Fan specification and tender adjudication for mine ventilation engineers with particular reference to turnkey projects

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ABSTRACT

The correct specification and then selection of primary or major fans for an underground mine is a critical decision not only in terms of fan capital and operating costs, but also safety and reliability which usually has a major impact on mine production. In addition, fan manufacturers may spend tens of thousands of dollars preparing proposals for a purchase enquiry for primary fans especially where they have complete responsibility for the installation (turnkey projects). There are many good reasons to thoroughly and fairly adjudicate fan tenders. This paper describes the process to achieve this starting with the initial fan specification through to the final award.

INTRODUCTION

Primary and secondary fans are the heartbeat of the mine ventilation system and need to perform their job at the required duty continuously for many years. There can be a bewildering range of fan types and options available for the mine ventilation engineer. It is not uncommon to find mines using fans that are less than ideal and in some cases unsuitable for the application or to find expensive fan options or accessories installed that add no value, and other important options not selected which are really needed. In most cases this results from the mine ventilation engineer not understanding the key requirements of the fan application so the specification is wrong or incomplete, or not communicating these requirements to the tenderers. In some cases, it is due to the ventilation engineer being 'sold' on matters by over-enthusiastic or even unscrupulous fan salespeople, or due to poor technical assessment of fan offers.

THE PROCESS

For a successful major fan installation, it is important to understand the process on four levels:

1. understanding the limits of the mine design process
2. understanding how to specify the fan requirements
3. understanding the role of the fan supplier
4. understanding how to correctly assess (adjudicate) fan tenders.

The fan duties (the single most important criteria for a fan installation) are developed from a ventilation model or models which in turn comes from a mine design and schedule. It is important to understand the limits and uncertainties of the mine design and the schedule. Any design needs to be 'stress tested' and also risk assessed to ensure potential flaws or shortcomings are understood especially with respect to the impacts on the primary ventilation and the fan duties. Whilst it may be tempting to add in a margin of 'fat' in the fan duties in terms of pressure or volume (or both) to cover contingencies, this can easily be overdone, resulting in a fan that is far larger and more expensive to buy and to operate than needs to be the case.

In terms of mine fan specification and evaluation, there is already some excellent work available, eg Stachulak and Mackinnon, 2001. However, this paper provides additional information and looks at the process specifically from the perspective of achieving success via a 'turnkey' project, which is different to most earlier work where the ventilation engineer or the mine client has already made many of the key decisions in the supply (such as the type of fan and overall configuration etc). In a turnkey contract, the supplier (usually the fan manufacturer) provides not only the fan but also the electrics, the civil design (and usually the actual civil works), transport, assembly and commissioning, and he does this in the context of a more open set of specifications.

The key success factors in a turnkey project are getting the specification correct, adjudicating the tenders accurately, co-operating with and facilitating but otherwise 'getting out of the way' of the contractor during site works, performance testing the fans using not only the aerodynamic criteria but also the other critical specification issues, and all this needs to be backed up by a practical and robust warranty and financial guarantees by the supplier. There is usually a premium to pay for this type of contract over the 'theoretical' cost if the principal were to manage each of these tasks via separate contractors, but the risks to the mine in managing all these separate packages are substantial and in most cases, mining

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companies do not have the skill set, or the people with the time, to competently do this.

By contrast, a turnkey package covering mechanical, electrical and civil works generally offers clients a number of benefits such as:

- single line of responsibility for complete system (no issues of split responsibility)
- lower cost of project delivery, taking into account the cost of risk
- shorter delivery period
- greater reliability and service life of the installation.

Projects which have sourced electrical systems and civil works separately have had problems such as:

- Major disputes between contractors and client, most of which are associated with issues of split responsibility.
- Foundation problems on sites. Fan foundation stiffness and natural modes of vibration do affect fan rotating assembly critical speeds.
- In the case of using VVVF drives, there are complex vibration issues that arise mainly with axial fan blade vibration. This issue also depends on who manufactured the VS drive (VS drives are not all equal in this regard).
- Serious electrical problems on sites, eg operators find that they do not know what the safety and management systems for the fans need to be. In many cases this information is the fan manufacturer's proprietary knowledge and they will not provide this information to their own electrical competitors
- Delays in final commissioning (not uncommon to be in excess of 12 months).
- Reduced warranty periods due to delays in completion.
- Substantial additional rectification costs to the client

In summary, splitting responsibility for the success of a major turbo-mechanical, civil and electrical installation such as a large mine fan invites problems and subsequent disputation. In some cases, the dispute is never really resolved to anyone's satisfaction, and the mine owner usually 'wears' most of the downside by way of a de-rated fan or increased maintenance costs and downtime. Even if the installation itself goes well, if there are subsequent problems, the legal and 'moral' ability to enforce after-commissioning support (particularly after the warranty period is over) is much lower where a non-turnkey approach has been used and the responsibilities have been divided.

Finally, splitting responsibility for the job (such as to an overall EPCM from a third party EPCM contractor) is unlikely to save either time or money. One large Australian fan manufacturer found that appointing a third party to EPCM a fan supply and install is likely to have these additional negative effects:

- adding at least 25–40 per cent to the real cost of the fan project
- adding anything up to a year longer to project delivery
- overall supply not well integrated (at best), and generally end up being 'problem' sites
- EPCM Contractor has little or no interest in 'after sales' support.

Apart from these issues, the other very important benefit of a turnkey project is that it 'opens the field' to suppliers developing innovative solutions that would otherwise have never been considered by the principal whose experience of fan installations, and of current technological developments in turbo-machinery, is usually very limited. The reason freeing up the tenderers from excessively rigid and predefined solutions is so effective is because the suppliers have by far the best understanding of their product, so that assuming the specification is sound (and hence they also have a sound understanding of the client's performance requirements and constraints), then they are free to compete with one another in terms of quality, capital cost, operating cost, delivery etc

For this reason, the Australian preference (and certainly this author's preference) has been to use turnkey contracts for key ventilation infrastructure such as primary fans.

Understanding how to specify the fan requirements

For a successful turnkey project, the following general principles apply:

- The client needs a suitable project manager or 'champion' who has experience with turnkey contracts, and preferably with primary fan purchases using this system.
- Do not start off with more constraints than necessary, but ensure all absolutely fixed boundaries are provided. This means there must be very strong input and ownership of the specification by all the 'stakeholders' at the mine site *before* the tender documents are issued. However, the project manager must ensure that frivolous or unnecessary constraints are adjusted or eliminated.
- The objective in a good specification is to not close off 'innovative' offers but neither is it to be wasting tenderers' time (or the principal's time in evaluating) offers that do not meet the 'must comply' criteria.
- Give as much useful information to the tenderers as possible (the client's musts and wants) including the 'weighting' for the criteria that will be used for the adjudication on the 'wants', noting to the tenderers that these criteria and weightings are not binding on the principal as once the adjudication process starts, it may become apparent to the principal that the weightings need to be adjusted or new criteria added or original ones changed in value. But with good preparation, the amount of such changes should be minimal. Providing the adjudication criteria and weightings to the tenderers will significantly help them target their offer or offers and will also make it much easier to compare offers within and between tenderers.
- Give any new information to *all* tenderers during the adjudication so they *all* have the same info. It is unethical and may even be illegal to provide information selectively to the tenderers.
- *However*, questions relating to a particular tender can go to just that tender, providing no new information or advantage is given to that tenderer over the others. For example, this may be important where, to do otherwise, might jeopardise some innovative aspect of a tenderer's offer by disclosing it to other tenderers.

Some of the essential information that needs to be in the specification includes:

- A very clear understanding of the location (reference plane) at which the fan duty applies and the duty itself. In most cases, for surface fans this will be the collar total pressure (CTP), collar airflow and density.
- The resistance curve for the fan (for surface exhaust fans, the collar total pressure versus flow). This is particularly important if the fan is in 'competition' (parallel) with other fans, eg multiple surface exhaust fans, even if these are on different shafts.

- A clear understanding of the *essential* features for the offer to be 'complying'. Apart from these truly 'essential features', the specification should otherwise take a minimalist approach to further demands. In addition, non-complying offers should be invited in the sense that they may present clever or innovative opportunities. Any such offers should be strictly protected from disclosure to other tenderers.
- For most fans, the duty will change over the life of the fan, so that it is appropriate to give several fan duties (eg duty A, B and C).
- Whether the fan can be a single fan or must be twin (or trifurcation etc) fans. In general, if the mine will be severely affected by a ventilation shaft going offline (other than by power failure), then multiple parallel fans should be specified. Power failure is excluded as this will take the entire fan installation offline, whether it is a single or multiple fan. If there are multiple primary ventilation shafts so that other useful activities can be done underground with an entire ventilation shaft 'offline', then a single fan is *usually* more appropriate, being quicker to build, cheaper to operate and maintain, with higher efficiency and with lower running costs.
- The site power cost, both kW/hr and also the 'capital charge' for each additional MW of power.
- The life-of-mine, as this has a significant bearing on the 'appropriate' mix between capital and operating costs in terms of assessing the lowest lifetime ownership cost (or 'net present cost') of the installation. Where the fan has several duties, then the tenderer should be told that the fan will have (say) three years at duty A, then 13 years at duty B, and then two years at duty C, so that he can understand the relative importance of each duty
- A clear understanding of the 'battery limits' of the scope of supply and the nature of the contract.
- It is of no use to simply specify the national or international *in situ* fan test codes that will be applicable to any performance tests. It is equally important to also nominate the specific manufacturing tolerances and measurement uncertainties that will be applicable to the site performance tests.

The principal's responsibilities

Correctly specifying the fan and then evaluating the tenders is clearly the responsibility of the principal. However, the principal must then remain responsible for their choice of supplier and, ipso factor, the actual choice of fan. For example, if the principal chooses the cheapest option disregarding the potential risk of excessive corrosion or erosion on the fan blades then the cost of that decision must be borne by the principal.

Another current problem is where VOD systems are being purchased by the principal from third parties and primary fans retrofitted with variable speed drives as part of that VOD installation. These fixed speed fans may never have been designed for VOD operation, and certainly no design checks performed for anything other than the synchronous motor speed. There may be major impacts on rotor dynamic issues such as half critical speed resonance or foundation resonance.

Finally, items such as providing clear and realistic details of the space available for the fan and associated works, including during installation, can be critical. For example, primary fan installations may require 130 t (or larger) cranes for installation of the fan and ductwork. Laydown area is also important, preferably close to the fan to avoid double-handling.

Understanding the role of the fan supplier in the overall process

Fans are not the simple electro-mechanical devices they may appear to be, and this is a particularly difficult misconception to overcome when a purchaser has had a lot of experience with *small* fans and now gets involved in the purchase of *large* fan installations. With small fans, the required expertise for the foundations, controls and installation are negligible. It is therefore important that the fan manufacturer (and designer) has experience with the size of fans being tendered.

Small fans have an advantage in the following areas:

- They involve low levels of energy and this limits what can go wrong (vibration, mechanical failure, aerodynamic problems associated with surge and to a lesser extent stall).
- The small rotating assemblies are dynamically very stiff because they are physically small. This generally eliminates the risks of high cycle/low stress failures, and also makes it virtually impossible to get into trouble with VVVF drives.
- Bearing design is a simple task.
- Fan support stiffness requirements are minimal and generally difficult to get wrong as the rotating masses are low.

Large fans present the opposite of all of the above points. There are examples in Australia where major fan commissioning problems and underperformance due to some of the above factors have cost the mine owners hundreds of millions of dollars in lost production and wasted capital investment.

The larger fan manufacturers (who actually design their own fans) have highly specialised skills and experience in at least the following fields: fan design, system aerodynamics, stress analysis, fluid mechanics (eg CFD), rotor dynamics, foundation design, local and environmental acoustics (including site modelling), fracture mechanics and fatigue.

Smaller fan suppliers often have few if any of these critical technical skills, or must outsource them, or do not have the financial resources to rectify defects or service warranty issues.

This is not to say that smaller fan suppliers cannot do a satisfactory job, but the purchaser needs to be aware of the extra risk when using a smaller supplier especially on large fans and especially in remote regions.

Most of the major fan manufacturers are not too concerned with being involved in the installation of smaller fans, say up to about 250 kW; they prefer a supply-only contract for small fans. However, above this size a turnkey project is preferred by most fan suppliers as it reduces their problems interacting with other contractors and will provide a better and more reliable solution for the client and protecting everyone's reputation.

In some cases, the fan manufacturer may not be willing to offer a full turnkey project, in which case the client can engage an EPCM contractor or a fan supplier and EPCM contractor may jointly tender for the works. As noted earlier, this is a less desirable outcome than a full turnkey contract but may be necessary in certain circumstances (eg fan installation in a third world country). However, even in these cases, it may be possible for the fan supplier to be introduced by the principal to a list of 'recommended' contractors already on-site who have the necessary personnel, equipment, approvals/licences and skills (eg civils, electrical installation).

Alternatively, the fan supplier may be willing to offer a turnkey project in which he does the design and supply of all the works, and then puts his own supervisors on-site to supervisor construction of the civils and installation, ie supply all the mechanical and electrical equipment and then to supervise the mine operator's own construction workforce. The fan supplier continues to offer full performance and completion warranties in this case.

At the very least, all civil and electrical designs completed by third parties *must* be checked and endorsed by the fan supplier (usually at extra cost).

Most of the major fan suppliers prefer for the electrical works to be pre-installed and pretested prior to arriving on-site, frequently with all the main electrical and control equipment (Switchgear, MCC, PLC etc) in a switchroom which is fabricated and fitted out prior to transporting to the fan site.

This author would strongly recommend that any client *not* wanting the fan supplier to take on a turnkey role should at least have a formally appointed representative of the fan manufacturer based on-site from the commencement of the civil works through to completion of commissioning, at extra cost.

Fan adjudication

Fan adjudication must cover the following process and carefully and fairly assess at least the following:

- ensure that the potential contractors have the financial capacity to undertake the Works and support any potential Warranty liabilities
- identify any technical issues and clarify with tenderers
- identify any missing information and obtain from tenderers
- ensure fan offers will meet the required fan duties
- assess power consumption and fan efficiency
- compare all other critical items in the specification
- input fan curves into the Ventsim model on which the specified fan duties were based and ensure fans will meet the required flow
- capital and operating costs
- delivery, ie whether the fan offered can meet the required operational dates
- other commercial factors, eg conditions relating to insurances, payments, liquidated damages
- supplier risks, eg the ability of the tenderer to build the fan to the quality required, to meet the performance requirements, within the correct time frame, and to remain solvent during the process
- develop a fair and unbiased evaluation template and assess all key criteria in terms of weighting and score
- provide a confidential formal written report for management review.

In most cases, such an assessment requires a multiskilled team from the principal, eg mechanical, electrical, instrumentation, safety, environment, commercial, as well as the ventilation engineer.

As noted earlier, the impartial technical assessment of fan tenders is not only essential in terms of purchasing the most appropriate fan for a particular situation, but also to ensuring the integrity of the tendering process, which encourages competitive tenders and innovation, and rewards the very considerable cost and time spent by tenderers preparing tenders. In addition, all reputable organisations have strict rules regarding the commercial confidence of tender information and appropriate and inappropriate communication with tenderers. Any person involved in the assessment process, or with access to tender information, should ensure they are aware of such requirements and strictly observe them.

A possible template outline (which will vary with the specification) for tender evaluations is shown in Table 1. In this case, the fan specification called for the fan to meet three different duties (duties A, B and C).

SPECIFIC ISSUES WARRANTING FURTHER DISCUSSION

Instrumentation

The more expensive or more critical the fan, the more important it is for it to be well instrumented. For primary fans, it would be normal practice for all key fan instrumentation to be telemetered back to a central control room. There are often statutory requirements in terms of fan monitoring as well. Most critical fans are also under PLC control which, with variable speed drive, allows the use of soft start and/or damper control.

Key parameters should not only be monitored but also available as trends, as it is often the trends that are more important than the absolute values at any point in time.

For a low powered 'basic' surface fan, minimum instrumentation would include: on/off local indication, motor amps, motor bearing vibration protection and possibly motor winding temperature protection. There may be no remote monitoring or remote control.

Typical alarm annunciation provided for a major surface fan would be as follows:

- motor overload (amps)
- main fan shaft bearing over-temperature
- motor windings over-temperature
- motor bearing over-temperature
- motor and fan bearing vibration monitoring
- electrical cabinet over-temperature
- impeller speed (for variable speed drives)
- air flow
- fan static pressure (or static pressure at the fan inlet or outlet, which is not the same).

In coalmines it is frequent practice to install a differential pressure switch inside the shaft elbow or collar to detect falling system pressure, as would occur during a fan failure. Activation of this switch trips all underground power and avoids the situation whereby the surface fan could be re-started with the underground power still live, possibly triggering a methane explosion due to a build-up of methane in the workings while the surface fan is off.

Warranty

Tenderers should be pushed, if necessary, to offer a warranty that is 24 months from handover, or 30 months from delivery to site, whichever is the earlier.

Liquidated damages

Liquidated damages are important especially in a turnkey project. A typical requirement would be one per cent per week to maximum of five per cent.

TABLE 1

Potential adjudication criteria for a major primary fan installation.

Criteria	Comments
Type of installation (main [complying] offer)	A check that at least one offer from that tenderer is 'complying'.
Alternative offers	Discussion of alternatives and why the tenderer has offered these. Do they have sufficient merit to warrant further consideration, even though they are 'non-complying'.
Diameter of fans, number of blades per impeller	In general, fully bladed impellers are the most efficient.
Assumed shaft internal diameter at collar	This is a critically important check.
Blade type, materials	Are these suitable for the environment in terms of corrosion and erosion.
Hub type, materials	Are these suitable for the environment in terms of corrosion and erosion.
Tip clearance	Smaller clearances generally mean more efficient fans, especially for axial fans.
Hub Φ and ratio	
Blade adjustment	This is important if the blade angle is likely to need to be changed over the life of the installation (eg if the blade angle is different for duties A, B, C etc).
Steel thickness of casing, rotor track (axial fans) and other steelwork	The rotor track should be stiffer and thicker than the main fan casing. Thicker casing also has a longer life in corrosive or erosive environments. Arguably the best system is for the rotor track to be independent to the main fan casing and without welded supports to avoid concentricity issues. Machined rotor tracks (impeller casings) are preferred.
Evasé length × outlet Φ, internal fairing?	This should be reflected in the total pressure loss in the evasé .
Height of fan above collar	An important factor for craneage.
Weight of fan above collar	An important factor for craneage.
Fan efficiency at duties A, B, C (based on collar total pressure (CTP) and shaft power)	
Impeller shaft power, duty A, B, C [kW]	
Motor ingress protection (IP rating), size [kW], voltage, mains frequency (Hz), poles, rev/min (sync speed and speed range)	
Motor and impeller mounting	
Basis of recommended curve and Rev/min	Why has the manufacturer recommended this particular curve and Rev/min.
Motor margin at highest powered duty point	Too low will reduce motor life; too high may result in less efficient motor and higher power costs.
Motor margin at highest powered duty curve and motor Rev/min	A check that the motor could not be overloaded at the duty curve. Not as relevant for variable speed fans, as the PLC can be programmed to reduce Rev/min. For non-variable speed fans, the only option for the PLC can be to trip the fan to protect the motor.
Stall margin (as a per cent of duty pressure and system resistance) *on duty curve*	The ratio of the peak (stall) pressure to the duty pressure for the duty fan curve and Rev/min. This stall margin identifies the increase in system resistance that the fan can sustain without changing either the blade angle or the speed, ie within its normal working limits and operation and with no disruption or downtime. Note that as a fan moves up its curve, its flow reduces, so that a fan could have only a ten per cent margin to stall on pressure, but this will be a larger margin to stall on resistance. However, an excessive margin will mean an unnecessarily expensive fan, oversized motor, and inefficient in terms of power consumption.
Stall margin (as a per cent of duty pressure and system resistance), for *any combination of blade angle and Rev/min*	The ratio of the peak (stall) pressure to the duty pressure for the fan at any combination of blade angle and speed (within the motor and system limits). This margin identifies the increase in resistance that would render the fan completely unsuitable and unusable for the application at that duty, *even at lower flows and even with changes to blade angle and Rev/min*. In the case of blade angle changes or Rev/min, this may require downtime for the adjustment. This stall margin identifies the increase in resistance that would render the fan completely unsuitable and unusable for the application, *even at lower flows and even with changes to blade angle and Rev/min*. Some discretion is required in selecting this peak value, ie the fan must still produce some practical useful volume and must still have some practical useful range over its fan curve. Note that as a fan moves up its curve, its flow reduces, so that a fan could have only a 10 per cent margin to stall on pressure, but this will be a larger margin to stall on resistance. However, an excessive margin will mean an unnecessarily expensive fan, oversized motor, and inefficient power.
Volume margin between duty flow and maximum flow for this curve	The additional volume available if the system resistance is overestimated. This is the maximum flow on the duty curve less the duty. In general, higher values mean more volume flexibility.
Efficiency margin on power	The extra shaft power required to operate the fan if the system resistance is overestimated or underestimated by a nominal 50 per cent. This is a measure of the ability of the fan to retain high efficiencies away from the duty point. Smaller positive and negative values mean the efficiency loss at the fan moves off its duty resistance is less, and hence lower values are better.

TABLE 1 CONT ...

Criteria	Comments
Ability to start fan against backpressure from system resistance	Margin between the 'dip' in stall zone and the operating duty pressures. This can be important in terms of understanding whether an isolation damper is essential, or whether special precautions or procedures will be required to start the fan and, in some cases, may render certain fan selections unworkable.
Rev/min at the various fan duties	In general, for a given hub and casing diameter, slower impeller speed means less aggressive blade angles (axial fans) and less blade wear (all fans).
Blade angle at the various fan duties	
Damper (isolation doors): none, manual, powered, self-closing	Does the operation need the damper to close when power is lost? If so, how is this achieved?
Brake (including ability to hold impeller at maximum motor torque)	
Electrical interlocks on damper and access doors	
Motor electrical, vibration and temperature protection	
Motor protection from rain/weather	A physical description of the method this is achieved. For 'tropicalised' motors or motor enclosures, a full description of the actual manufacturing differences compared to standard motors.
Flow and pressure monitors	
Complexity of civils and fan tenderer involvement	
External lighting on fans	
Lightning protection	
Corrosion protection	
Fasteners materials	
Ability to handle blast overpressures eg mass blasts adjacent to exhaust shafts	
Reverseability (if needed)	Some regulators require fans to be reversible. This is problematic for both axial and centrifugal fans, but much more so for centrifugal fans where major ducting systems will be required.
Blast relief doors (if needed)	Some regulators require blast relief doors to be provided, on the basis that quickly re-establishing the primary ventilation after an underground explosion is vital. An authoritative source should be used for the design (eg USBM).
Recommended spare parts to be held on-site (including cost and storage requirements)	
Any special trade skills required to maintain the fans, including motor or impeller changeouts	
Any special tools or equipment (eg size of mobile cranes) required to maintain the fan, including motor or impeller changeouts	
Warranty	The activation date for the warranty needs to be clearly established. In most cases, this is straightforward (the date the 'care, custody and control' of the operational fan moves from the fan supplier to the customer). However, in some cases, the warranty may expire before the fan is built (eg if the client purchases the fan ex works and then takes a long time to get the fan built and operating).
Performance/ acceptance test clause	See also warranty above. The performance testing procedure and equipment, and the acceptable criteria must be clearly and unambiguously set out and must coverall possibilities. As an example, refer to Brake (2013). A factory test is useful in establishing the fan curve but an *in situ* field test, sometimes combined with a factory test, to establish all the various above collar losses or system effects, is essential.
Purchase cost for base offer exclusive of site costs and others	
Electrical power consumption incl step-down transformer losses (depending on where electrical battery limits are)	
Power cost per annum	
Net present cost ('Discounted lifetime ownership costs')	
Supply from (where are the various parts of the fan and electrics coming from)	
Delivery schedule compliance	
Defect rectification requirements or Liquidated damages for non-compliance with performance testing or commissioning schedule	
Technical support ability and location of technical support, including time zone or language issues?	
Ability to support local language during commissioning, training or subsequently?	

Retention monies

It is common for the principal to require a certain portion of the contract value (five per cent to ten per cent) to be held back until 'Practical completion' and in some cases, some retention monies until the warranty and defects liability period is complete.

Specific issues for smaller fans (eg auxiliary fans)

Smaller fans tend to be 'off the shelf' items and therefore the 'system effects' that always need to be taken into account for any fan are the responsibility of the purchaser moreso than the supplier.

The following are essential information that needs to be supplied and carefully checked:

- make and model of fan/impeller and date curve produced
- whether tested to ISO5801 or not
- intake air density
- fan outlet diameter on which curve is based
- where the curve is being offered as representing the fan that is on offer to a prospective purchaser, then the fan curve should match the offer, or any differences between the fan curve and the offer must be clearly pointed out, eg the standard curves should be adjusted for any inlet or outlet pieces used in the fan test (eg inlet cone, screen, silencer, duct adaptor), or which are not in the fan test but which are part of the proposed supply
- impeller Rev/min (note: where the fan is sold with a motor in it, then the curve Rev/min should be the motor Rev/min)
- FTP versus flow from the stall point to the wide-open (nil resistance) point, ie over the entire operating range of the fan, and not just the portion of the curve excluding the low pressure/low efficiency zone (mine fans often need to operate in this zone!)
- fan shaft power versus flow (and motor electrical absorbed power versus flow where motor is sold with the fan)
- where noise levels are shown, they must match the configuration of the rest of the fan (eg without or without silencers)
- noise levels should be shown as SPL dB(A) based on a nominated distance (eg 400 m) and context from the fan, although there is an alternative view that noise should be based on SWL values back-calculated from SPL measurements at (say) 400 m, which minimises the problems of taking SPL measurements close to a 'large body emitter'. The principal needs to ensure any comparison between tenders is valid, and also reflects their actual noise criteria on-site
- either on the fan curve or in the GA, the following data should also be noted
  - motor IP rating
  - motor ambient operating temperature rating
  - blade materials and construction (cambered plate, aerofoil casting etc)
  - blade adjustment (non-adjustable, adjustable at standstill etc).

CONCLUSIONS

It is possible to consistently obtain a very successful and long-life fan installation every time providing a certain process is followed by the client, the fan installation is carefully specified (but not over-specified), tenders are properly assessed, the criteria and weightings are fair and unbiased, and the award is made to a supplier with the necessary experience and skills. By contrast, there are many primary fan installations around mines today that are unsuitable or unreliable or involved excessive capital or operating cost.

In almost all cases, the best result for a new fan installation (or major refurbishment) will be obtained where the fan supplier is awarded a 'turnkey' type of contract, with very explicit and quantifiable performance and acceptance criteria, backed up by a solid (preferably 24 month) warranty, and suitable financial penalties and retention monies.

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