Ventilating the English Channel Tunnel

A unique ventilation system design ensures a supply of fresh air to 95 miles (150 km) of tunnels

By Terence M. Dodge Member ASHRAE

he idea of a fixed link (a tunnel) between France and England was first proposed in 1751 by the French Armiens Academy when they launched a competition to find a "better means of crossing the Channel?"

The first tunnelling commenced in 1880. However, it was halted in 1882 due to a reluctant British government fearing a continental invasion.

In 1974, tunnelling started again on both sides of the channel. However, it was abandoned in 1975 due to a change of British government and the economic malaise of the day.

In 1978, interest was raised when European contractors formed a consortium to resurrect the tunnel. Several other

About the author

Terence M. Dodge is the managing director of Raxcrest Project Management Ltd., Birmingham, England. He graduated from the London National College of Heating, Ventilating, Air Conditioning and Refrigeration. Dodge acted as project manager with ABB Flakt for the design, procurement and installation of the Channel Tunnel ventilation system up to its final installation and commissioning stage, which was completed in January 1993. groups also put proposals together and, in 1982, French and British governments requested feasibility studies into privately funding the massive undertaking from the banking institutions.

In March 1983, agreement for a tunnel was reached and a consortium of five French and British contractors formed to put forward proposals for the fixed link.

In October 1985, formal submissions were made. In February 1986, an Anglo-French treaty was signed and a concession was granted to Eurotunnel in March 1986 for a 55-year operating contract.

The contractors' formal signing of the contract with Eurotunnel occurred in August 1986. This was followed in July 1987 by Her Majesty The Queen assenting to the Channel Tunnel Bill becoming The Channel Tunnel Act.

Under the terms of the contract, the contractors are responsible for the design, construction and commissioning of the full integrated transportation system. This includes modifications to the infrastructure to accommodate terminals in each country, integrating with road and rail transportation systems as well as the tunnelling.

Tunnel description

The tunnel system connects Sangatte, France, to Folkestone in Kent, England. Accordingly, the Channel Tunnel is the largest civil engineering project incorporating the longest tunnels the world has ever seen.

The underground system consists of three tunnels: north- and south-running tunnels of 7.6 m (25 ft) internal diameter; and, between them, a service tunnel of 4.8 m (16 ft) internal diameter (see *Figure 1*). The north tunnel takes shuttles and trains from England to France, and the south tunnel from France to England.

At 375 m (1,230 ft) intervals, all three tunnels are linked by 3.3 m (11 ft) internal diameter cross-passages. At 250 m (820 ft) intervals, the two running tunnels are linked with a 2.0 m (6.5 ft) internal diameter piston relief duct (see Figure 1).

The service tunnel is used to provide fresh air to the running tunnels, as a safety refuge in case of incidents within the running tunnels, and for access for emergency services and maintenance personnel. It also contains electrical and mechanical services, control rooms and pumping stations.

Boring and lining the tunnels commenced in March 1988 and formed 150 km (95 miles) of tunnels. The tunnelling produced 8,000,000 m³ (282,000,000 ft³) of spoil in the form of liquid mud. This was pumped to settlement retention lagoons.

The spoil on the English site was used to form 45 hectares (111 acres) of reclaimed land at the foot of Shakespeare Cliff, Dover. When construction is completed, this land will form a public amenity area.

Cooling/ventilation systems

The environmental services provided to the Channel Tunnel consist of the cooling and ventilation systems.

The cooling system consists of a refrigeration plant with dry coolers for heat rejection at each end of the tunnel complex. This plant provides cooled water to feed a pipework circulation system run into each of the tunnels.

Heat transfer is by conduction into the pipework. Each cooling system and its pipework run to the mid-point of the tunnels.

The ventilation system consists of a normal ventilating system (NVS) and a supplementary ventilating system (SVS) at each end of the tunnels.

Each ventilating system consists of two fans in parallel housed in purpose-built fan stations. These fan stations are located at ground level and are connected via shafts to the tunnels. The exception is the English NVS which is installed vertically in a 9.25 m (30 ft) internal diameter shaft that is 23.5 m (77 ft) deep. The normal ventilating system (NVS) is connected direct to the service tunnel and provides fresh air through the crosspassages into the running tunnels. There the fresh air is dispersed by the piston effect of the trains and shuttle movements.

The piston effect causes both negative and positive air pressures within the running tunnels with shuttle movements. The piston relief ducts relieve the pressure by transferring air from one running tunnel (via the piston relief duct) into the adjacent running tunnel and then back to the shuttle running tunnel, again via the piston relief ducts (see Figure 2).

The supplementary ventilating system (SVS) is connected into both running tunnels. Under single-mode operation, fresh air can be provided to one or both running tunnels by the selection of control dampers. Under dual-mode operation, both running tunnels are provided with air.

The SVS is a separate emergency system and can be used to control smoke or supply emergency air within the tunnels. On both systems, the fans are normally run on supply mode, but they can also be used in the extraction mode.

Each fan is a axial flow fan, with sinsect and direction motors, fitted to which pitch aerofoil blades. This enables ar it to be reversed without stopping and eversing the motor.

Under normal control mode, only one but per station operates. However, both thus per station can be used for commissociate or maintenance under local manual control.

The NVS fans operate at a design point of $\$8.2 \text{ m}^3/\text{s}$ (187,000 cfm) with a seven pressure of 2.92 kPa (12 in. wg). They are fitted with 390 kW (525 hp) myors using 3.3 kV AC supply.

The SVS fans operate at a design point of 300 m³ s (635,700 cfm) with a system pressure of 1.52 kPa (6 in. wg). The fans are fitted with 900 kW (1,200 hp) motors using 3.3 kV AC supply.

When the fans are operated, it is essennal to cool their motors. This cooling is provided by a ducted cooling system taking firsh filtered air through a centrifugal fan, connecting to the main fan motors casing and exiting from the exhaust casing con-

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nection via ductwork to atmosphere outside the fan station.

On the NVS system only, an electric air heater battery system, with a rating of 1.2 MW (4,000,000 Btu/h), is installed to maintain temperature control of the tunnel ventilation air. With the large volume of air, the heater battery gives a $10 \,^{\circ}$ C ($18 \,^{\circ}$ F) rise over the battery.

Each electric heater battery consists of modules of smaller heater batteries. These are switched on and off by a thyrister control system fitted to one of the battery modules when deviation from the control setpoint occurs.

On a temperature fall, the thyrister module switches on and modulates up to 100% capacity output. If heat demand is still required, the thyristor switches on a fixed output module (with the thyrister controlled unit returning to zero output), whence the cycle recommences until all modules required are in operation. On rise of temperature, the control system acts in reverse manner.

Ventilation system operation

The principle of the NVS ventilation to the Channel Tunnel is relatively straightforward. However, the scale of operation and the fact that the running shuttles cause extreme pressure variations as they pass through the tunnels combine to create significant problems for most conventional ventilation systems.

The fan feeding the air supply into the Channel Tunnel complex would run at constant speed, volume and pressure if there were no shuttle movement. But with the movement, both volume and pressure will vary, and the system operating point will move up and down the fan performance curve.

With the computer control system, the Channel Tunnel fans adjust the fan blade pitch to continue supplying air at the required volume. If the pressure increases due to shuttle movement, then the system resistance will increase until the fan reaches its stall limit.

At that point, a conventional axial flow fan will start operating in an unstable mode and the volume and pressure output will fail. This situation will cause severe stress to occur in the fan and it may be damaged, causing a breakdown to the whole system.

However, with the Channel Tunnel fan system, this stalling problem has been

eliminated by the addition of special antistall rings. This unique ring-shaped stabilizing device is one of only a handful of its type in operation in the world. It is incorporated into the fan casing entry but located outside the main flow stream adjacent to the fan blade tips (see *Figure 3*). As system pressure increases to approach the fan stall point, air flow at the rotating fan blade tips is reversed as the stall progresses. This backflow rotates with the impeller and imposes a pre-rotation of the entering air, which also affects the blade roots causing severe stress in a conventional



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fan system. Once induced, this pre-swirl reduces air flow and the pressure capacity of the fan.

The introduction of the anti-stall ring eliminates the air flow reversal at blade tip by means of turning vanes incorporated into an annular chamber of the anti-stall ring. The air stream off the ring is returned into the main air stream in a completely axial sense. Therefore, the blade tip region still receives high axial flow vector and continues to support pressure generation, and the problem of backflow causing pre-swirl in the fan inlet is eliminated.

At certain times, shuttle movement will cause abnormal pressure resistance to occur within the Channel Tunnels, leading the fans to operate well beyond the system design pressure. However, the anti-stall system will prevent the tunnel fans from stalling and maintain air flow into the tunnels.

Ventilation control system

The tunnel ventilation system consists

of air intake louvres, air heater (NVS only) acoustic attenuators and isolating dampers to each side of the main fans, cooling system and an integrated control system linked to the principal engineering management system (EMS).

Each fan station has installed a control panel that can operate at three levels:

• Level 1 allows the control panel to operate the fan station automatically under normal operation, with monitoring and operating commands direct from the engineering management system operator located in the Channel Tunnel central control. The operating point of the fans is selected by the EMS operator using the programmable logic controller within the fan station panel which confirms back to the EMS when its commands are achieved.

• Level 2 allows operation from the fan station local control panel with the EMS only able to monitor the operations and functions carried out.

• Level 3 operation of equipment is again from the fan station but by keyboard

and displayed on a VDU. The system is totally separated from the EMS. Level 3 is used primarily for maintenance purposes.

The electrical power to the ventilation stations is provided from two independent grid supplies (one domestic, the other overseas), each connected to its own switch board. The primary supply is the domestic supply using the overseas supply for backup in case of failure.

The domestic primary supply to the fan station control system is fed through an uninterruptable power supply. The overseas supply is connected direct to the control system.

The domestic supply feeds the running fan system whilst the overseas supply runs the standby fan system. Should a failure occur in the running system, then the overseas supply to the standby system automatically takes over and the current running system closes down.

The overseas supply can be used to feed the running system by selection of the switchgear by the EMS operator.

Operational life of the ventilation system is designed for 25 years.



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