DESIGN CONSIDERATIONS FOR A DUST EXTRACTION SYSTEM

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As the design of a dust extraction system is based on airflow principles, Ewart van Geuns argues that environmental staff should be integrally involved in designing, tendering, commissioning, and maintaining the systems. The paper covers the practicalities and considerations involved when designing a dust extraction system.

Introduction

On a mine and its related works some environmental aspects are neglected during environmental control work. The reason for this could be that environmental control has recently been used more and more in the different types of surface plants that fall under the Mines and Works Act. Some examples of surface plants are various refineries, surface dump treatment plants, etc. Many very sophisticated extraction plants are installed in these plants and, after commissioning, are left to Engineering Departments to be maintained. If these systems are not monitored for pressures and quantities by trained staff, preferably with environmental backgrounds, on a routine basis, they can eventually function very inefficiently, for example, loss of extraction at fume hoods can cause a health risk to the workers. The Engineering Departments usually do not have a basic understanding of the principles of airflow, and I feel that it is essential that environmental departments be involved in:

- the design of extraction systems by liaising between Engineering, Production and Project departments;
- the tender for the complete system — hoods, ducting and equipment control;
- tender adjudication; and
- liaising with the equipment suppliers and finally commissioning installed equipment by informing the Mine Management with an acceptance test report.

Although the above might appear to be very complicated, the design of a dust extraction system is all based on airflow principles.

I will try to give a very brief description of how to design an extraction system. There are many excellent references available should more information be required.

Design of a dust extraction system

Proper hood design

This requires sufficient knowledge of the process or operation so that the most effective hood or enclosure can be installed to provide minimum exhaust volumes for effective contaminant control. The more complete the enclosure, the more economical and effective the installation will be. The main criterion is to have the smallest possible air ingress opening that will still be acceptable to the worker in doing his daily work. Obviously the size of the dust particles, toxicity of contaminant, and temperature will also influence the design of the hood.

The next step is to decide which cleaning device is to be installed. They are available in a wide range of designs to meet variations in air cleaning requirements. The degree of removal required, quantity and characteristics of the contaminant to be removed, and conditions of the air or gas stream will all have a bearing on the collector.

Then finally, but probably a very important aspect often neglected, is that fire safety and explosion control should be considered.

Selection of dust collection equipment

Dust collection equipment is available in numerous designs, utilising a number of principles and featuring a wide variation in effectiveness, capital cost, operating and maintenance costs, and space requirements. Usually the equipment manufacturers are consulted as they have experience of the most suitable dust collector or dust filter plant that should be installed.

Factors influencing equipment selection include the following.

(1) Concentration and particle size of contaminant.

(2) Degree of collection required. For example valuable material would require very efficient control equipment.

(3) Characteristics of air or the gas stream. For example is it wet and is the temperature above or below dew point?

(4) Characteristics of contaminant such as the toxicity, shape, hygioscopic, etc.

(5) Energy requirements.

(6) Method of dust disposal.

(7) Design procedure for the rest of the system which would include duct work, fan type, size and stack.

Duct-work size and route

Calculations discussed below are essential to determine the duct sizes and the total exhaust system pressure loss, which with the total air volume to be exhausted, would determine the fan duty, as well as its speed and motor power required.

(1) Obtain a layout drawing, preferably drawn to scale, showing positions of equipment, etc.

(2) Draw a line diagram which would include elevations of the complete system (including position of fan, collector and stack).

(3) Draw a rough sketch of each hood, with direction of airflow, and the elevation of the outlet of the duct.

(4) Gather information as to the details of the operations and the toxicity of materials. Number the line diagram branches and the sections of the main line, etc., for convenience of calculation.

Factors influencing hood design are the size of the dust particles, toxicity of particles and temperature

Design procedure

The type of system, calculation method as well as any corrections for temperature, moisture and elevation must be determined.

- *Type of system*

a) Balanced without blast gates (dampers), or tapered.

b) Balanced with dampers.

c) Plenum type system.

The choice of the system depends on the application, but factors that influence the type are listed below.

(a) Dampers are open to abuse.

(b) A 'tapered' system air volume cannot easily be changed.

(c) Cleaning of plenum.

(d) Future requirements.

(e) Is the system installed as per design?

(f) Contaminant to be conveyed — is it a dust, gas, or both?

- *Calculation Method to be used*

Either the Equivalent Pressure or Velocity Pressure method can be used. I normally prefer the Velocity Pressure method, as it makes more sense and recalculation of branch duct sizes for a balanced exhaust system design becomes easier.

The method is based on the fact that all losses in ducts, hoods and bends are directly proportional to total pressure losses, determined by obtaining fractions of the prevailing velocity pressure inside the system.

Calculations.

All systems, no matter how complex, have hoods and ducts that lead to a fan. A complex system consists of many simple exhaust systems leading to a main duct and then to a fan. In designing, start at the hood, proceed down stream to the fan, and finally to the atmosphere.

Design as follows.

(1) Select the hood best suitable for the operation.

(2) Determine the air volume (hood) and minimum hood air velocity.

The minimum conveying velocity is obtained from charts in most air pollution textbooks. Calculate the minimum branch duct size, then use the standard size that is closest to the required size, which is easily obtainable from duct manufacturers.

To calculate the total pressure losses across the system, always start at the branch with the anticipated highest resistance, which is in most cases the longest duct. In a multiple branch system, it is necessary to provide a means for distributing air flow, either by a pressure-balanced system, or by dampers. The reason for this is that air will always take the path of least resistance. If the design does not provide for proper distribution, a natural balance of the air will occur, that is, the exhaust volume will distribute itself automatically according to the resistance of the available flow paths. To provide distribution that will result in the design airflow quantities at each hood, make sure that all ducts entering a junction will have equal static pressure at design flow.

Equipment manufacturers have the experience to advise on the most suitable dust collector or filter plant that should be installed

Typical work sheets consist of:

(1) a detailed line diagram, numbered in logical order, e.g. each hood having a number whilst the branches have letters;

(2) details of operation where the dust creating process is described, with hood number (related to line diagram) and the air quantity required; and

(3) then a tabulated sheet with the following information: number of branch or main duct, minimum air quantity required, straight run in metres, elbows and entries.

The previously mentioned data should then be transferred to the calculation sheet which is drawn up in a logical, orderly and concise way.

First calculate the total pressure across the longest branch, the hood, duct, air cleaner and stack. This is the total static pressure of the system and the fan will operate at this pressure.

After the main branch is calculated, the resistance of each branch is calculated, based on design data, and totalled for the length running from exhaust hood to the junction of the next branch. At each junction the static pressure for each parallel path of airflow must be the same. Where the ratio of the higher static pressure over the lower one is greater than 20%, the branch with the lower pressure loss should be re-designed to increase its pressure drop. A normal method is to decrease the pipe size, thereby increasing the static pressure loss on that run. Where pressure losses of parallel paths are within 20% of the governing static pressure, a balance can be obtained by increasing the airflow through the run with the lower resistance.

$$\text{Corrected Q } (m^3/s) = \text{Design Q } (m^3/s)\sqrt{\frac{\text{SP run with higher SP loss}}{\text{SP run with lower SP loss}}}$$

where SP = static pressure.

Where the balance is < 5%, treat as balanced.

The Velocity Pressure Method of calculation assumes that all losses in ducts, hoods and bends are directly proportional to total pressure losses

Corrections that should be made are as follows.

(1) If friction loss charts are used, correct for the K factor or roughness correction factor.

(2) The shape of duct is a factor for consideration. Round and rectangular ducts have different pressure losses. Round ducts are preferred as they are stronger.

• *Corrections for temperature, moisture and elevations*

Fan tables, exhaust volume requirements, and resistance charts assume standard atmospheric conditions (based on a density of 1,2 kg/m^3). A fan connected to a system will exhaust the same volume of air, regardless of density. Where corrections have to be applied due to high temperatures or elevation above sea level then:

(1) increase the exhaust air volume by the reciprocal of the density, to keep the same mass flow as those for standard volumes moving into the hood to prevent dust escaping. Size the branch and main ducts, calculate pressure losses and select fans as if the corrected volumes were for standard air. This procedure will arrive at the correct size of fan. Power and pressure losses will decrease directly as the density factor; and

(2) moisture corrections should also be made if steam-saturated air is handled.

Evasees are often used to improve fan performance.

If the collected material could pose an air pollution problem when leakage occurs, the discharge of the fan stack should be 1,3 to 2,0 times the height of the adjacent roof to ensure that the contaminants do not enter the other side of the building. Often a stack height as specified by the Department of Health and Welfare has to be adhered to.

Fans

Aspects to be considered before a fan is chosen are given below.

- Volume required.
- Fan static pressure required.

Always start calculations at the branch with the anticipated highest resistance when determining total pressure losses across the system

- Contaminant to be handled, for example a radial bladed fan is usually chosen for a very heavy dust load. In most cases the fan used is a backward curved centrifugal fan fitted with a belt drive.
- Temperature of material to be handled. If very hot then an injector type fan, or bearing cooling should be considered.
- Where the air is corrosive, then the fan should either be rubber lined on the inside or stainless steel should be used.
- Noise and space limitations.
- Efficiency — always choose the fan running at the operating duty using the least electric power.
- If the fan is operating in an explosive area, then use an explosion proof motor.

Guidelines on the construction of extraction systems

- The duct material is very important as a duct cannot only corrode on the inside if corrosive gases are handled, but if the system is not operating as per design, then the stack outlet gases, mixed with rain and wind, can corrode the outside of the duct.
- Round ducts are always stronger than rectangular ducts for a given mass.
- Temperature is also a very important aspect when the type of duct material to be used is selected.
- Dampers should not be positioned where a dust build-up can make them ineffective.
- Dust can settle out in ducts. Clean-out openings should be considered along the pipe line.
- If abrasive materials are handled, elbows, and such

like should be of the heavy duty concrete re-inforced types.

- Elbows should always have long radius bends.

Testing of the installed extraction system

The following areas and aspects could be monitored in the system.

- Stack outlet concentrations.
- Efficiency of the air cleaning equipment.
- Determination of whether the system is operating per design.
- As the system has to be balanced, dampers have to be set requiring various pressure and air quantity measurements.
- Establishing if system can be altered at a later date.

The above factors require suitable static pressure connections, velocity pressure tappings and source sampling ports.

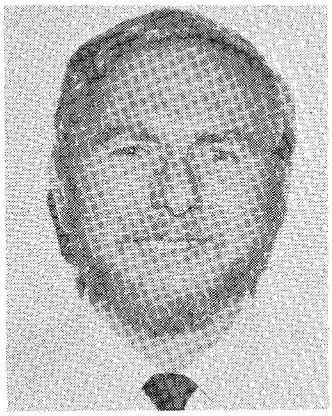
Conclusions

This paper discusses very briefly the various aspects of exhaust system design and, if more information is required, then the reader should refer to any of the following publications:

- **Design of Industrial Ventilation Systems** — Alden/Kane.
- **Air Pollution Engineering Manual** — US — EPA.
- **Industrial Ventilation** — ACGIH.
- **Plant and Process Ventilation** — Hameon.

THE AUTHOR

Ewart van Geuns started his career in Mine Environmental Control in 1968 at Grootvlei Gold Mine. He obtained the Certificate in Environmental Control in October 1977 and was appointed Environmental Officer at Impala Platinum Refineries. Ewart was employed by Haggie Rand Ltd from 1983 in the Group Environmental Control Section of the Medical Services Department. At present he is employed by the Gencor Group Environmental Control Department as a Sectional Environmental Control Officer, seconded to Haggie Rand Ltd.



Ewart van Geuns

HISTORY OF THE MINE VENTILATION SOCIETY

A History of the Mine Ventilation Society is currently being written and members are urgently requested to submit any material or photographs which could add human interest to the document. Old letters, photographs of the pioneering members, memories of amusing situations, and accounts of reactions to new developments in technology or to issues which had a major impact on the Society and the profession of environmental engineering would be very much appreciated.

As a guide, the document will be about nine or ten chapters, each about four pages in length. The chapters will each cover a time span of approximately five years and will consist of the events which had a major impact on the profession and mining in general; the society's response to the event; and the people who played prominent roles.

All contributions should be sent to:
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