Blow the lid on ineffective energy usage

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1. Energy efficiency of electric fans and blowers

In common with most other countries in both the developed and the developing world, South Africa needs more generation capacity. The extent to which Eskom is able to supply the country’s demand for electric power has a direct impact on economic growth.

All sectors of the economy can reap major benefits from implementing energy efficiency policies. By optimising processes and plant efficiency, companies reduce input costs and increase their return on investment. As an added benefit, reduced energy consumption means reduced environmental impact, an important part of the “triple bottom line.”

This information brochure aims to assist industrial and commercial users of electricity to improve the energy efficiency of electric fans and blowers. It explains the benefits of energy efficient fans, types of fans and blowers, factors impacting fan performance, the importance of simple regular maintenance and ways to improve performance while also reducing electricity consumption and operating costs.

It concludes with a summary checklist and details of free energy efficiency advisory services available from Eskom.

2. Optimising the efficiency of fans and blowers

Widely used in various industrial applications, fans are more subject to misuse, abuse and faulty applications than virtually any other type of equipment. The result of ineffective usage is an unnecessary high energy cost which can be reduced to yield sizeable savings. Such savings are particularly desirable given the growing international move towards reduced environmental impact.

In industrial settings, fans provide the motive power to circulate air for heating or cooling. Specially designed fans or blowers in selected applications are also used for materials handling. The control of the energy consumed by fans is important to the overall efficiency of the systems in which they operate.

By applying several simple principles of design and maintenance, the power consumption of fans can be optimised, enabling energy savings. Furthermore, implementing variable speed drives, at a cost, will enable the performance of fans to be adjusted to accurately meet the demands of the task at hand, providing further energy savings.

3. Definitions

**Fan**

A fan is a device that causes the flow of a gaseous fluid by creating a pressure difference on the medium to be transported. The gaseous fluid transported by the fan is most often air and/or toxic fumes (whereas blowers may transport a mixture of particulates and air).

**Blower**

A blower is similar to a fan, except that it can produce a much higher static pressure. Sometimes higher pressure is achieved by a multi-stage impeller arrangement. Engineers distinguish fans and blowers for low pressure and centrifugal compressors for high pressure. In this brochure, blowers and fans are considered to fall under the same broad definition.

4. Fan Pressure

- **Fan Total Pressure** – Velocity pressure + Static Pressure.
- **Fan Velocity Pressure** – It can be expressed as resistance to flow of air or as the drag resistance of the air.
- **Fan Static Pressure** – It is a stationary pressure that can be either positive or negative and can be expressed as a bursting pressure.

5. Fan efficiency

Is expressed in percentage (%) and describes the ratio of the fan output power (kW) to the fan input power (kW).

- **Fan (motor) input power** – Is the power to the motor that is required to drive the fan and may include belt drive, gear box etc.
- **Fan output power** – Is the product of the fan pressure and the volume.
- **If the fan total pressure is used, then it is expressed as “Fan Total Efficiency.” If the fan static pressure is used, then it is expressed as “Fan Static Efficiency.”**
6. Fan types

There are four basic types of fans:

### 6.1 Centrifugal fans

Centrifugal fans move air by the centrifugal force that is produced by moving the air between the rotating impeller blades, and by the inertia generated by the velocity of the air leaving the impeller. They can be either direct drive or indirectly driven by belts, gear box or friction clutch. Performance control is achieved by altering speed or adjusting variable inlet vanes. When rotating in the wrong direction, air will continue to flow into the eye and out through the blades. It can be either single or double inlet.

<table>
<thead>
<tr>
<th>Fan Type</th>
<th>Applications</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Backward Curved  | HVAC/Industrial, Clean air supply & extraction | • Medium to high efficiencies (80 – 85%)  
• High volume & medium pressure  
• Non overloading characteristics | • Can’t handle dusty environments  
• Larger casings for the LFC fans |
| Forward Curved   | HVAC/Industrial, Clean air supply & extraction | • Medium/Low efficiencies (60 – 70%)  
• High volume & low pressure  
• Relative small & compact casing  
• Silent operation  
• Available in small sizes | • Can’t handle dusty environments  
• High local manufacturing costs |
| Radial Bladed    | Industrial/Mining/Petrochem, Dust extraction applications, High pressure applications | • Medium volume to high pressure  
• Robust, can resist wear against abrasion | • Low efficiencies (35 – 70%)  
• High speed operation  
• High noise levels  
• Overloading characteristics |
| Radial Flow Blading | Industrial/Mining/Petrochem, Dust extraction applications, High pressure applications | • Medium to high volume to high pressure  
• Robust, can resist wear against abrasion | • Low/medium efficiencies (50 – 70%)  
• Overloading characteristics  
• Available in larger size 45” and up |
| Aerofoil Blades  | Industrial/Mining/Petrochem, Clean air supply & extraction | • High efficiencies (85 – 90%)  
• High volume & medium to high pressure  
• Non overloading characteristics | • Extremely high labour input to manufacture  
• Only available in 45” and up |

6.2 Axial fans: move air by the change in velocity of the air passing over the impeller blades. It can be direct or indirect drive. Tip clearance between the tip of the blade and the fan casing is typically 0.25% of the impeller diameter. Blades can either be flat (solid plate) or Aerofoil (cast alloy). Aerofoil sections can apply greater force to the air, increasing pressure and maintaining better efficiency over a wider range. Increasing the thickness and curvature increases stiffness, allowing operation at higher speeds. When rotating in the backward direction, they will reverse the direction of flow through the fan and deliver 60% to 70% of the forward quantity of air. A true reversible fan will have alternate blades rotated through 180º and deliver 85% of the normal setting in either direction. Performance control is achieved by altering speed, adjusting impeller blade pitch angle or adjusting variable inlet vanes. Performance is enhanced by installation of inlet cone, inlet or outlet guide vanes, tail fairings and diffusers. To obtain the correct airflow/pressure combinations for axial flow fans, different numbers of blades can be used for the optimum design as seen in figure below.

### 6.3 Mixed flow fans

Air enters parallel to the axis of the fan and turns through an angle which may range from 30º to 90º. The pressure rise is partially by direct blade action and partially by centrifugal action.

### 6.4 Cross flow fans

Air enters the impeller at one part of the outer periphery, flows inward and exits at another part of the outer periphery.
7. Relative merits of axial and centrifugal fans

- Axial fans offer better efficiency over a wider range of duties whereas the centrifugal fans can have a higher efficiency, albeit over a smaller range, on a single performance curve.
- The performance of a single speed axial fan can be altered simply by adjusting the impeller blade pitch angle.
- The performance of a single speed centrifugal fan requires the installation of variable inlet vanes.
- Axial fans generally run faster than centrifugal fans and, as a consequence, are much noisier.
- Axial fan impellers are generally manufactured from aluminium in an effort to keep weight to a minimum.
- As a consequence the potential for erosion is greater, particularly if there is water in the shaft.
- The light material used in the blades along with the high rotational speed of axial fans makes them prone to erosion and, even in good, dry conditions, it is reasonably expected that this erosion will significantly reduce the fan performance within five years.
- Centrifugal fan impellers are fabricated from plate and are generally hollow. As a consequence, when there is water in the shaft, the nose of the blade is prone to pitting allowing water to enter the hollow section. Sufficient water in this section will cause the impeller to become unbalanced and, if allowed to continue, it will result in high vibration and eventual failure of the impeller shaft.
- Centrifugal fans traditionally require the construction of large concrete foundations to the motor and ductwork.

8. Choosing the correct fan

There are several acceptable ways to determine a fan design for a specific application. In the first method, where the application requirements do not vary greatly and fan designs have a diameter approximately 1.2m or less, a standard or pre-engineered fan may be used. These fans can be selected from a supplier’s brochure.

When the application involves more complex specifications or a larger fan, then a design based on an existing model configuration will often satisfy the requirements. Many model configurations already cover the range of current industry processes. An appropriate model from the fan company’s catalogue is selected, and the company’s engineers apply design rules to calculate the dimensions and select options and material for the desired performance, strength and operating environment. Some applications require a dedicated, custom configuration for a fan design to satisfy all specifications.

All industrial fan designs must be accurately engineered to meet performance specifications while maintaining structural integrity. For each application, there are specific flow and pressure requirements. Depending on the application, the fan may be subject to high rotating speeds, and operating environments with corrosive chemicals or abrasive air streams, and extreme temperatures.

Larger fans and higher speeds produce greater forces on the rotating structures; for safety and reliability, the design must eliminate excessive stresses and excitable resonant frequencies.

9. Fan performance

9.1 Fan power requirement

The work done by a fan can be measured by the quantity of air it delivers, and the pressure against which this air is delivered. The overall fan efficiency relates to the theoretical output against the electrical power supplied to the fan system – this includes fan losses, belt drive losses, and motor losses.

Understanding the points at which losses occur provides the context in which optimisation can occur to maximise the work done by a fan while minimising energy usage.

Fans operate under a predictable set of laws concerning speed, power and pressure. A change in the speed (revolutions per minute - RPM) of any fan will predictably change the pressure rise and kilowatts necessary to operate it at the new RPM, i.e. reduction in speed is directly proportional to a cubed reduction in power.

9.2 System effect factors

A fan is normally tested with open inlets with a straight duct attached to the outlet. This results in uniform airflow into the fan and efficient static pressure recovery at the fan outlet. If these conditions are not matched in the actual installation, the performance of the fan degrades; this must be allowed for when selecting a fan.

Fans are sensitive to their application in the air distribution system. This characteristic is called “system effect” and involves air movement at the inlet and outlet connections of the fan. The changes in direction of flow at the outlet or inlet of the fan will adversely affect its performance. Dampers very close to the inlet or outlet and branch ducts very close to the discharge will also have an adverse effect on fan performance. The biggest problem with the system effect is that it cannot be measured in the field even though it reduces the output of the fan.

10. Typical fan system problems

10.1 Oversized fans

Design engineers tend to oversize fan requirements. This may initially be an oversized fan and, thereafter, an oversized motor to drive the fan. Oversizing is often an attempt at providing adequate impact; however, this creates operating problems such as expensive operating costs, noise and airflow problems.

10.2 High operating and maintenance costs

This is generally caused by inefficient fan operation that can be a result of poor fan selection, poor system design and wasteful airflow control practices. In order to reduce maintenance and operation costs, a fan should be kept operating within a reasonable range of its best efficiency operating point.

10.3 Poor airflow control

This problem typically refers to inadequate delivery of air to various points in the system surging operation and high levels of noise. This may be caused by poor system balancing and leakage. Leakage can be as a result of dampers left open or leaks in the duct work. In the case of forward inclined and radial blade fans, it can lead to overwork and motors overloading. Depending on where the operating point of the backward inclined blades and axial flow fans on the fan curve is, it can result in an increase in power, but these two types of fans have non-overloading characteristics.
10.4 Electrical system wear

Electrical systems take strain when there are frequent start ups of large electrical loads. The use of soft starters for large motors helps to extend fan motor life and keeps the motor temperature low. Variable speed drives (VSD) are also used to soft start fans.

11. Energy management opportunities

The balancing of an air handling system normally requires the services of an experienced specialist and is generally performed after the system is installed. While fan systems are generally optimized at installation, the components of the system wear down over the years. Fan wheels go out of balance due to dirt accumulation, which causes vibration and noise. Bad bearings on the fan shaft can contribute to vibration as well as cause damage to fan wheels. Dirty filters can reduce airflow considerably, reducing the motor load, and creating false savings.

It is therefore evident that the first step in assessing and optimizing air handling systems is to keep them at the designed operating conditions through proper maintenance.

11.1 Implementing a maintenance programme

A maintenance programme for fans should be tailored to the specific needs of the facility in which the fans are being used. A suggested programme includes the following actions:

- Daily: observe fan sounds, vibration, bearing temperature, and reading of installed gauges and meters.
- Monthly: check drive belt alignment, belt tension, and lubricate the fan bearings.
- Semi-annually: inspect fan shaft seals, check inlet and outlet dampers, inlet vanes, drain and refill oil lubricated bearings.
- Annually: check lubrication lines to assure proper movement of grease or oil, fan auxiliaries, recalibrate all associated instrumentation and carry out performance tests.

11.2 Specific maintenance opportunities

By understanding how inefficiencies creep into fan systems, maintenance crews can identify better how to correct problems, and ensure optimum performance of fan systems. Among some of the common issues that arise are losses from poorly fitted belt drives, improperly lubricated components, failing bearings, losses due to air leaks and dirty filters. Monitoring and addressing these issues are low-cost opportunities for energy optimisation that also ensure the longevity of the equipment.

11.2.1 Belt drive losses

Improper alignment of the fan drive sheaves can cause excessive power requirements and damage to belts. Properly aligned and tensioned belt drive systems have predictable mechanical losses; misaligned and loose belts cause additional losses that have an impact on energy consumption. When using a direct drive where the impeller is attached to the motor shaft, losses of up to 10% can be experienced. In the case of belt driven fans, a power loss of 17–25% between the pulleys and fan belts can be expected.

11.2.2 Lubricating fan components according to manufacturer’s instructions

Lubrication of fan components such as couplings, shaft bearings, adjustment linkage and adjustable supports must be maintained with proper lubricants, and at intervals, as recommended by the fan manufacturer.

11.2.3 Cleaning fan components regularly

Fans and filters, particularly those handling dirty air, should be cleaned regularly to maintain their efficiency. Contamination on blades and the housing interior causes higher static pressure loss in the fan, thereby reducing efficiency.

11.2.4 Correcting excess noise and vibration to ensure smooth and efficient operation

The noise and vibration of the fan can be caused by one or more factors:

- The fan wheel is out of balance.
- The bearings are worn.
- Insufficient isolation.
- The shaft seal is misaligned.
- There is corrosion between the shaft and bearing.
11.2.5 Repairing leaks

Energy is lost when air leaks out of loose connections, improperly-sized damper shaft openings and unsealed expansion connections. These and similar conditions at fan suctions and discharges should be corrected.

11.2.6 Replacing loaded air filters

Loaded (dirty) air filters are a common cause of poor performance in fan systems. Filter manufacturers provide recommendations for the pressure drop at which their filters are considered fully loaded for various air velocities at the inlet to the filters. Filters should be replaced before their pressure drop reaches the loaded values for the particular air velocity. Balancing a system with loaded filters will result in excessive air flow, and higher fan energy consumption when the filters are replaced.

11.3 Additional low cost opportunities

Simple energy management actions present opportunities to reduce the power consumption of industrial fans at a low cost that is quickly recouped through the reduced power bill. Typical energy management opportunities include:

- Reducing fan speed to suit optimum system air flow with balancing dampers in their maximum open position for balanced air distribution.
- Improving fan inlet and outlet duct connections to reduce entrance and discharge losses.
- Shutting down fans when not required.

11.4 Higher cost retrofit opportunities

Optimising fan systems is also possible through investing in more advanced modern equipment. Upgrading fans in this manner requires a capital investment and professional intervention including detailed analysis and implementation expertise.

Typical energy management opportunities that can be achieved by retrofitting new equipment to existing fans include:

- Adding variable speed drive motors which allow fan output to follow system requirements.
- Replacing outdated equipment with new units sized for optimum efficiency.
- Replacing oversized motors.
- Installing a microprocessor-based energy management control system.

11.5 Addressing flow control

Air handling systems are usually engineered for 100% design flow, but can in many cases operate with less flow - or just enough flow - to address the task at hand. In many cases, fans operate at 100% only despite the fact that they could potentially be adjusted to operate at a far lower rating. Controlling the flow with dampers or air inlet vanes or installing a variable speed drive can achieve optimal airflow.

Dampers or vanes are not considered an option, since this approach wastes energy. Variable speed drives, which have the ability to re-adjust the fan to exact needs through speed control, reduce fan noise and more importantly save the most energy.

Fans and the motors driving them are usually oversized because:

- Filters clog and leaks develop.
- Design engineers are conservative.
- The next smaller sized fan could not meet design flow requirements.

If preliminary investigations by specialists indicate good potential savings with the use of the adjustable speed drives, a speed control specialist should be consulted to work out the details.

Fans serve over a wide range of operating conditions. These conditions vary according to ambient conditions, occupancy and or production requirements. If a fan is not appropriately sized, then there are several means of controlling the flow rate of a fan, e.g. temporarily reducing the air or gas flow rate. These can be applied to both centrifugal and axial fans.

### Type of flow control

<table>
<thead>
<tr>
<th>Type of flow control</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulley change: reduces the motor/ drive pulley size.</td>
<td>Permanent speed decrease.</td>
<td>Fan must be able to handle capacity change.</td>
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<tr>
<td></td>
<td>Real energy reduction as per fan laws.</td>
<td>Fan must be driven by V-belt system or motor.</td>
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<tr>
<td>Dampers: reduce the amount of flow and increase the upstream pressure, which reduces fan output.</td>
<td>Inexpensive.</td>
<td>Provide a limited amount of adjustment.</td>
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<td></td>
<td>Easy to install.</td>
<td>Reduce the flow but not the energy consumption.</td>
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<tr>
<td>Inlet guide vanes: create swirls in the fan direction thereby lessening the angle between incoming air and fan blades, thereby reducing both the motor load and airflow.</td>
<td>Improve fan efficiency because both fan load delivered airflow are reduced.</td>
<td>Higher operating and maintenance costs.</td>
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<tr>
<td></td>
<td>Cost effective at airflow between 80-100% of full flow.</td>
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<tr>
<td>Variable pitch fans: change the angle between incoming airflow and the blade by tilting the fan blades, thereby reducing both the motor load and airflow.</td>
<td>Can keep fan efficiency high over a range of operating conditions.</td>
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<tr>
<td></td>
<td>Avoid resonance problems as normal operating speed is maintained.</td>
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<tr>
<td></td>
<td>Can operate from a no-flow to a full-flow condition without stall problems.</td>
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<tr>
<td>Variable Speed Drive (VSD):</td>
<td>Most improved and efficient flow control.</td>
<td>Mechanical VSDs have fouling problems.</td>
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<tr>
<td>redusing the speed of motor of the fan to meet reduced flow requirements.</td>
<td>Allow fan speed adjustments over a continuous range for VFDs specifically.</td>
<td>Investment costs can be a barrier.</td>
</tr>
<tr>
<td>Mechanical VSDs: hydraulic clutches, fluid couplings, and adjustable belts and pulleys.</td>
<td>Effective and easy flow control.</td>
<td></td>
</tr>
<tr>
<td>Electrical VSDs: eddy current clutches, wound rotor motor controllers, and variable frequency drives (VFDs change motor's rotational speed by adjusting electrical frequency of power supplied).</td>
<td>Improve fan operating efficiency over a wide range of operating conditions.</td>
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<tr>
<td></td>
<td>Can be retrofitted to existing motors.</td>
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<tr>
<td></td>
<td>No fouling problems.</td>
<td></td>
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<tr>
<td></td>
<td>Reduce energy losses and costs by lowering overall system flow.</td>
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</tr>
<tr>
<td>Multiple speed fan.</td>
<td>Efficient control of flow.</td>
<td>Need to jump from speed to speed.</td>
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<tr>
<td></td>
<td>Suitable if only two fixed speeds are required.</td>
<td>Investment costs can be a barrier.</td>
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<tr>
<td>Disc throttle: a sliding throttle that changes the width of the impeller that is exposed to the air stream.</td>
<td>Simple design.</td>
<td>Feasible in some applications only.</td>
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<tr>
<td>Operate fans in parallel two or more fans in parallel instead of one large one.</td>
<td>High efficiencies across wide variations in system demand.</td>
<td>Should only be used when the fans can operate in a low resistance, almost in a free delivery condition.</td>
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<td></td>
<td>Redundancy to mitigate the risk of downtime because of failure or unexpected maintenance.</td>
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<td></td>
<td>Two smaller fans are less expensive and offer better performance than one relatively large one.</td>
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<td></td>
<td>Can be equipped with other flow controls to increase flexibility and reliability.</td>
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<tr>
<td>Operate fans in series using multiple fans in a push-pull arrangement.</td>
<td>Lower average duct pressure.</td>
<td>Not suited for low resistance systems.</td>
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<td></td>
<td>Lower noise generation.</td>
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<tr>
<td></td>
<td>Lower structural and electrical support requirements.</td>
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<tr>
<td></td>
<td>Suits for systems with long ducts, large pressure drops across system components, or high resistances.</td>
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</tbody>
</table>
12. Optimised fan systems: saving power, preserving equipment

As this brochure has made clear, improving the performance of fan systems in industrial settings can be achieved through simple interventions that need not incur any substantial cost to the enterprise. By optimising maintenance regimes, the energy consumption of fan systems can be improved while an ancillary benefit of better reliability and longevity of equipment can be achieved. For those organisations where fan systems significantly contribute to energy costs, it may be necessary for professionals to evaluate the systems carefully and examine the potential viability of implementing variable speed drives, and electronic controls of fan systems for optimisation.

13. Energy efficiency checklist

Good housekeeping and regular maintenance of fans makes perfect energy sense, saving your business downtime and money. Shown below is a summary of relatively simple actions that you can take with the fans and blowers in your business:

<table>
<thead>
<tr>
<th>Check</th>
<th>Date</th>
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<tbody>
<tr>
<td>1. Check and adjust drive belt alignment and tension.</td>
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<tr>
<td>2. Regularly listen to fan sounds, vibrations and check for signs of wear.</td>
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<td>3. Regularly lubricate fan bearings and clean fan components.</td>
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<td>4. Regularly replace loaded air filters.</td>
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<tr>
<td>5. Check for air leaks and faulty damper settings.</td>
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<tr>
<td>6. On an annual basis check lubrication lines, fan auxiliaries, calibrate instrumentation where necessary and carry out performance tests.</td>
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<tr>
<td>7. Establish and follow a regular maintenance programme, and ensure staff are trained accordingly.</td>
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<tr>
<td>8. When fitting new fans and blowers ensure your supplier conducts a proper needs analysis, replaces oversized motors, new units are sized at optimum efficiency and that your air handling system is properly balanced by an experienced specialist.</td>
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<tr>
<td>9. Whenever fitting a new fan or blower, install variable speed units when appropriate, to get your job done more efficiently.</td>
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<tr>
<td>10. Use smooth, well rounded air inlet cones for fan intakes.</td>
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<tr>
<td>11. Avoid poor flow distribution at the fan inlet.</td>
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<tr>
<td>12. Minimise fan inlet and outlet obstructions.</td>
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<tr>
<td>13. Clean screens, filters and fan blades</td>
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<tr>
<td>15. Use low slip or flat belts for power transmission.</td>
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<tr>
<td>16. Check belt tension – monthly.</td>
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<tr>
<td>17. Use variable speed drives for large variable fan loads.</td>
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<tr>
<td>18. Variable speed drives in good working order.</td>
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<tr>
<td>19. Use energy efficient motors for continuous or near continuous operation.</td>
<td></td>
</tr>
<tr>
<td>20. Use energy efficient motors for continuous or near continuous operation.</td>
<td></td>
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<tr>
<td>21. Minimise number of bends in ducts.</td>
<td></td>
</tr>
<tr>
<td>22. Ensure that fans and blowers are turned off when not needed.</td>
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</tr>
<tr>
<td>23. Monthly fan maintenance:</td>
<td></td>
</tr>
<tr>
<td>• Inspection of all components</td>
<td></td>
</tr>
<tr>
<td>• Bearing lubrication and replacement required</td>
<td></td>
</tr>
<tr>
<td>• Belt tightening and replacement</td>
<td></td>
</tr>
<tr>
<td>• Motor repair or replacement</td>
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<tr>
<td>• Fan cleaning</td>
<td></td>
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<tr>
<td>25. Operate the fan near to its best operating point (BOP).</td>
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<tr>
<td>26. Reduce transmission losses by using energy efficient flat belts or cogged raw-edge V-belts instead of conventional V-belts.</td>
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<tr>
<td>27. Minimise system resistance and pressure drops by improving the duct system.</td>
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</table>

Remember, if you reduce fan speed (RPM) by just 10% you could reduce the power required by as much as 27%.

14. Support and advice

Call the Eskom Contact Centre on: 08600 ESKOM (08600 37566) and log a query for an energy advisor in your area to contact you. Or visit www.eskom.co.za/dsm for information on energy efficient technologies and adaptations.

15. References

- SADC Industrial Energy Management Project - Module 9
- Donkin Fans Training Seminar 2009
- AMC Basic mine ventilation