinery noise, identified and parts ordered for their correction. Annual savings from a days survey have been up to £150 000

Heat Losses – Like air leaks heat is another form of energy where if it were kept in the system then less energy would be used to generate it. The obvious technology to use here is thermography.

A thermal imaging camera is used to give a picture of the infrared radiation being emitted from a machine or a building – see right. The amount of infrared radiation is proportional to the temperature of the item and by the setting of internal parameters within the camera the image can be shown as a temperature scale. Good thermographic cameras operate in real time and the refresh rate is at least 50Hz in temperatures above 0° Celsius which produces a crisp image even when moving the camera.

Furnace/oven/kiln insulation, steam traps coupling and belt overheating are just some of the energy applications that can use thermography. If keeping things cool is your priority then cold spots can be found using the same technology.



Process Energy Savings

If we consider a baker, his energy costs will depend upon the following factors:

- How energy efficient his ovens are
- His procurement of supplies –transport and purchasing
- His delivery of product – transport of goods
- Getting new customers – salesmen transport and effort (remember energy is work done)
- Reliability of his process

One may raise a few eyebrows at the list above but a business's energy costs are not limited to the spend inside the factory. Perhaps the most important in the most important of all the points listed is the last one. The reliability of his process has an effect on all of the other points. Going back to our baker if his timing system is unreliable then he will end up with overcooked or undercooked bread. This means he will

- need to bake more bread, using his ovens more thus increasing his energy bill
- need more ingredients, thus more journeys to/from the supplier using fuel
- not be getting the product out on time and therefore will be making more journeys to deliver the items
- be looking for new customers to replace the ones he has let down, which means a lot of time and energy

Thus one needs to look at maintenance and reliability of plant as a whole

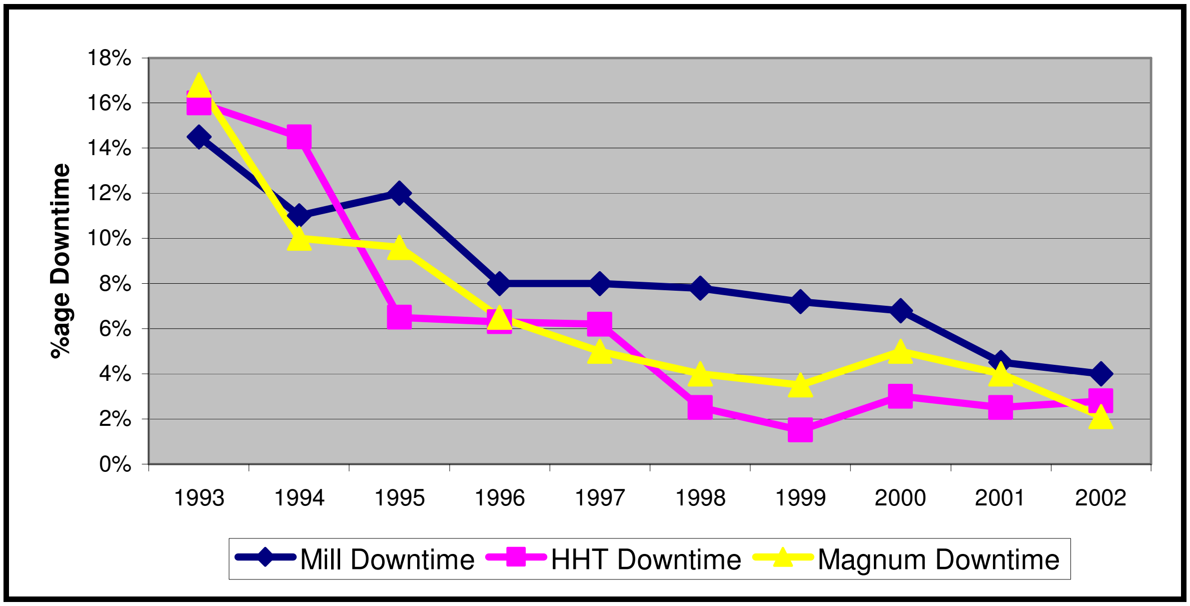
Maintenance has evolved over the years to mean many things to many people. The approach to maintenance changes not only from company to company but also from department to department within the same company. This philosophy in general is perfectly acceptable, as maintenance is not a 'one-size-fits-all tool.' Consider your maintenance at home. You may decide that your exterior wood needs to be treated or painted every 4 years, but you would not consider the same approach acceptable to maintaining the paintwork on your car, equally you would not weekly clean all your exterior wood on your house. The same can be said for industrial maintenance and in particular predictive and preventive maintenance.

In order to select the right maintenance one always has to consider the failure mode of a machine. This can be done before the machine has actually gone into production as the manufacturer often issues guidelines on the checks necessary and at what frequency they should be done. For example greasing schedules are issued stating that this bearing is to be lubricated weekly and that one monthly and these ones every 1000 hours and need replacing after 10 000 hours etc. However the best information one has at one's disposal is historical evidence of failures or corrective repairs on a machine. If the root cause of a particular failure can be found it can be prevented either by re-engineering, such as increasing the size of the bearing or by changing the maintenance approach or frequency.

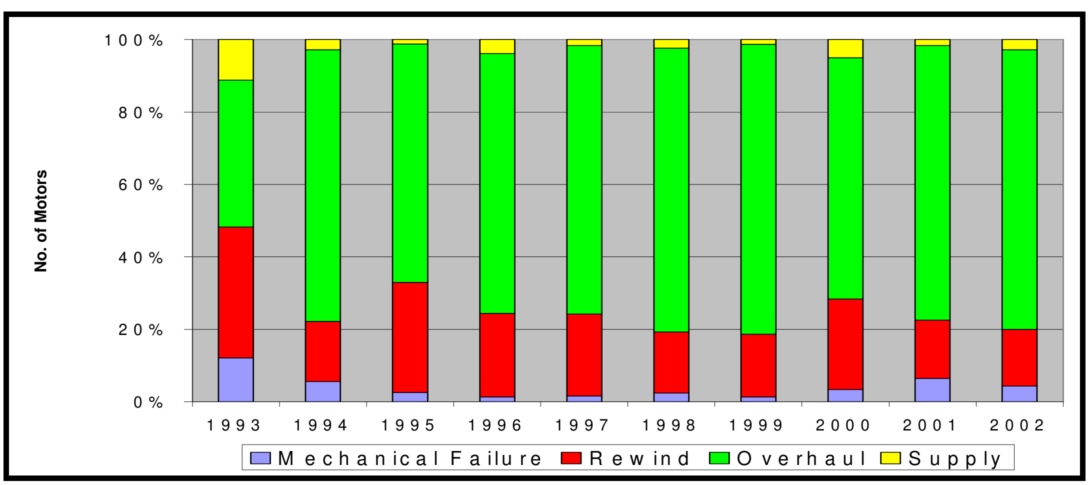
Using all this data, one can begin not just to maintain a machine in a correct manner, but also to use the knowledge as a guide to the frequency of gathering data, in order to prevent a catastrophic failure of the machine. This approach of monitoring the condition of a machine has the advantage that one can then restructure maintenance or carry out planned corrective repairs on the basis of the machine's condition and thus using condition monitoring, implement condition based maintenance.

The ultimate price can be paid if the maintenance philosophy and culture is not right within an organisation. However if machine reliability is increased then energy will be decreased as products only have to made once, scrap is reduced so therefore supplier costs are reduced, deliveries can be structured in order to make the most of scheduled deliveries and production output will be increased thus profitability is increased as more product is being made for the same or less cost.

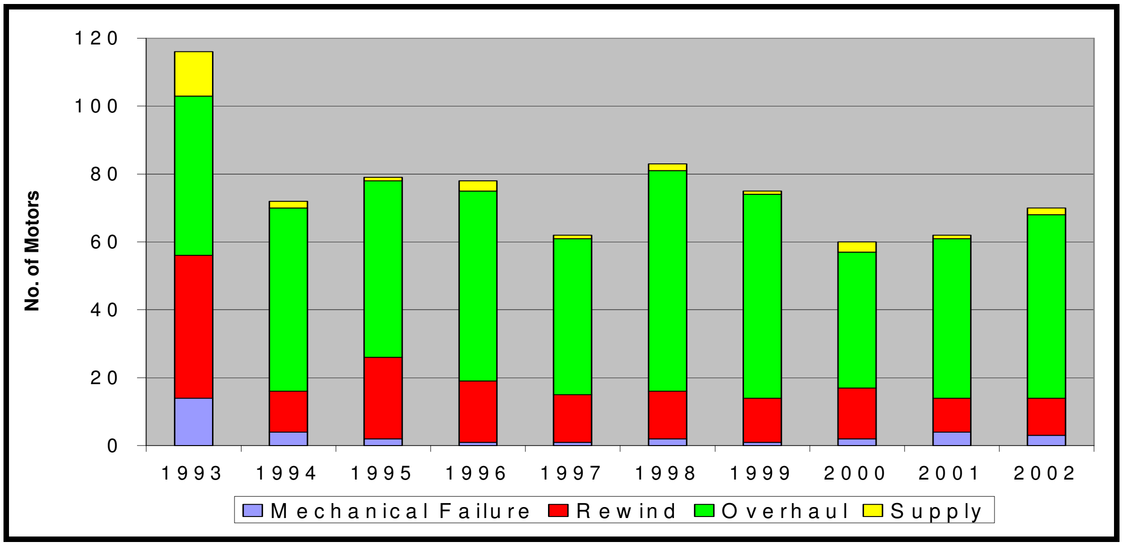
The following are genuine graphs that were submitted to WYKO from an aluminium casting and rolling company.




This customer applied all forms of good maintenance practices to including Reliability Centred Maintenance, Total Production Maintenance, Kaizen, Continuous Improvement Teams, Crosby and Condition Based Maintenance. This took total commitment from the operators through to the managing director. This plant is now one of the most efficient in the group though its machinery is one of the oldest. The success of a good maintenance regime can be measured in the change in failure mode of machines over time; here is the failure mode graph for electric motors at the same aluminium company.



One can see that the percentage of units that failed has been reduced from 50% to 20% and that almost 80% of all motors are now sent in for an overhaul as opposed to a failure compared with 40% ten years prior. In that time production has increased and new plant has been purchased thus increasing the number of motors on site. We can look at the total number of motor repairs.




The total reduction in the number of repairs is evident, but behind all these charts is the reduction in energy from all aspects of the business. Get the plant reliable and all aspects of the business including partner suppliers and see the spin-offs.

**What is condition monitoring and where is its role in maintenance?**

One definition of condition monitoring is, “The collection, storage, comparison, and evaluation of data taken from a machine to establish the running condition of that machine.“

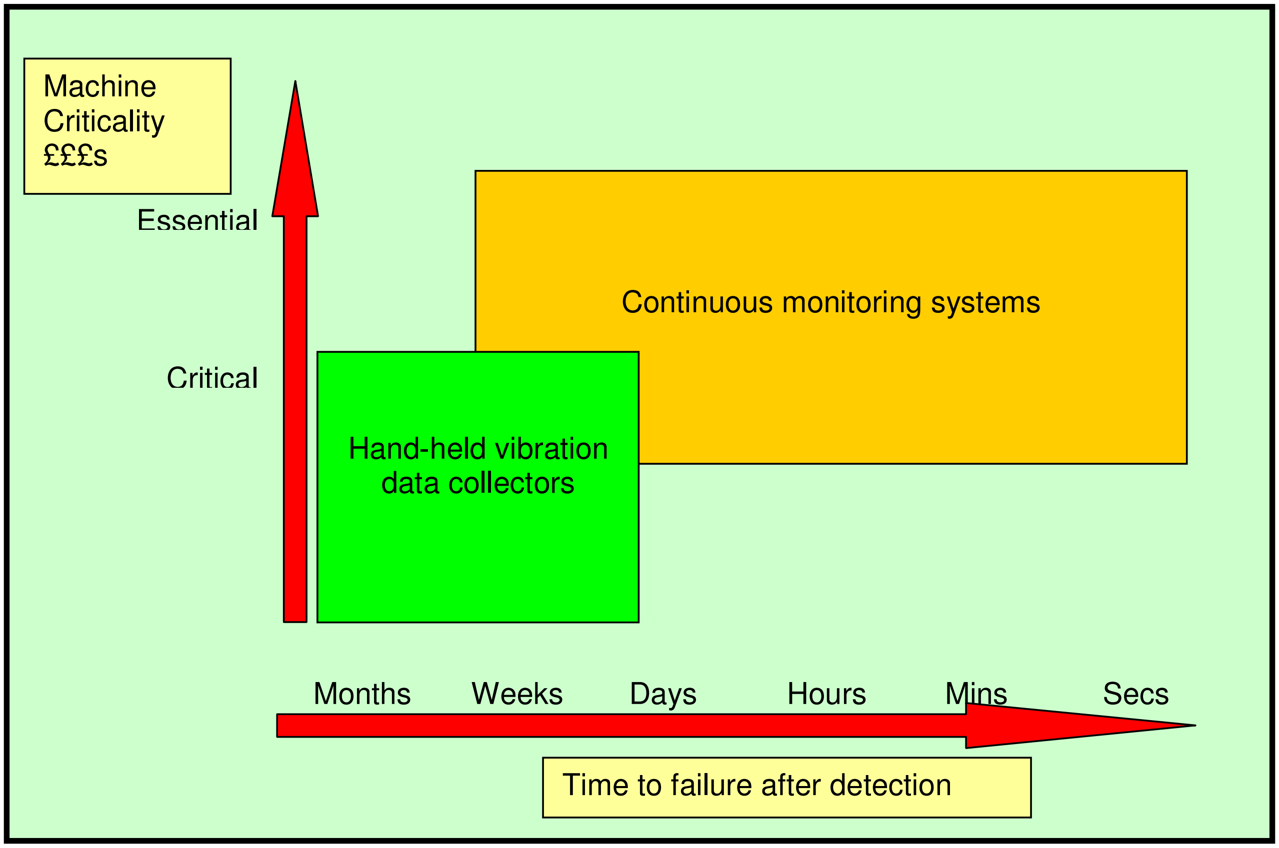
The data could be made up of several parameters. For example, looseness/play due to mechanical wear, electric current, pressure, surface finish brush wear, vibration and temperature, to name a few.

A database needs to be initialised, itemising the data to be collected from the individual components of a machine and what frequency that data needs to be taken. The frequency of the data acquisition is dependant upon several factors.

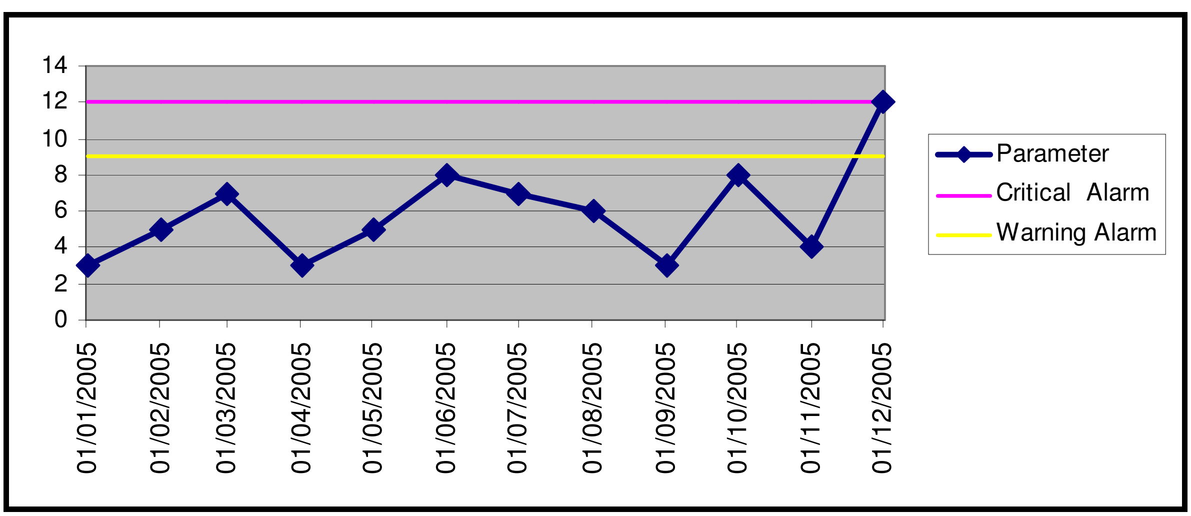
- Criticality of machine to production – cost of downtime
- Cost of damage to machine from individual component failure
- Time to repair or replace component
- Criticality of component within the machine
- The failure mode, failure rate and time between failures
- The maintenance needed on the item and its frequency and method of maintenance
- Access to specialised data acquisition equipment
- Access to machinery

This data is then evaluated against known set limits for that machine, based on international standards, manufacturers guidelines or previous repairs on that machine or similar machines.

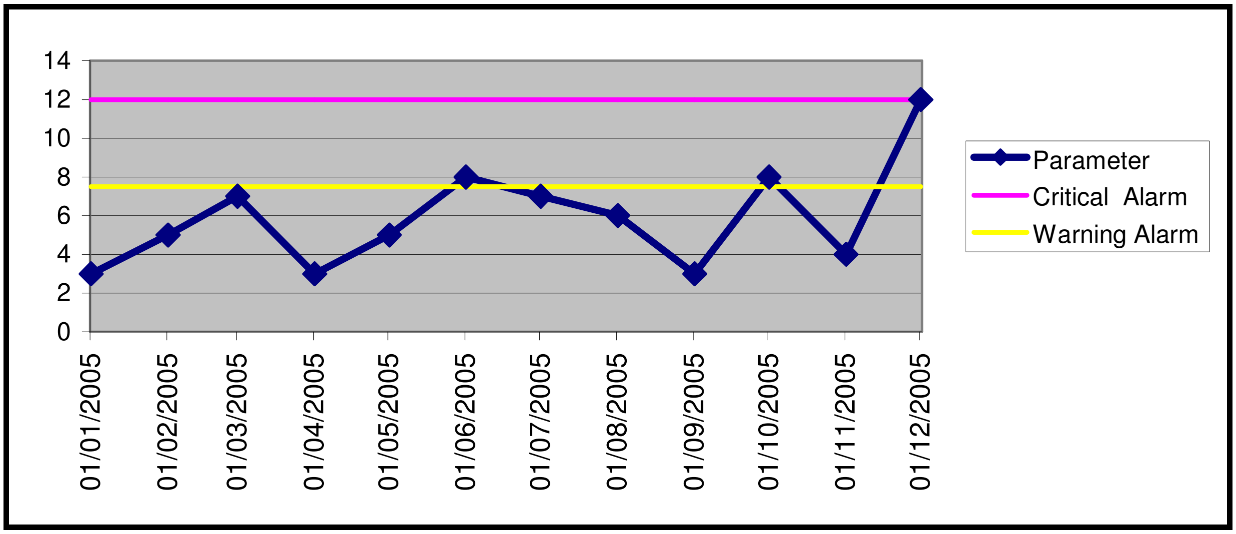
Knowing the correct frequency of data collection along with the correct warning condition levels are the key to any successful condition monitoring regime. This can depend upon quite a few parameters as the following diagram suggests.



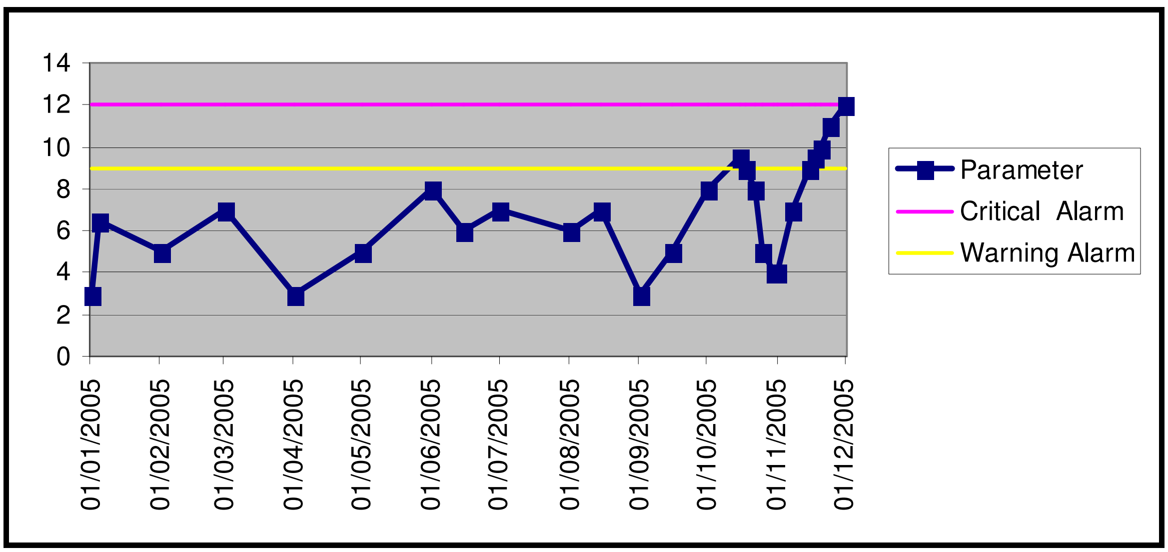

Consider the following parameter measurement trend graph.



If we knew that the critical alarm was 12, then there was no warning of failure due to the steepness of the failure curve until the last reading, and we are now in a panic situation, which could with a better data acquisition approach have been avoided. We can reduce the warning alarm to 7.5; this would have given rise to several false alarms.




However that ‘false alarm could have alerted us to take more data more often at those times or even done a machine inspection. If the machine inspections had found nothing then the alarm would have to be re-evaluated otherwise a “cry wolf” situation would exist. There are two further solutions for this problem. The first is to protect the machine, for instance if we were reading a pressure gauge we could fit a sensor wired to a PLC which would then compliment, *not replace*, our monthly data acquisitions. The second is to take data more frequently especially as we can see that the parameter curve is getting steeper after each reduction.

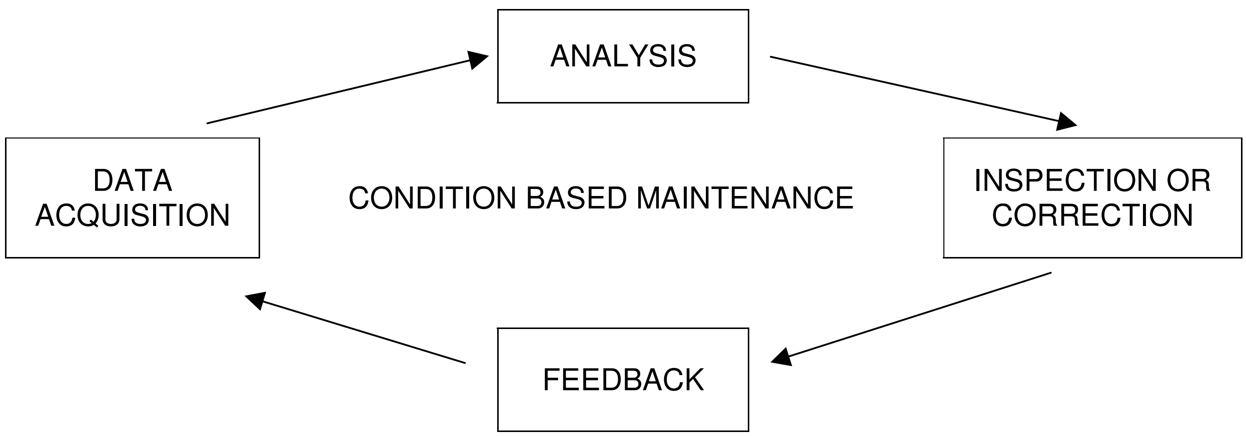



The constant fine-tuning of the data acquisition frequency and method are key parts of any condition based maintenance programme.

**What are the tools of condition monitoring for condition based maintenance?**

COMMUNICATION

The primary tool for condition based maintenance is communication. One can take the best data, using the latest technology and have it analysed by world class analysers but if its interpretation is not acted upon then it is useless. Communication has to flow in all directions, if a diagnosis of some data says that a problem exists with coupling and on inspection it is found that the shaft is eccentric then that information needs to be sent back to the diagnoser. Communication has to exist between the data parameters, the electrician needs to know that the filters have been changed on a fan unit in case he experiences current changes in his data.




This constant information flow is the life-blood of the programme. Without the information links, the system will collapse, regardless of how good any of the individual elements are in the chain.

INSPECTIONS / DATA ACQUISITION

A lot of companies are doing more condition monitoring than they actually know. Many companies carry out a planned maintenance regime of testing this, inspecting that and checking the other. Reports are sent back into the maintenance management system saying that the item is worn but serviceable, that there is backlash present but it is still okay or that the oil level is acceptable. The very fact that feedback is being issued is commendable, but the one thing missing from all the reports is data. What is worn? Has it decayed since the last inspection? What is still serviceable? How long till we need to replace it? What is acceptable? Are we getting less acceptable by the day? The statements in the feedback lead to the follow up questions. It would be better to say that the item has grooves in it that are approximately 1mm deep across 10mm of the surface, there was ¼ turn of backlash on the input shaft, and the oil is ¾ of the way between min and max.

The subjectivity needs to be replaced with objectivity. With reliable and tangible data comes the ability to compare and plot the result, eventually being able to predict the potential failure and thus ensure that any corrective action that can be implemented to extend the lead-time to failure or prevent the failure. Inspection procedures therefore need to be written to ensure that when data is being acquired it is collected using the same method each time. The same data needs to be taken using the same instrument, from the same point under the same conditions. Where any of these conditions differ then that is recorded and stored separately this can be used for judgement against where those conditions exist again.

The types of inspections can be numerous; most of them though can be done using engineering instruments such as the dial test indicator or by reading gauges or dials on the machine. The dial and gauge data collection can be incorporated into an operator's TPM inspection at the start of a shift, whilst more complex checks need to done by engineers.

WYKO's Condition Monitoring Services.

From the above discussion it is clear that a lot of condition monitoring and condition based maintenance could be being done in a factory by the company's own personnel. However due to capital outlay or resource constraints certain forms of condition monitoring may need to be done by an outside consultant. WYKO offer a very wide range of condition monitoring services including:

- Vibration data collection and analysis
- Thermographic surveys
- Electrical, lubrication and hydraulic oil analysis
- Electrical current signature analysis
- Partial discharge analysis
- Dielectric Loss Analysis
- Equipment inspections

Within WYKO we also have many product and service specialists including, bearings, seals, belt, chain, pumps, motors, gearboxes, hydraulics, pneumatics, condition monitoring, electronics, motion control and all of these are backed up by an unrivalled number of supplier partners. This gives WYKO the opportunity to bring the best in the market place to you regardless of the manufacturer.

CONCLUSIONS

Reliability of plant cannot be dismissed with respect to energy saving in fact is should be one of the first requirements of a plant's engineering department.

Within WYKO's organisation experts exist with respect to inverter selection plant modifications, gearboxes, pneumatics, hydraulics and condition monitoring. Examples of cost savings have been shown within this paper

Within this publication it can be seen that taking the correct data often enough can prevent the majority of failures and taking it all the time may even eliminate failures and thus improve the reliability. However how does one make the decision of whether to monitor or protect? What form of monitoring/protection is needed? Whether to use a meter or a collector? Whether to monitor in-house or sub-contract? The answers to these questions and all your condition monitoring needs are only one phone call away.