VENTILATION of MINES
INTRODUCTION

BUILDING SERVICES ENGINEERING

A Review of Its Development

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4.4.4 *Ventilation of mines*

Excavation of the oldest underground mines so far discovered (*ca.* 1400 B.C.), in the Negev desert of Israel has revealed that the copper miners, apparently Egyptians, were enabled to breathe freely underground at depths of more than 100 m by ventilation "air channels" of about 75 mm diameter (*Sunday Times*, 8th December 1974).

It has been noted that the metal mines in Saxony were ventilated by bellows and fans in the 16th century. The pollution in coal mines was more considerable, and more copious supplies of air had to be provided. Agricola, in the same century, used a fire to induce air movement.[4] Hinsley notes that at first, fire baskets were placed at the top of the upcast shaft, usually with a chimney to increase the draught.[29] This arrangement used a great deal of fuel, and better results were obtained by putting the furnace at the bottom of the shaft.

In 1727, Dr Desaguliers designed a machine for the Earl of Westmoreland to clear a mine of foul air. It consisted of a triple iron crank a foot long, working three copper-barrelled pumps of 18 in (450 mm) internal diameter, which, by means of three regulators, were alternately applied to force air into a space, and extract it through trunks or pipes 250 mm square. One man was able to discharge 17 m^3/h. It does not seem to have made much impression — probably for lack of engines to drive it — and ventilation by fire remained the common method.[8]

John Duddle Jr. (1773-1843) was an acknowledged authority on mine ventilation at the time; he introduced the "dumb drift" whereby the dangerous gases bypassed the furnace. The pressure developed by the furnace depended on the depth of the shaft, and even in the deepest mines, pressures greater than 600 Pa were difficult to achieve. Buddle in 1810 was able to reduce the resistence to air flow by his "Double or Compound Ventilation" — the workings were arranged in two parallel air circuits. In 1818 he introduced the "panel" system which consisted of working the mine as a number of separate districts. This opened the way for split ventilation. i.e. the use of several parallel air circuits, and much greater air quantities could be induced by a single furnace.[29]

From about the middle of the 19th century, the advantages of mechanical ventilation were realised. The furnace was inefficient in shallow mines, and although thought to be more reliable than mechanical power, J. J. Atkinson showed in 1858 that the latter had economic advantages. His first paper in 1855 was almost a complete thesis of ventilation theory of the time, and dealt with friction in airways, generation of air currents and flow in networks. At the time, there was little accurate data on air resistance, and Atkinson's calculations never appeared to give results of practical value. Hinsley notes that the use of steam-driven fans, and larger airways, so improved the practice of ventilation that interest in the theory waned, and Atkinson's work was largely forgotten. Interest in the theoretical side did not revive in UK until the 1920's, with contributions from J. S. Haldane and Professor Douglas Hay.

Ventilating machines of diverse types were employed in the early years, including the Archimedean screw, centrifugal fans, positive displacement and reciprocating machines. Struve is said to have installed a dozen of his reciprocating machines in Wales, the largest being at Ruabon. It had pistons 7.6 m in diameter, and pumped 92000-100000 m^3/h at 800-1000 Pa.

A high-pressure steam jet was used at Orwell Colliery, Wigan to induce the flow of air through the workings. A 24-horsepower boiler delivered steam at 340 kPa through 12 jets pointing along a mine "road". These caused the air to move along the road to the base of the main upcast shaft and thence to atmosphere. The system was able to move 78000 m^3/h.(57)

In 1849 Brunton installed a centrifugal fan at Gelly Gaer Colliery, and James Nasmyth designed a double-inlet centrifugal fan for the Abercarn Colliery in 1834. The Guibal fan was introduced to Britain in 1860, and rapidly became popular because of its high efficiency (*ca.* 60%); by 1875, there were some 180 in use or being built. The consumption of coal for fan ventilation was between 3 and 7 kg/h per hp of ventilation, and compared with 18-20 kg/h per hp for a furnace.

Bagot, in his book on Colliery Ventilation of 1882, discusses both furnace and fan ventilation.(6) By that time, the Coal Mines Regulation Act of 1872 had required some form of ventilation in mines. Bagot calculated the air volume required as a function of the length of the coal face and the tonnage cut, and not on any measured CO content of the mine air. He made a particular point of limiting the air speed in the mine to 1.8 m/sec., as otherwise gas might be forced through the gauze of the Davy lamp. He also notes the importance of coal dust as a factor in explosions and insisted on adequate wetting.

From 1860 onwards, mechanical ventilation became increasingly used on account of its economy, safety and flexibility. Ventilation pressures were no longer limited to 50 or 80 Pa, but could be raised by speeding up the fan.

In more recent years, axial fans have been introduced (1930's). Modern versions use variable-pitch blades to give a wide operating range. Most of the main fans in British collieries are now of the aerofoil-bladed centrifugal type.

Ventilation surveys in existing mines, initiated by David and Davies in 1928, enabled experimental data on air flow to be obtained. Estimates could be made of the effect of any proposed change in the mine system. (Mines are not static, and the ventilation arrangements have to be able to handle changes in the use and layout of the faces and airways.) The development of the Hardy-Cross method of solving network equations by successive approximation (1936), and of the electrical analogues a few years later, enabled accurate solutions to be quickly obtained.

4.5.5 *Mine fans*

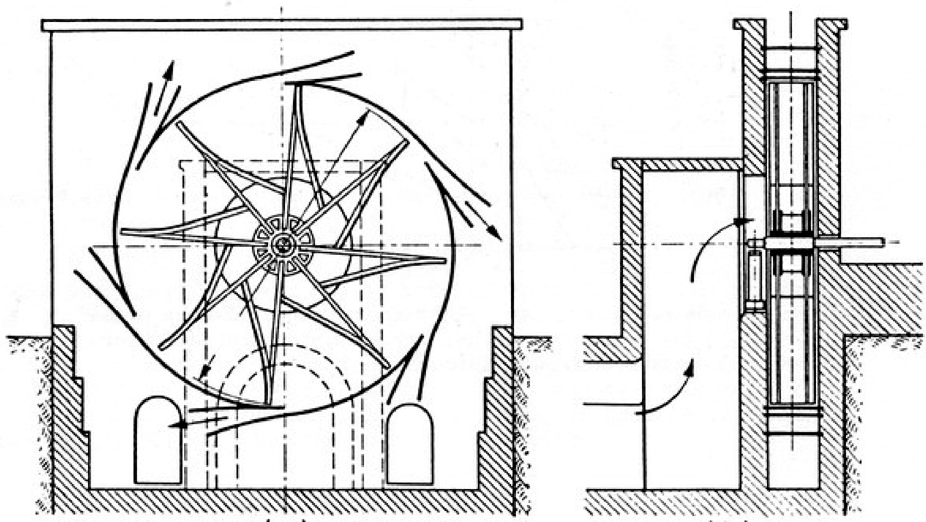
In the middle of the 19th century, fans were chiefly employed for mine ventilation, and only occasionally for the ventilation of buildings. In 1852 a committee of the House of Commons was set up to consider the methods of ventilating coal mines, and reported:

> "Your Committee are of the opinion that any system of ventilation dependant on complicated machinery is undesirable, since under any disarrangement or fracture of its parts, the ventilation is stopped or becomes inefficient; that the two systems which alone can be considered as rival powers are the furnace and the steam jet.
>
> Your Committee are unanimously of the opinion that the steam jet is the most powerful and at the same time least expensive method for the ventilation of mines."

This view was soon overturned. In 1861, the centrifugal fan at the colliery at Elsecar was described to the North of England Institute of Mining Engineers by J. J. Atkinson, who clearly showed for the first time the superiority of mechanical ventilation over every other system.[29]

The Capell fan was originally designed in 1883 for mine ventilation and continued in use for over 40 years. The wheel comprised a circular plate to which were attached a number (about 10) of "scoop" blades. These were forward curved at the inner radius and backward curved at the tip; in addition, the outer edge, adjacent to the inlet eye was turned in the direction of rotation (hence "scoop"). Between each pair of scoop blades, two narrower, forward-curved blades were fixed at the tip of the wheel.

Rateau designed a mine fan with the blades in a "somewhat inclined position" and projecting into the axial suction space. Another early design by Harzé, used for mine ventilation in Belgium, incorporated a volute casing with a number of discharge points (an idea subsequently adopted for aircraft engine superchargers) (Fig. 4.24).



(a) (b)

Fig. 4.24. Mine fan of Harzé with free-discharging partial diffusers.

Tests on several types of mine fan were carried out in 1892; these are reported by Innes. Other tests were made by Heenan and Gilbert (*Proc.ICE* Vol.123) to study fan design parameters, and by Bryan Donkin (*Proc.ICE* Vol.122) and others.

For sheer size, some of the early mine fans have not been equalled. The change from slow-speed steam engine drive to electric motor drive resulted in the development of smaller-diameter, high-speed rotors.

Daniel Murgues, engineer to the Colliery Company of Besseges, developed the first satisfactory theory of fan operation, published in 1872, and showed that simple plane radial blades were not compatible with high efficiency. He proposed the use of blades which are tangential to the air flow at the root and radial at the tip. These were in effect forward-curved blades. Kinealy (*ca.* 1904) mentioned that in one fan designed at about that time, the idea of using curved blades was carried to such an extent that the blade extended round one quarter of the fan wheel.

On this point, Kinealy says that all the fans employing curved blades were designed so that the blades were radial at the root and were given a backward curve at the tip. He goes on:

> "this is rather curious in the face of the fact that theoretical considerations indicate that the floats (blades) should be tangent to the radius at the periphery of the wheel and that at the inlet they should make an angle of about 45° with the radius."

The Guibal "chimney" or discharge tube was invented and applied to centrifugal fans in 1860 (Fig. 4.20). This device was a venturi, continuing the scroll at the point of delivery to form a trumpet-shaped expander. By its use, some of the kinetic energy of the air leaving the fan was converted to pressure energy, so increasing the pressure developed by the machine.

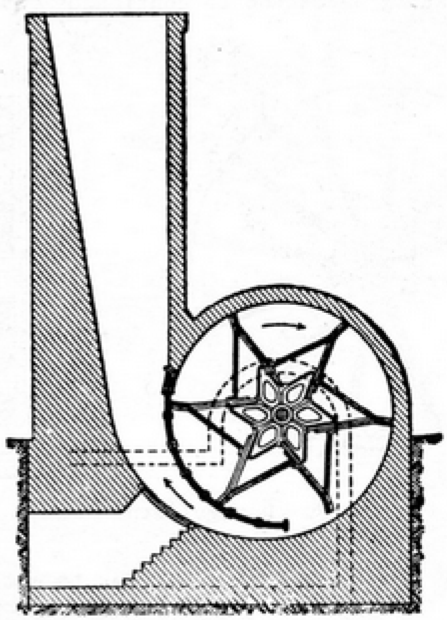


Fig. 4.20. Guibal fan and chimney.