Auxiliary ventilation is vital in the mining industry, with dilution of dust and gases and removal of heat being some of the primary reasons. Poor air control creates an unhealthy and unsafe environmental climate on the one hand, while increasing ventilation costs in term of increased fan power requirements on the other.

Energy efficient fans for deep-level auxiliary ventilation systems

Electric motors in ultra deep level conditions

Courtesy of gold mines and some fan manufacturers, 45 kW fan performance tests have been conducted on site with the same impeller (named “1,2” impeller) at different shaft levels, i.e. air densities of 1,2 kg/m³ and 1,4 kg/m³.

These figures explain the high rate of failure of standard motors when run at deeper levels: at 1,4 kg/m³ air density (air flow is a constant characteristic of impeller), where motors are working at 117% overload shaft power. New dedicated energy efficient motors with superior performance have been manufactured (and tested) in accordance with the US Energy Policy Act.

Comments on Table 2:

Standard motors perform with a “1,2 impeller” in standard conditions (1,2 kg/m³ air density). If auxiliary fans are installed in higher air density conditions (deep levels) the impeller will heavily overload the motor by moving an increased amount of air mass, in proportion with air density. Energy efficient motors perform according to their class of insulation, up to 1,75 kg/m³ air densities.

High power impellers or not?

As reference, “F” and “FDL” fan performances @ 1,2 kg/m³ air density are specified [2].

A normal 1,2 impeller performs its airflow function regardless of the air density. Working at ultra deep levels, its air power will increase in direct proportion to air density. As a result, the impeller will overload a standard motor because motor shaft power will increase proportionally. That is why this impeller was denominated “high power impeller”. Should impellers be de-rated? Typical fan design problems are presented in Fig. 1.

The impeller design requires high air power output, high efficiency and low noise levels. Impeller design has been improved to a certain extent. As an interim solution, in order to prevent standard motors failures at ultra deep levels (where air densities of 1,4 kg/m³ or more have been recorded), a de-rated impeller has been designed and manufactured.

<table>
<thead>
<tr>
<th>Air density</th>
<th>Air flow volume</th>
<th>Static Press</th>
<th>Electric abs. input power</th>
<th>Estimated output motors power</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,2 kg/m³</td>
<td>12 m³/sec</td>
<td>2000 Pa</td>
<td>40,4 kW</td>
<td>45,01 kW</td>
</tr>
<tr>
<td>1,4 kg/m³</td>
<td>12 m³/sec</td>
<td>2333 Pa</td>
<td>56,5 kW</td>
<td>52,5 kW</td>
</tr>
</tbody>
</table>

Table 1: Results of fans tests at different levels

Fig. 1: Axial fan power flow diagram (with losses)
The so-called “1,4 impeller” achieves only a 10 m³/s volume air flow @ 2333 Pa (static pressure), loading standard motors (when running in ultra deep levels) at its rated shaft power (corresponding to 1,2 kg/m³ air density) and prevents motor temperature rise beyond motor class insulation conditions. Despite this, however, electric motor failures have still been recorded.

Not surprisingly, daily measurements at ultra deep levels indicate large variations in air density (some ±20%). Air density variations bring motors into a temporary overload condition. Windings are overheated in a relative “quasi adiabatic” thermal process determined by the large amount of material involved in the heat transfer process (2 poles stator cores having large values of black iron). In order to maintain environmental conditions by using the 1,4 impeller, an increase of at least 20% in the number of fans is required.

Following the mines’ trend to expand deeper mining operations it becomes clear that the 1,4 impeller will soon be in the same situation as the normal 1,2 impeller for 1,4 kg/m³ air density. Then, a new de-rated “1,5 impeller” should be required.

How can fans containing different types of impellers be differentiated, before commissioning underground? Should the 1,2 impeller be scrapped? Should a high power 1,2 impeller be used at any mining level, including ultra deep levels, while keeping fans standard?

A 1,2 impeller used in ultra deep level conditions must be driven by an electric motor having:
- Rated power between 55 - 75 kW (in order to withstand overload conditions);
- Same frame size as original 45 kW frame (keeping same size fan casing, impeller and ducts);
- Improved class of insulation (H class, able to withstand to 125 °C temperature rise overload conditions)
- Improved performance (energy efficient in a range of 75% - 105% of rated power).

These motors are available. They are able to sustain the overload conditions generated by using a high efficiency 1,2 impeller at any shaft level, withstanding air densities of 1,75 kg/m³. Prototypes of 55 kW and 75 kW PAD motors in D200 - 45 kW existent frames have been tested successfully. Designing various increased output power for the same motor frame will allow environmentalists and mining engineers to keep the fans’ casings and ducts unchanged. Fans fitted with energy-efficient motors and standard 1,2 impellers do not need special marking, being able to perform at any mining level.

**Economic implications**

Based on accepted fan performances, the quantity of ventilated air delivered annually can be estimated. It has been measured that a 1,2 impeller powered by an energy efficient motor delivers an extra 88 300 t of air annually, saving between R10 000 and R20 000 per fan.

**Energy costs of ventilated air**

Using absorbed apparent power [kVA] data from Table 2, the annual energy cost @ 1,4 kg/m³ air density is R89 904 for a standard motor and R70 775 for an energy efficient motor. Considering electricity costs and air quantities delivered annually, a useful fan efficiency estimator is proposed, i.e. Fan Energy Efficiency Indicator - FEEI

\[
FEEI = \frac{S \times \text{electricity price}}{Q \times \rho \times 3.6}
\]

where: \( Q \) = volume air flow on site \([m^3/s]\)  
\( \rho \) = air density on site \([kg/m^3]\)

**Conclusions and results validation**

Impeller design was somewhat improved when mining activity required higher efficiencies. Energy efficient motors offer a boost and a global solution for auxiliary ventilation systems (high efficiency and reliability at any level of mining shaft) with power increase without motor or ventilation system frame alteration. FEEI estimator is a useful indicator in assessing fans’ efficiency. It can evaluate efficiency of every type of fan; FEEI value is inversely proportional to fan efficiency.

Auxiliary fans fitted with energy efficient electric motors driving high power 1,2 impellers produce low and approximately constant FEEI values regardless of environmental working conditions.

In order to save existing standard motors, an interim solution has been adopted: a de-rated 1,4 impeller driven by a standard motor. This interim solution generates an increase of

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Description of impeller type and working conditions</th>
<th>Tons of ventilated air annually delivered by a “F” and “FDL” 45 kW fan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>“1,2 impeller” @ 1,2 kg/m³</td>
<td>454,118</td>
</tr>
<tr>
<td>2</td>
<td>“1,2 impeller” @ 1,4 kg/m³</td>
<td>529,805 (using energy efficient motor)</td>
</tr>
<tr>
<td>3</td>
<td>“1,4 de-rated impeller” @ 1,4 kg/m³</td>
<td>441,504 (using standard motor)</td>
</tr>
</tbody>
</table>

Table 2: Motor performance comparison tests at different air densities (deep and ultra deep levels)

Table 3: Air quantity delivered annually by one “F” type fan in different cases.

January 2005 - Vector - Page 24
Fig. 2: Features of new energy efficient motor.

20 - 40% of FEEI. To comply with required environmental conditions, FEEI will further increase to 60 - 70%.

Validation: courtesy of gold mines, measurements on FDL type fans in ultra deep level shafts have been done (average air density = 1,40 kg/m³), with results presented in Table 5.

**Comments on Table 5**

Energy efficient motors ensure very good technical and economical fan performance. These electric motors are able to perform at ultra deep level mining conditions where air density can reach values of 1,4 – 1,6 kg/m³ (including transient variations of air density).

<table>
<thead>
<tr>
<th>Fan no.</th>
<th><em>F</em> Fan Description: impeller type @ 1,2 and 1,4 kg/m³ air densities driven by standard and energy efficient motors</th>
<th>FEEI in [Rand/ton of ventilated air]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&quot;1,2 impeller&quot; @ 1,2 kg/m³ air density driven by a standard motor</td>
<td>0,1555</td>
</tr>
<tr>
<td>2</td>
<td>&quot;1,2 impeller&quot; @ 1,2 kg/m³ air density driven by energy efficient motor</td>
<td>0,1333</td>
</tr>
<tr>
<td>3</td>
<td>&quot;1,2 impeller&quot; @ 1,4 kg/m³ air density driven by a standard motor</td>
<td>Burned out</td>
</tr>
<tr>
<td>4</td>
<td>&quot;1,2 impeller&quot; @ 1,4 kg/m³ air density driven by energy efficient motor</td>
<td>0,1335</td>
</tr>
<tr>
<td>5</td>
<td>&quot;1,4 de-rated impeller&quot; @ 1,4 kg/m³ air density driven by standard motor</td>
<td>0,1877</td>
</tr>
<tr>
<td>6</td>
<td>Same as no. 5 but taking in consideration required environmental conditions (see the NOTE from chapter no. 4, i.e. min. 20% increase of standard motors number)</td>
<td>0,2253</td>
</tr>
</tbody>
</table>

Table 4: Estimations of FEEI for auxiliary ventilation "F" type fans in different scenarios.

In spite of relatively cheap energy cost per ton of air (R0,14/t), technically, the standard modified fan is under-performing (air volume is 10,64 m³/s only), extra fans are necessary to keep environmental conditions unchanged; this further increases the total cost of electric energy spent on a specific shaft, equivalent to FEEI increase at R0,1571 per ton of ventilated air.

A standard motor with a de-rated 1,4 impeller is a 54% more expensive energy cost solution.

FEEI estimates are confirmed by direct measurements performed underground.

A FEEI estimator per shaft (for a specific mine level) can be produced as a global efficiency indicator, part of company corporate energy policy.

**Advantages of using energy efficient electric motors at ultra deep levels**

Based on year 2003 energy cost indicators it was calculated that a R0,03 increase of FEEI value is equivalent to R15 000 annual losses per FDL fan. On average there are ten 45 kW fans of FDL type installed per shaft and 10 - 15 shafts per mine. Using energy efficient electric motors in conjunction with high power impellers, an estimated annual savings per mine shaft of R100 000 - R150 000 (excluding maintenance, repair and logistical costs) can be obtained.

Energy efficient motors run cooler, being able to drive high power impellers at ultra deep levels (high air density values) where increased volumes and large variations in air density require increased shaft power.

Regardless the shaft level, high performance fans (impellers equipped with energy efficient motors) pay for themselves in 0,8 - 1,1 years, after which they continue to generate savings.

**References**


Contact Constantin Pitis, Femco Mining Motors, Tel (011) 887-0953, danpiti@femco.co.za