Best practice in motors involves:

1. Selecting the motor with the lowest life cycle cost.
2. Setting up and maintaining the motor properly to ensure a long life at peak performance.
3. Making the correct repair and replacement decisions when a motor fails.
4. Having good documentation so continuous improvement is possible.
5. Managing your utilities to ensure the best outcome for your organisation.
6. Integrating best practice into existing management systems (including quality assurance, environment and health and safety).
7. Strong senior leadership.
8. Well-trained and confident staff.

Best practice organisations also pay attention to the potential savings of 30 to 60 per cent that can be gained through a whole-of-systems approach to process optimisation and innovation. The level of savings from systems optimisation depends on the effort and money you invest, and the skills, imagination and motivation of your project team. This web site provides information on some aspects of system optimisation.

Selecting the best motor and equipment

Best practice organisations save money by applying accepted financial investment principles when selecting commercial and industrial equipment. Purchasing equipment commits you to many years of operating costs, and what you buy impacts directly on the overall effectiveness and reliability of your operations and future profits.

Selecting the best motor and equipment involves thinking *beyond* traditional approaches. Careful selection can reduce the total operating cost or ten times the initial purchase price.

This section walks you through a best practice system of motor selection which will lead you to make the right decisions. It will help you avoid acting on assumptions and making decisions that may not be in the best interests of your organisation. It will steer you away from making decisions based on purchase price only, or on simple pay back options. Although the information provided is generally directed toward motor purchases, the same principles can be applied when selecting other energy consuming equipment.

1. Life cycle cost analysis

When selecting motors and equipment using best practice principles, you should begin by analysing life cycle costs, or the 'real' cost of ownership. In the case of motors, this is critical since your three-phase induction motors can consume more than half the energy used by your plant.

Life cycle cost analysis is a proven and accepted financial principle, which involves:

- assessing purchase price
- assessing operating costs
- using a method which accounts for the time value of money.

Purchase price

When assessing the purchase price of an electric motor, you need to consider issues like different models and suppliers, warranties, quality, expected lifetime and type of motor. For example, the price of an electric motor may vary widely between models and suppliers. If you are a high user of electric motors from a regular supplier, you may receive a good discount.

Usually, but not always, the consumer adage 'you get what you pay for' applies. Cheaper motors are often less efficient and of poorer quality, and they may be less reliable and have shorter lives. This is often reflected in the warranty. Even in cases where you are only considering one brand, there is still a choice between standard and high efficiency motors. Be careful to analyse the life cycle cost of your options - a few extra money spent at the time of purchase may save you thousands in the years to come.

Operating costs

When determining how much it will cost to operate a piece of equipment over its lifetime, you must:

1. estimate the expected load on the equipment through production cycles (load profile)
2. chart the motor's efficiency rating at each load point (efficiency profile)
3. chart the amount of electricity the equipment requires to operate at that level of efficiency (energy required profile)
4. combine your energy required profile with your tariff information to calculate your true operating costs.

The machine design and the type of control system may also have a big impact on operating costs. Careful analysis often demonstrates that in the long term the *cheapest* option is not the *best* option.

Another common myth is that buying a more efficient motor automatically means you will use less energy. Sometimes motors with higher efficiency may run at slightly higher speeds. In centrifugal pump and fan applications, for example, the energy consumed is proportional to the speed cubed. Therefore, small increases in speed can increase your energy consumption significantly.

Time value of money

To determine how costs and benefits spread out over the lifespan of a piece of equipment, use accepted discounted cash flow techniques. This time value of money method puts a present value on future benefits or costs.

It is recommended that you use this method (rather than simple payback) when analysing equipment options since simple payback ignores the full value of *future* benefits. Motors generally have a long life of between 15 and 25 years so analysing options using simple payback may neglect 23 years of savings opportunity.

2. Dealing with suppliers

When purchasing equipment, always ask your supplier for information beyond price. Describe your needs in detail and ask for information on efficiency and what it costs to run a piece of equipment. This is important since while a product may be price competitive, its annual operating costs may be extremely high.

Working with your supplier in this way will help you make the best choice based on your needs. You will also be sending the right message to suppliers that equipment choice should be based on more than price. This will encourage suppliers to stock equipment that is life cycle cost competitive.

http://www.greenhouse.gov.au/motors/reference/r2.html

Commissioning

Commissioning takes place after:

- new equipment is installed
- existing equipment has undergone significant repair
- there has been a significant change in the operating requirements of a machine.

Failure to pay attention to detail when commissioning electric motors and motor driven equipment can lead to a dramatic increase in operating costs, through inefficient operation, and an increased risk of early motor or equipment failure.

This section outlines basic steps of best practice commissioning and provides an easy-to-use checklist. It also explains some of the major consequences of poor commissioning practices.

The benefits of best practice commissioning

A best practice approach to commissioning electric motors and driven equipment will:

- maximise equipment life
- reduce unexpected downtime
- reduce maintenance costs
- reduce operating costs
- improve plant safety.

Steps to best practice commissioning

To achieve best practice commissioning you must develop a plan to allow the technicians involved adequate time to thoroughly complete the tasks. Your best practice commissioning plan should include:

1. A requirement that all your organisation's safety procedures are followed.
2. Clear delegation of authority and responsibility.
3. A method for checking that the specifications of the supplied equipment are in line with the process design requirements and that the equipment documentation is complete (including installation requirements, operation guidelines and maintenance specifications).
4. A method for checking that the equipment is set up correctly, mechanically and electrically, in accordance with the original manufacturer's specifications.
5. Verification that the actual machine output meets design intent at the specified load range. It is important that the machine delivers what is required and not any excess, which becomes waste.
6. Refinement of the control system to optimise energy efficiency and reliability for typical operation.
7. A process for recording and documenting the results of commissioning for future reference and updating relevant maintenance profiles and schedules.
8. Ensuring relevant reference manuals are available to operation and maintenance staff.
9. Ensuring that appropriate staff know or are trained in the skills necessary to operate and maintain the equipment.

Often all commissioning tasks cannot be completed before the machine is required. It is important to have a system in place which ensures that unfinished tasks are completed at the earliest opportunity and not forgotten.

Commissioning checklist

Your best practice motor commissioning plan must be supported by a commissioning checklist. The basic checklist below covers the key actions required when commissioning new motors. You should also complete any tasks or other checklists provided with the equipment. If you have done this and can tick all the boxes below, your equipment should deliver reliable and economic service. It is also important during commissioning that you follow all of your organisation's relevant safety procedures.

- Is the motor suitable for the application?
- Are the foundations rigid, stiff and to the machine supplier's specification?
- Is the drive base plate stable and are all mounting surfaces in the same flat plane?
- Are all motor feet individually and appropriately shimmed?
- Are all foundation and anchor hold-down bolts in place and tightened to torque specifications?
- Does the foundation avoid resonance (for example, no excessive vibration during start up, shut down or at the operating speeds)?
- Where applicable, does the coupling connecting the motor to the equipment meet the equipment specification and is it carefully selected and set up to avoid locking the driving and driven shafts together?
- Has alignment been completed within specification by an accepted alignment method?
- Where applicable, are the pulleys the correct type and size for the V-belts and are they properly aligned?
- Where applicable, are the V-belts correct and tensioned to specification?
- Have you ensured that there are no restrictions to motor ventilation?
- Is the motor grounded with adequate surge protection?
- Are all electrical connections clean, tight and properly sized?
- Is the terminal cover suitably gasketed and adequately tightened?
- Is the motor circuit resistance and impedance balanced?
- Are motor current and voltage balanced?
- Is the motor temperature rise in accordance with type test certificate?
- Are machine vibrations within manufacturer specified limits?
- Are all lubrication points accessible and adequately lubricated, and are all the lubrication drain plugs removed?
- Is all documentation complete and are access permits signed off?
- Does the machine deliver what is required?
- Has the control strategy been evaluated in terms of its energy efficiency?

Consequences of poor commissioning

The failure to apply an appropriate commissioning strategy for your electric motors and driven equipment can lead to the following consequences:

- Misalignment - which can impact on a motor's air gap, leading to asymmetry being reflected to the machine windings. This can result in a temperature rise in the windings, increased operating costs and a reduced winding life. In addition, misalignment will lead to fundamental mechanical vibration of the motor and driven equipment and a higher risk of premature bearing failure.
- Soft foot - which can lead to distorting of the motor frame, as the motor is bolted down to the foundation. This distortion can cause eccentricity in the motor air gap, leading to overheating of the motor, increased operating costs and a higher risk of winding or bearing failure. Soft foot is caused by inadequate shimming under one of the motor's holding down feet.

- Ventilation restrictions - which can detract from the cooling efficiency of an electric motor, leading to excessive heat rise in the motor windings and increased power consumption caused by increases in winding resistance.
- Asymmetrical power supply - which can result in increased thermal rise through the presence of negative sequence currents within the machine winding. This can lead to additional running costs through extra energy consumption and reduced motor insulation life.

Motor and system maintenance and operation

Improving the way you maintain your electric motor systems can be a risk free, easy and cost effective way of increasing your organisation's efficiency and lowering costs. According to the Electrical Power Research Institute in the United States, for example, many organisations can increase the operating efficiency of their equipment by 10 to 15 per cent, through proper maintenance alone.

Various international studies suggest that most organisations can also achieve large and cost-effective energy savings through best practice maintenance and operation, by developing a better understanding of their process requirements and by optimising controls and equipment to ensure these requirements are efficiently met.

There are many other benefits to best practice maintenance and operation, including:

- improved plant reliability
- improved operating efficiency
- lower operating costs
- prolonged equipment life
- improved staff morale.

This section discusses best practice operation and best practice maintenance.

Best practice operation

Best practice operation ensures that machines operate only when necessary, and efficiently deliver what is required.

There are many opportunities to improve operating efficiency. Some are simple, such as turning equipment off when it is not needed. Others require a better understanding of a technology or process, such as substituting inefficient control of flow from pumps and fans by throttling or damping with more efficient methods such as impellor trimming or inlet guide vane flow control.

A regular review of your process requirements and how these are being met will help you to discover savings opportunities. Often, the exact operating requirements of your plant were not known during its design, or your plant or operation has changed since installation, and although it appears to function well, significant inefficiencies may now exist. A review will most likely identify many and varied opportunities that can be carefully assessed to determine which ones offer the best return for the least risk.

Best practice maintenance

Best practice maintenance requires the right type of organisational *culture* and the willingness of well-trained staff to perform maintenance *activities* regularly, efficiently and effectively.

A best practice maintenance culture values the maintenance function, has qualified and experienced maintenance staff supported by systems, procedures and resources (including tools). This culture:

- includes maintenance as an integral part of production or service delivery
- regularly considers main maintenance issues at board level
- regularly trains and evaluates maintenance technicians
- has a maintenance function with clear objectives
- adopts predominantly preventive, predictive and proactive maintenance strategies
- carefully monitors equipment down time and other maintenance performance parameters
- uses maintenance management systems effectively.

Many maintenance activities are simple and others more complex - they can all help you avoid the costly consequence of motor failure.

Best practice maintenance activities include:

- machine cleaning
- machine set up and alignment
- bearing selection, fitting techniques and lubrication
- machine condition assessment
- electrical performance assessment.

Machine cleaning

You must regularly clean and protect your electric motors and equipment and ensure they are well ventilated. This makes it easier to inspect and detect problems. Also, cleaning reduces wear and tear - dirt can be highly abrasive to moving parts, contaminate bearings, coat windings and often combines with water to create a corrosive mixture.

Regular cleaning also guarantees adequate cooling. This is critical, since the life of an electric motor is halved for every 10^{o}C rise above operating temperature.

Machine set up and alignment

Machine set-up is critical to alignment and reliable machine performance. You should ensure that all technicians involved in setting up machinery are trained in at least one advanced method of alignment. Of course, they should also follow machine manufacturers instructions and recommendations.

You should mount machines on a rigid base, and check that no distortion occurred after the machine was fixed to the floor or another structure.

Use the reverse dial indicator or laser techniques to align your machines. Ensure your staff are trained and accredited by recognised experts, so they can deal skilfully with the many variables involved in alignment. You should engage the services of specialists, as needed, to assist with alignment.

Since V-belts often make up 25 per cent or more of the drives in an industrial plant, a belt tensioner is an essential item for every technician's toolbox. By ensuring your V-belt drives are set up properly, you can improve their operating efficiency by up to four per cent at very little cost. This can save many thousands of dollars for large motor users. It can also prolong the life of your belt drive since wasted energy is dissipated as heat and the life of a V-belt, like the life of the motor itself, is halved for every 10^{o} Celsius rise above the operating temperature.

Most manufactures recommend a re-check on V-belts tension after they have been operating for 24 hours, and this is critical to ensure efficient operation and long life.

Bearing selection, fitting techniques and lubrication

Ensure that bearings on all critical and high-value machines:

- meet manufacturer's specifications
- are fitted using recommended methods and tools
- are lubricated and sealed properly, and are monitored to give advanced warning of failure.

Bearings are a fundamental part of all rotating machinery. They are generally reliable and, if selected, fitted and lubricated properly, they will provide five to 20 years of service.

The most common causes of premature failure of bearings, in order of probability, are:

1. poor fitting
2. poor sealing
3. inappropriate selection
4. unsuitable lubrication
5. outside factors that place great stress on bearings, such as misalignment or vibration.

Always examine failed bearings to determine the fundamental cause of failure and rectify the cause before you replace the bearing. This reduces the chance of the next bearing failing for the same reason.

Machine condition assessment

Ongoing knowledge of machine condition is vital to reliable machine performance. Plan regular visual and operational checks on machinery and ensure your organisation's maintenance staff are well trained. Staff should use all of their senses - sight, smell, hearing, and touch - as well as basic monitoring equipment (for example, a hand-held vibration meter or thermometer) to monitor machine condition. All results should be recorded and made readily available to staff.

Conduct a regular vibration survey for high-value machines, and machines critical to process that operate above 600 rpm. Always conduct a vibration check after repair, cleaning, or alterations to speed of rotating components.

Use infrared condition monitoring of switchboards to help identify problems that may lead to switchboard failure or fires.

Electrical performance assessment

Poor power supply quality will have an adverse impact on both motor efficiency and reliability. Best practice organisations ensure that:

1. The supply voltage at the motor terminal is within 90 to 110 per cent of nominal voltage marked on the motor nameplate. Voltage fluctuations can result from improperly adjusted transformers, undersized cables or poor power factor in the distribution network.

2. Voltage imbalance - or the maximum difference of the voltages in relation to the average voltage - is under one per cent. Common causes for voltage imbalance are: non-symmetrical distribution of single-phase loads on the three-phase network; an open

circuit in one of the phases; or unequal cable lengths and sizes causing voltage drop in one of the phases. Voltage imbalance leads to high current imbalance, which leads to high losses.

3. Harmonic distortion producing devices (such as variable speed drives, other power electronic devices and arc furnaces) are isolated from other equipment by separate feeders, transformers or harmonic filters. In motors, harmonics can increase losses, reduce torque, cause torque pulsation and overheating.

Understanding the quality of a power supply and rectifying quality problems often requires specialist skills and equipment. Your organisation may need support from a qualified consultant or your electricity supplier.

Maintenance management systems: plant inventory and records

Best practice organisations have a well-maintained management system for tracking plant details and maintenance history. It takes time to develop and resource such a system, but it is fundamental to effective motor and equipment management.

This section deals with the:

- benefits of a best practice maintenance management system
- how to develop a maintenance management system
- the contents of a maintenance management system.

Benefits of a best practice maintenance management system

Accurate and comprehensive plant inventory and records are essential for:

- implementing preventive and predictive maintenance planning, to maintain machinery efficiently and effectively
- avoiding routine maintenance problems turning into extended downtime
- avoiding making repetitive and costly mistakes
- tracking patterns and trends in motor and equipment performance
- continuously improving plant reliability and efficiency by eliminating poorly performing equipment
- predicting future (capital) expenditures
- conducting cost analysis and comparisons of maintenance for specific machines.

In best practice organisations, the maintenance department is responsible for the plant inventory and records system. Technicians must be trained on the importance of, and method for, updating and maintaining records.

The type of system used will vary depending on the type and quantity of machines you are maintaining. Computer records are the most effective, and there are many different proprietary maintenance software packages available on the market (ranging from simple to highly sophisticated). If you are investing in software, make sure you choose the package the best meets your needs.

A well maintained card system can also be effective if your plant does not have too many machine items or if a computer is not readily available.

How to develop and implement a best practice maintenance management system

The first step in developing and implementing your best practice motor maintenance management system is to review and evaluate your present maintenance policy. Your policy should be clear on:

- the objectives of the maintenance team
- site safety procedures and emergency contacts
- levels of responsibility and authority (including budgetary authority)
- the identification system for equipment - both equipment identifier and repair priority
- responsibility and timing for condition monitoring and scheduled maintenance
- how work, work requests and equipment failures are prioritised, handled and tracked
- record updating and reporting procedures and responsibilities
- contacts in management, production and purchasing.

Repair priority

Equipment varies widely on factors such as value, operational cost, requirements for maintenance, impact of failure on the production process, environment, safety, and neighbourhood goodwill. You need to consider the impact of failure on each factor, and determine a repair priority system accordingly. Evaluating the repair priority for each piece of equipment, and recording its priority status in the plant inventory, is fundamental to a best practice maintenance system. The lack of a comprehensive yet simple priority system can result in confusion, too many emergencies, and an out of control maintenance group.

Your maintenance management system must complement your existing maintenance policy and procedures and be readily available to staff so they can easily update it and rely on it as a resource. If yours is a larger plant, keep your motor inventory separate from your plant inventory since motors can be moved from one place to another in a plant throughout their life. The motor should never be separated from its own detailed history. The plant inventory, on the other hand, needs only to contain the number of the motor, which you will use to link to more detailed information on the motor.

Contents of a management maintenance system

The contents of a management maintenance system will vary from plant to plant. Best practice systems can include the following features:

Motor record

- motor identifier
- date of purchase
- manufacturer and model
- enclosure
- rated power
- synchronous speed (number of poles)
- frame size
- rated voltage
- full load current

  phase

- full load speed

- efficiency and power factor at 50 per cent, 75 per cent and full load

Motor maintenance log

- date and reasons for failure
- repairs and repair shop details
- motor condition
- maintenance history
- scheduled maintenance

Plant records

- plant number, motor number and repair priority
- plant description, manufacturer and model
- location in plant
- information on spare components
- load type
- duty cycle
- estimated load
- starting method
- motor assessment and recommended replacement option
- transmission method, set up specification and driven speed
- vibration and balance specification
- machine drawing and replacement component list

Plant maintenance log

- date and reasons for failure
- repairs and repair shop details
- plant condition
- maintenance history
- scheduled maintenance