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Axial Flow Mine Fans

Introduction

The development, design, manufacture and support of fan systems for use in mines has a history of more than 100 years at TLT-Turbo GmbH and former companies such as Dingler, BSH, Babcock, TURM-AG, Turma, and KK&K.

More than 100 such systems are currently in service worldwide in various mining regions. While originally fans used in these applications were mostly of the centrifugal type, single and dual stage variable-pitch axial flow units are preferred today. Since fans are vital for underground mining operations, longevity and maximum reliability are critical requirements. As in other areas of technology, specific terms and concepts are used in the mining industry. These shall be described in the following text.

Terminology

In the context of pit fans the volume flow is referred to as **"ventilating current"** while the pressure increase is termed **"fan depression"**. This latter term reflects the fact that pit fans, also respectfully called ventilators, mostly operate on the upcast ventilating shaft or "uptake", drawing in air through the downcast shaft and extracting it through the mine. The inevitable underpressure upstream of the fan is the "depression"; this parameter corresponds to the total pressure increase produced by the fan system (including diffuser, silencer and leakage losses). VDI 2044 refers to this total pressure increase as Δp fa, where "fa" stands for "free outlet". The system's operating characteristic or airflow resistance curve is referred to as the "mine width", denoted by A_{Grub}. This term is defined as follows:

$$A_{Grub} = 1{,}19^{*} \frac{\dot{V}}{\sqrt{\Delta p}}$$

where V is the (volumetric) air flow in m^3/s and Δp is the pressure difference in Pa.

Components

The main part of a mine fan with integrated hub motor is sometimes designated its "active part". The fan is connected to the uptake via the fan drift, with interposition of the fan drift shutters. The latter term refers to an open/close-type damper organ designed so that none of its elements will remain in the duct in the open state. Upstream of the fan we have the measuring section or "inlet gallery" used for airflow and depression measurements; it also ensures a favourable air supply to the first fan stage. The "outlet section" downstream of the fan comprises a deflection elbow, the diffuser and, sometimes, a silencer. The fan is driven by a main motor. If the motor is built into the hub (i.e., integrated into the active part), the impellers are fitted directly on the motor shaft. In this case the motor bearing assemblies must be rated specifically for the resulting loads. In conventional designs the fan is driven by a tubular shaft passing through the deflection elbow, i.e., the motor is fitted outside of the airflow. Accordingly, the fan has its own shaft and

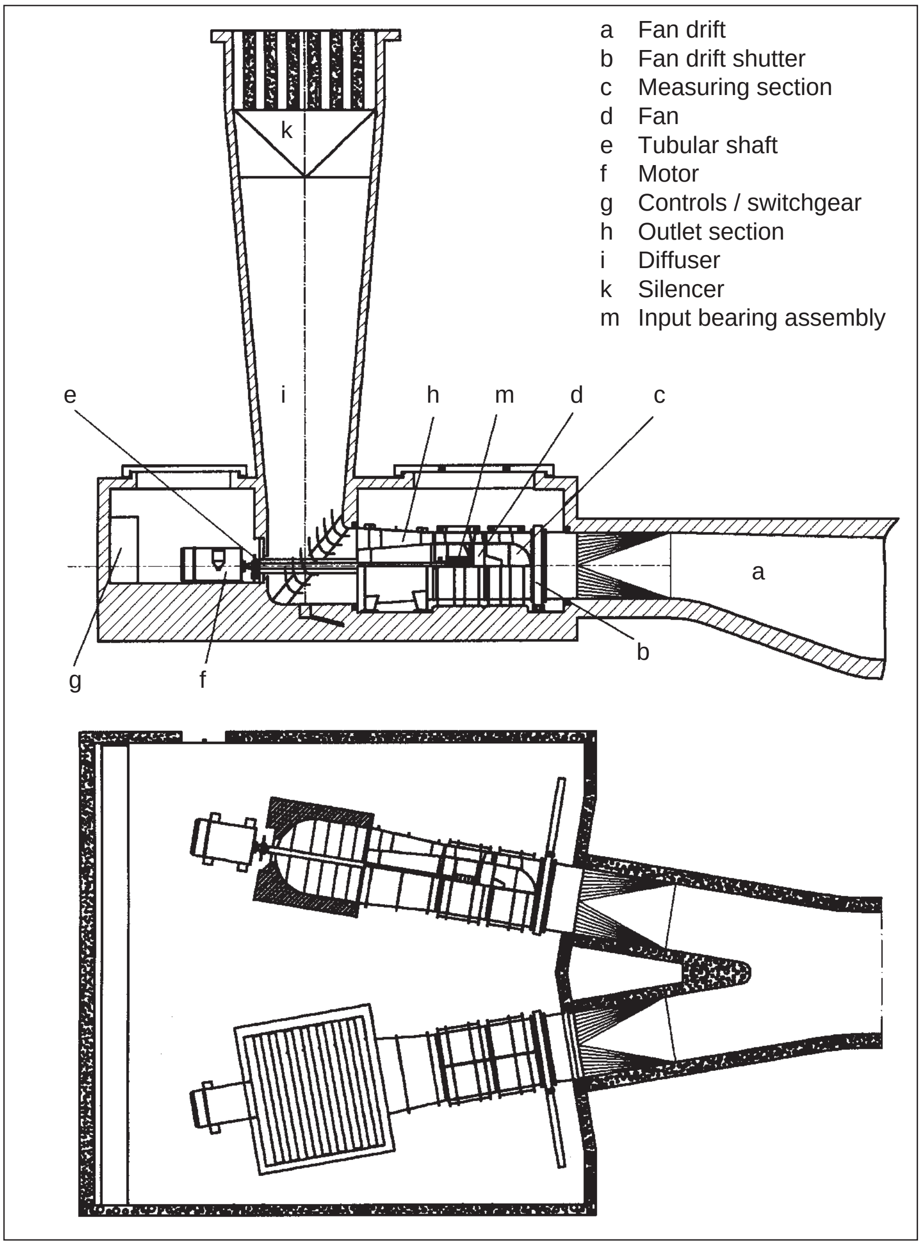

Fig. 1: Main fan system in a conventional configuration with two parallel fans

input bearing. The fan system further includes the control and monitoring equipment, the high-voltage installation, and the fan house with noise insulation and lightning protection, door, gates, windows, banisters, ventilation, drain system, and cranes.

Particularities

In Germany, pit fans are subject to the supervision of the Mines Inspectorates of the relevant federal Land. Depending on the mine, each fan system must meet particular requirements, e.g., concerning spare equipment, safety regulations for explosive gas-air mixtures, and reversibility (Fig. 1).

For collieries, a 100% spare equipment availability is stipulated. For cost reasons this requirement is met by installing systems with "replaceable active parts", i.e., expensive components such as the fan drift, fan drift doors, outlet section, diffuser and silencer are provided only once whereas two "active parts" are kept on site. The active part comprises rolling gear, a lifting device and two clearance seals for connection to the stationary system. One active part is mounted in its operating position, its duplicate remains on hand in standby position "A". Failure of an active part causes it to be automatically transferred to standby position "B" while the spare active assembly is moved into the operating position. The control system ensures that this entire process, including start-up and acceleration to the airflow setpoint, takes place automatically. Fans with replaceable active parts exist both in vertical and horizontal configurations.

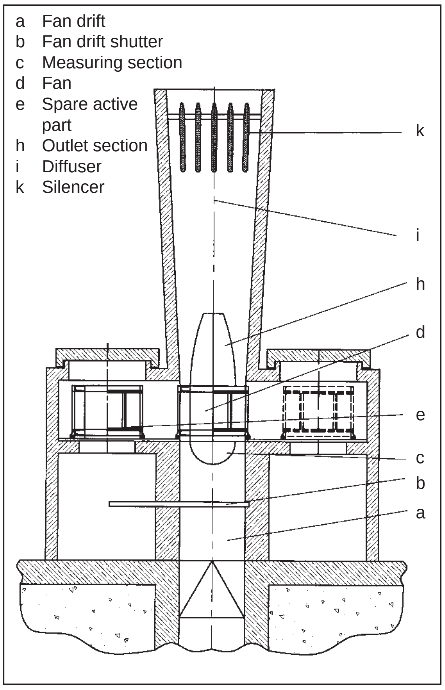

Fig. 2: Main fan system with changeover-type active parts in a vertical configuration with hub motors

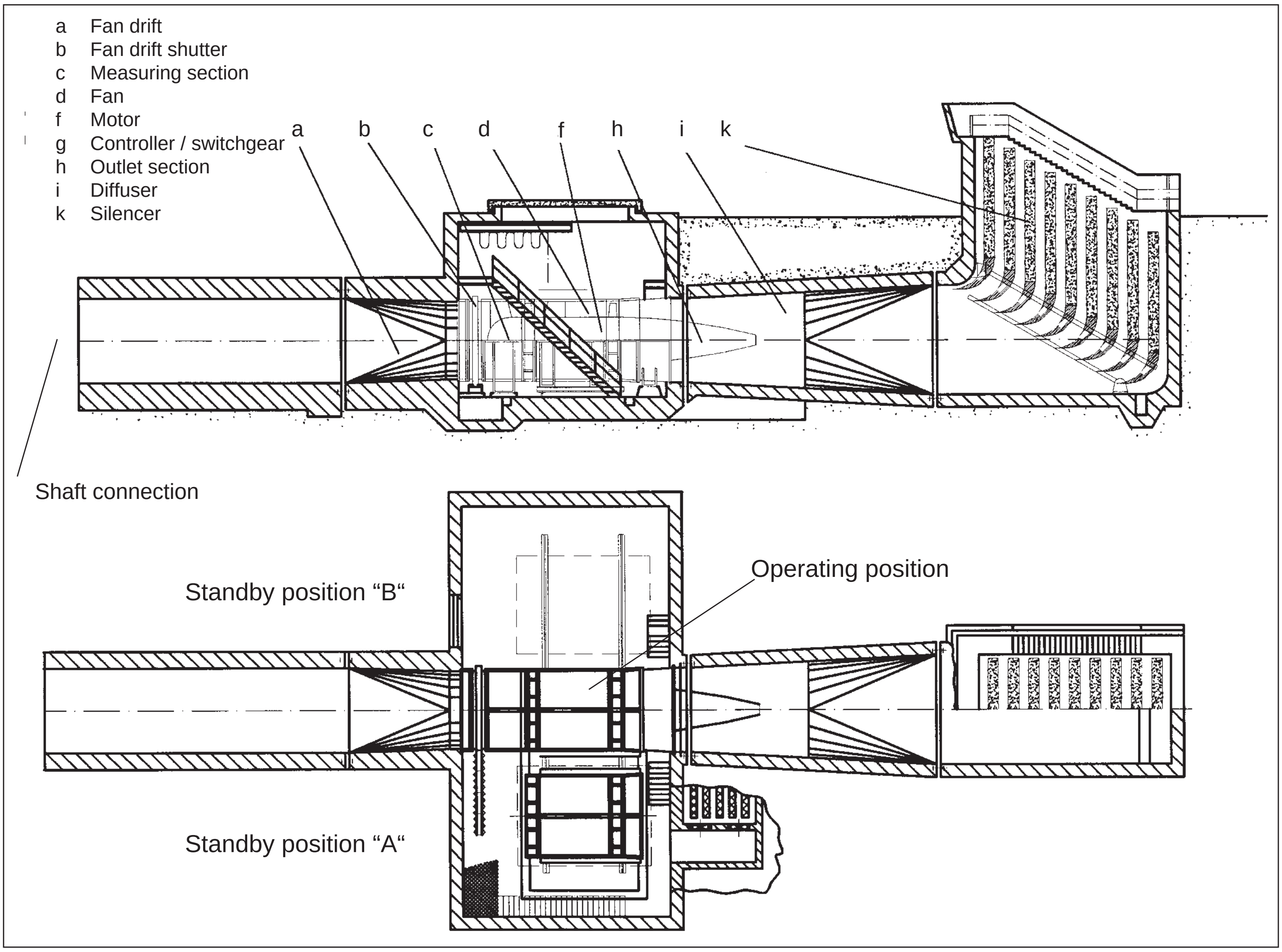

Fig. 3: Below-floor main fan system

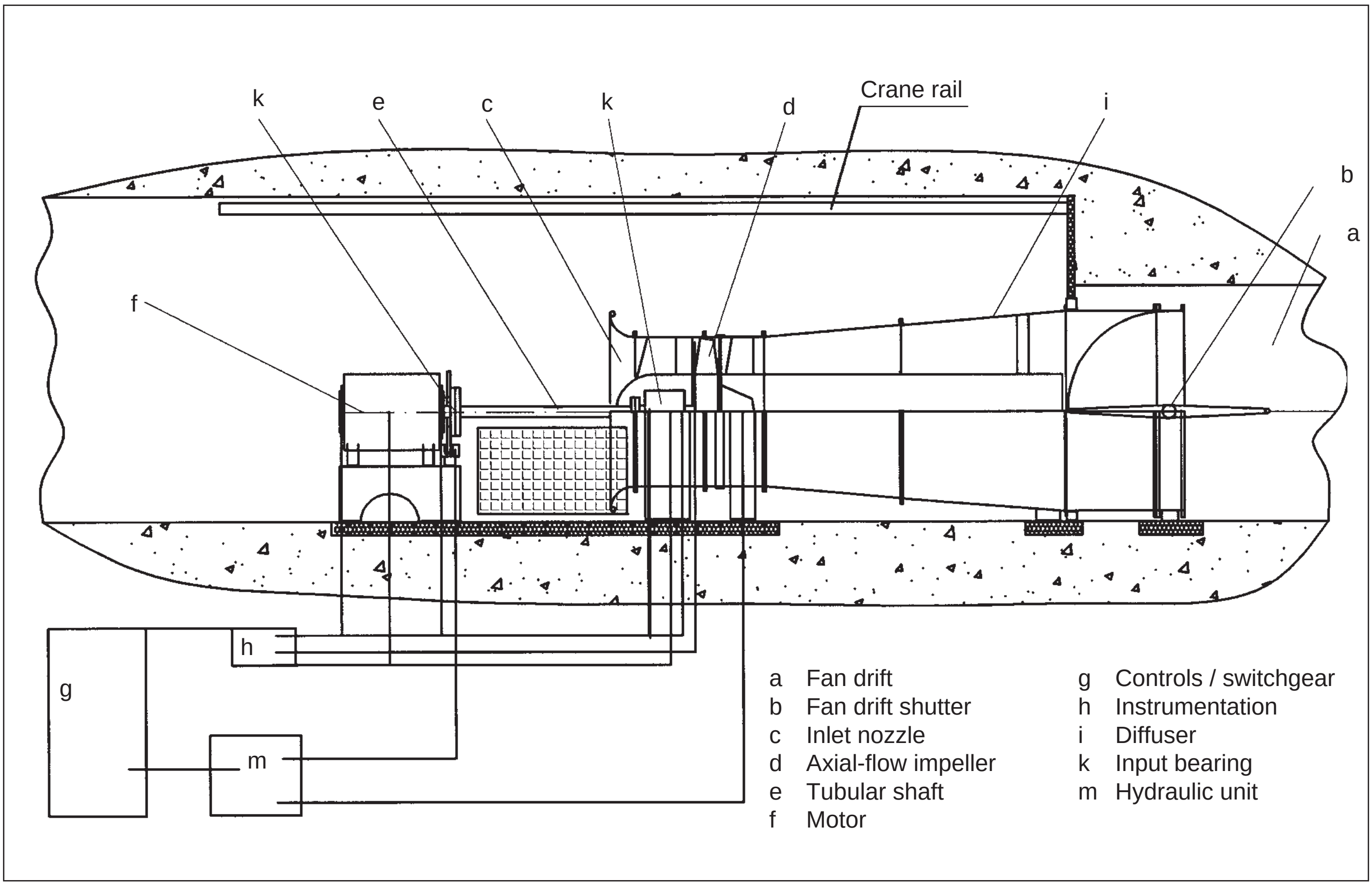

Fig. 4: Underground pit fan

Vertical type with built-in motor

Vertical fans with built-in motor (Fig. 2) are particularly advantageous where space is at a premium. The fan drift shutter is of horizontal design. The replaceable active part requires a square floor area for its travelling frame which must be slightly larger than the impeller's circular surface area. This yields a very low-cost design and a highly rigid running gear. The support surface on the inlet side of the active part functions like a seal, thus requiring only one clearance seal on the outlet side. The built-in motors draw cold ambient air from around the active part and pass their exhaust air into the airflow. On fans mounted in a closed room, which may become necessary for noise control, the air temperature inside this room is monitored and controlled by an air handling system. The fan motor bearing is rated to accommodate the unit's own weight as well as the axial (thrust) forces emitted by the rotor. The travelling frame carries the hydraulic unit which supplies the pressure for the transfer movement, the clearance seal and the blade pitch adjustment. Power supply cables and monitoring wires are routed to the active part via a chain-type dynamic cable carrier system.

Horizontal type with built-in motor

The horizontal fan design with built-in motor (Fig. 3) is particularly suitable for below-floor installation. In this configuration the active fan assemblies are connected to the stationary parts via clearance seals on the inlet and outlet side. The built-in motors have one or two shaft ends, depending on whether the machine is single or dual-stage. For dual-stage fans the shaft must be hollow to accommodate the blade pitch adjusting mechanism and synchronizing linkage. The motor bearing is rated for the radial loads exerted by the impeller weight and for the axial thrust load. This rating has a critical impact on service life and must be verified for the entire range of the characteristic curve. Since active part ambient air is used for motor cooling, the room temperature is monitored and controlled via an air handling system. Measuring section and fan drift shutter are arranged upstream of the active part. For systems of this type, the use of shutters with horizontal shutter blade movement is suggested. These shutters have no weight impact and can be fitted in the fan house without extra effort.

Underground pit fan (Fig. 4)

In pits carrying no explosive gas-air mixtures (e.g., potassium or ore mines), fans are usually installed directly in the air-way. These units are typically driven from the inlet side via a tubular or cardan shaft. Damping is ensured by a shutter at the diffuser end. To prevent the fan from running backwards when the motor is stationary and the air current reverses, an automatically actuated brake is provided. A compartment wall must be

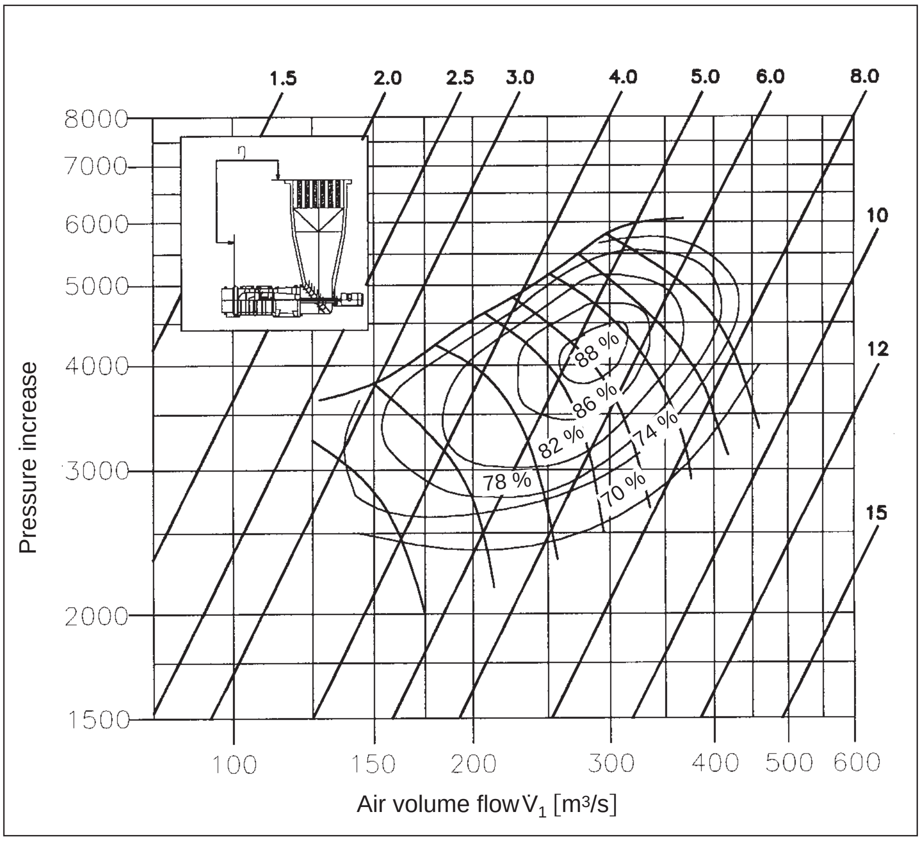

fig. 5: Typical characteristic curves of an axialflow underground pit fan with blade pitch adjustment under load

erected between the fan inlet and outlet side. Ideally, it should be attached to the shutter flange. The compartment wall should be provided with an air lock to provide access to the fan from all sides.

15 Characteristic curves (Fig. 5)

Fan performance characteristics are determined as a function of efficiency at the operating point, stall limit, and motor output limit. TLT selects the appropriate family of characteristic curves for each application, relying on a range of blade designs measured under test-rig conditions. Contrary to normal ventilating systems, the system airflow resistance in mining (“mine width”) changes over the life of the pit as it continues to be worked. In selecting the fan’s performance characteristic, the development of the underground workings must therefore be taken into account. This requires data concerning the volume flows and pressure levels required over a given time span. Mine fans are rated such that their performance maps extend over wide volume flow and pressure ranges. Fan speeds (rpm) are selected in a way to allow fans to be directly driven by means of available motors. Gear transmissions are avoided, given the associated losses. The airflow needed at a given time is produced by setting the blade pitch angle accordingly. Mine fans are typically designed with on-line blade pitch adjustment today. The ability to change the blade setting while the fan is running not only permits a continuous throughput adjustment but also reduces motor start-up cycles and the associated high loads, given that the fans can be started with closed blades (small blade angles).

Accessories

Specific measuring equipment used on mine fans include the following:

- Pressure measuring devices
- Volume measuring sensors
- Vibration monitoring technology
- Stall limit monitoring systems

Control system

The operation of mine fans requires a control and monitoring capability. The control and monitoring system comprises all manual and automatic control pushbuttons and switches. In many cases a changeover to remote mode is implemented allowing fan operation and monitoring from a central control facility (pit control center). Advanced systems comprise on-screen visualization and control features.

The control and monitoring system encompasses the readings from all accessory devices, bearing and winding temperatures, blade settings, shutter positions, brake status, and all hydraulic and auxiliary functions. The core of the system is a PLC with appropriate software.

Before lodging an enquiry for mine fans, the following specification data should be determined:

a) General ambient and mining conditions

Pit name and operator
Type of resource extracted (coal, copper, etc.)
Geographic location, longitude/latitude, site name
Height above sea level in m
Annual temperatures in °C
Air humidity in %
Susceptibility to seismic activity (Richter scale)
Other conditions
Responsible Mines Inspectorate
Site map

b) General mine air data

Density in kg/m^3
Temperatures in °C
Humidity in %
Dust load in mg/m^3
Explosion hazard (hazardous duty requirement)
Special conditions (corrosion, caking)
Operator's standards/regulations

c) Operating data

Is the pressure loss across the fan drift known? Alternatively, state the depression at the fan drift end, just upstream of the fan drift shutter.

Indicate the following for various mine working periods, stating period duration in years:

Ventilation current in m^3/s
Depression at shaft head or upstream of fan (in Pa)
Operating modes: summer/winter, volume flow / pressure
Operating modes: weeks/weekends, volume flow / pressure
Reverse fan operation, volume flow / pressure
Existence of transient interferences, e.g., due to hoisting cage operation

d) Noise level specifications

Inside the fan building
On fan building
At a distance of x meters from the fan building
In the shaft house, at shaft head

Measured as sound pressure level in dB(A).

Are there any other noise sources to be taken into account?

d) Design / type

Is the fan intended for surface, below-floor or underground (pit) duty?
Upright or horizontal diffuser arrangement?
Drive motor on outlet side, acting via tubular shaft passing through the diffuser
Drive motor on inlet side, acting via tubular shaft passing through the fan drift
Drive motor on inlet side standing before the fan.
Drive motor built into the fan hub.
Fan drift, deflection elbow and diffuser material: concrete or steel

e) Electrical system

Main drive motor

Squirrel-cage type
Slipring type
Synchronous type (phase-shifter)

Control and monitoring system

Medium voltage (V / Hz)
Control voltage (V d.c. or a.c.)
Specific hardware or software
Local control system
Visualization

High-voltage system

High voltage (kV / Hz)
System short-circuit power (MVA)
Separate networks?
Interfacing

f) Accessories

Instrumentation

Pressure measurement
Volume flow measurement
Vibration measurement
Stall limit monitoring (Petermann probe)
Bearing status measurement (SPM)

Room ventilation system

h) Items to be provided by customer / interfaces