Mersey Tunnel (Queensway)

When the first Mersey Tunnel, linking Liverpool with Birkenhead, was opened for traffic in December 1933 (the official Royal opening was actually in July 1934), it incorporated the largest ventilation system that had ever been installed anywhere in the world. It was also the longest subaqueous road tunnel in the world (at 2 miles 251 yards for the continuous length of the main tunnel), a position it held until 1958 when the Kanmon Strait Tunnel, 200 metres longer, was built in Japan.

By the time the second Mersey Tunnel (Kingway), linking Liverpool with Wallasey, was completed in 1972 such tunnels had become fairly common and the world's present longest subaqueous tunnel, across Tokyo Bay, is almost three times as long as the Queensway Tunnel. The world's longest subterranean road tunnel, in Norway, which opened in 2000, is more than seven times as long. The ventilation requirements, per vehicle, are the same regardless of whether the tunnel is under the ground or under water, however, it is obviously more difficult to deal with the supply and exhaust systems when most of the tunnel is underwater.

History

By the middle of the 19th Century the whole of the Liverpool river frontage from Seaforth to Dingle had been developed as docks and consideration was then given to developing new docks on the Cheshire side of the river. The river was deeper there and Wallasey Pool already provided an inlet sheltered from the prevailing westerly winds. An extensive dock system was thus built between Birkenhead and Wallasey over a period of about 20 years from 1847 and in 1866 an Act was passed to allow a railway tunnel to be constructed under the river.

Consideration for a road crossing of the river had first appeared in 1825 but construction of the rail tunnel began in 1879 and it was completed by 1885. It was powered by steam locomotives but no provision was made for ventilation and less than 20 years later the line was electrified. However, the rail tunnel had been designed primarily to carry foot passengers and goods still had to be transported between Birkenhead and Liverpool by ferry.

By the 1920s the ferries were carrying 35 million passengers a year and the railway 10 million passengers. Any vehicular traffic had to use the ferries, however, at that time, there were a number of ferry terminals all along the Wirral coast. It was thus only a matter of time before some sort of permanent roadway was built linking the two sides of the river and in 1922 a Committee was formed with representatives of the four main boroughs, Liverpool, Birkenhead, Wallasey and Bootle. The Committee was chaired by Sir Archibald Salvidge, who appears to have been the driving force behind the proposal. Eventually it became apparent that the crossing would almost certainly link Liverpool and Birkenhead so Wallasey and Bootle dropped out.

A feasibility study was commissioned to consider the merits of a bridge against a tunnel and the engineers employed were required to project the likely costs of each. They reported that the cost of a bridge would be about £10.5m and of a tunnel would be about £6.5m, the tunnel was to have two roadways one above the other, with the lower roadway reserved exclusively for tramcars. One serious consideration at the time was that a tunnel would be more difficult to damage in time of war!

The first Mersey Tunnel Act in 1925 led to the formation of the Mersey Tunnel Joint Committee which represented the Corporations of Liverpool and Birkenhead. Under this Act the method of financing the project was laid down. The Government would pay half, the two Corporations would pay a quarter and the other quarter would be paid out of tolls collected over the first 20 years. Two more Acts followed in 1927 and 1928 because firstly the location of the Birkenhead entrance was changed and secondly the location of the Liverpool entrance was changed. The change in Birkenhead involved the demolition of Birkenhead Library and so there was extra cost because a new Library had to be built. At about this time the decision was taken that a tramway would not be installed but that the Tunnel would be constructed in such a way that a lower roadway could be built at a later time.

The last Mersey Tunnel Act of 1933 allowed for a dramatic increase in cost (about 40%) because it was decided to vastly increase the ventilation rates in the Tunnel following problems of motorists becoming overcome by fumes in road tunnels in the United States. The projection then was that it would be necessary to collect tolls for 40 years to pay back the debt. The Chairman of the Joint Committee, Sir Thomas White, was reported in the Sunday Express on 29th July 1934, *less than two weeks after the Official Opening,* as saying that with the toll collection averaging £800 per day 'the Tunnel will be toll-free much sooner than anyone dared to hope'. The saga of the tolls continues almost 75 years later!

The Tunnel as built is a circular tube with an internal diameter of 44 ft (13.5m) with the roadway 18 in (450 mm) below the centre. The roadway width is 36 ft (11.8m) to allow for a maintenance walkway either side. In the dock branches the internal diameter is 26 ft (7.9 m) but only the upper semi-circle has been excavated with a shallow invert below. In the main section of the Tunnel the roadway is supported by two intermediate walls 21 ft (6.3 m) apart creating quadrant sections either side which act as ventilation ducts.

Ventilation System

The Tunnel was always intended to have powered ventilation but when early discussions were taking place in 1922 and even when the first Mersey Tunnel Act was passed in 1925, there was virtually no experience anywhere of the ventilation of long road tunnels. The Hudson River Vehicular Tunnel in New York (later named the Holland Tunnel in memory of Clifford Milburn Holland the engineer who had designed it) was only opened to traffic in November 1927. It had been the world's first sub-aqueous road tunnel to have mechanically driven ventilation.

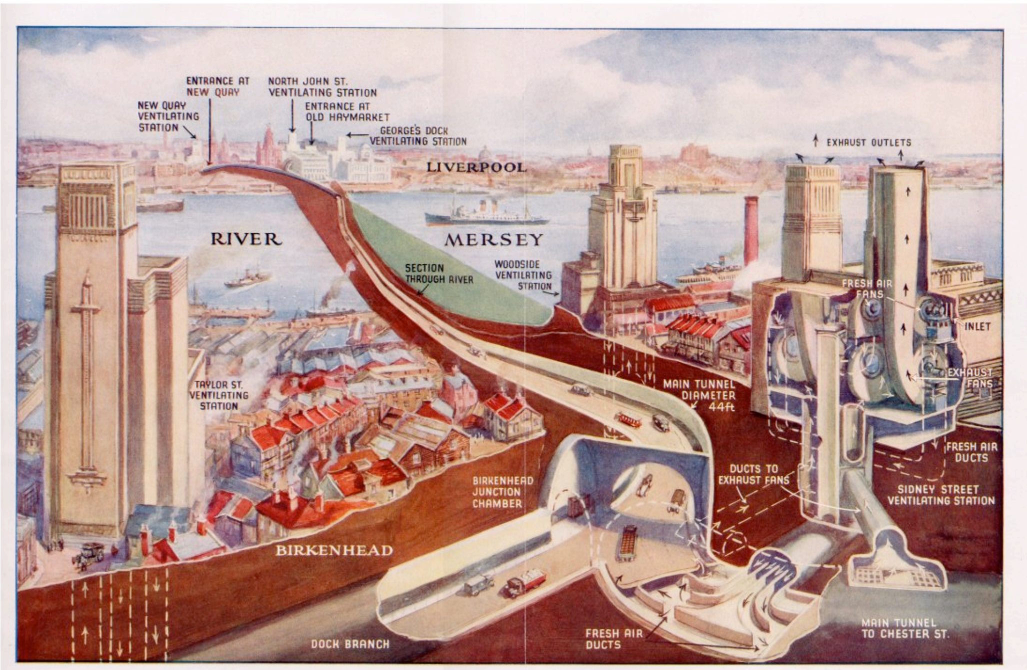
[It is widely believed that vehicle drivers had been overcome by fumes in the Holland Tunnel and that this had led to the demand for increased ventilation in the then proposed Mersey Tunnel causing a large cost increase. In fact it was the Liberty Tunnel under Mount Washington in Pittsburg, where drivers had actually passed out in Autumn 1930 when sitting in traffic, which caused a drastic rethink to the ventilation problem.]

The Holland Tunnel is actually a two tube tunnel and so the concentration of fumes is effectively halved and since all vehicles move in the same direction the air is effectively 'pushed' from one end to the other. Having two pairs of opposing lanes of traffic in the same tube, as in the Mersey Tunnel, creates a more severe pollution problem. The Mersey Tunnel was also to be almost half a mile longer than the longer of the tubes in the Holland Tunnel.

Research carried out as part of the design of the Holland Tunnel led to the recommendation that the concentration of Carbon Monoxide should not exceed 400 ppm*. The rate of ventilation to be provided in the Mersey Tunnel was thus reassessed and it was realised that much bigger ventilation buildings would be required. This explains why Herbert J. Rowse, one of the most prolific Liverpool architects of the 20th Century, was not appointed to design the ventilation buildings until February 1931, 3 years *after* the two pilot tunnels had met under the river.

**(The current ASHRAE recommendation, as of 1999, varies according to length of exposure time, it is 35 ppm for 60 minutes or 120 ppm for 15 minutes.)*

The ventilation system for the Tunnel is fairly straightforward but on an immense scale. When catering for dense traffic the rate of air movement is in the order of 2.5 million cubic feet per minute (about 1300 cubic metres per second). There are four ventilation stations for the main tunnel and one for each dock branch. The Birkenhead Dock Branch was closed soon after the opening of the Wallasey Tunnel and the Taylor Street Ventilation Station has been mothballed ever since. The under-river section of the tunnel is served by the Woodside Tower from Birkenhead and the Georges Dock Building from Liverpool. The land-based sections are served by the Sydney Street ventilation station in Birkenhead and the North John Street ventilation station in Liverpool.



Schematic diagram of the method of ventilation

The principle used for the ventilation of all sections is the same and is categorised as an Upward Semi-Transverse System. Fresh air is delivered from each ventilation station to the space underneath the roadway and the air is extracted from the roof of the Tunnel into the same ventilation station. For the roadway beneath the river the fresh air is delivered to the midpoint from Woodside Tower on the Birkenhead side and from Georges Dock Building on the Liverpool side, although there is no bulkhead under the roadway to stop the two airstreams mixing. The air is delivered along the quadrants formed by the roadway supports through apparently continuous slots in the edge of the maintenance walkways. However, baffles below these slots are spaced such that more air is supplied upwards the greater the distance from the ventilation station.


Simple (white) boards cover all openings here except the two in the centre

For the underground sections of the Main Tunnel, the fresh air is delivered under the roadway both upstream and downstream from North John Street and Sydney Street and then extracted from the Tunnel roof. The dock branches operated in a similar manner although only the New Quay ventilating station is still working and the Dock Branches are only semi-circular with an airway underneath about 2m high.

Each ventilating station consists of three airtight compartments with air-locks separating them. One compartment contains the supply fans, one the exhaust fans and one the switchgear and control system. In all cases, there are duplicate sets of supply and exhaust fans in case of failure and change-over can be effected in a very short time. Each building is a similar shape, this shape being dictated by the requirement to ensure that the fresh air supply is not contaminated by vehicle exhaust fumes from the surrounding streets nor is it contaminated by the fumes being removed from the Tunnel. In all cases the fresh air is drawn into the building around the shoulder of the high level plinth and the exhaust is released from the highest point at the top of the tower.

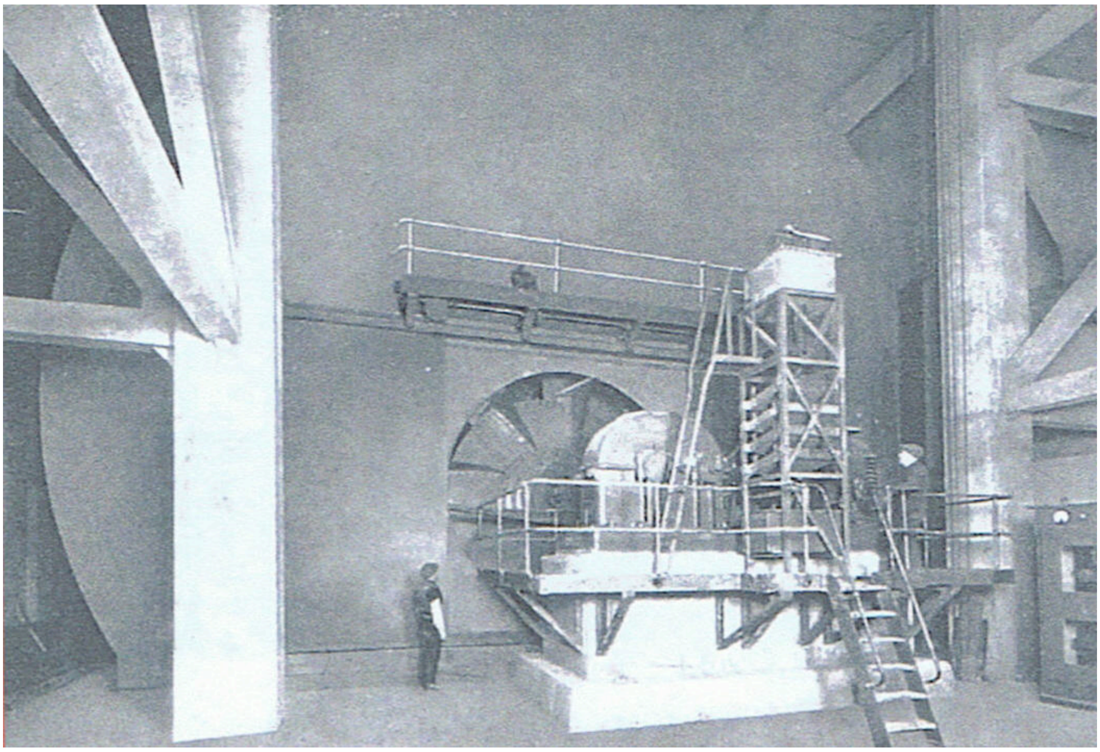

Curved duct splitter here is about 18ft (6m) high

In the early 1960s when traffic flow had reached unprecedented, and certainly, from the point of view of the designers, unpredicted levels, pollution in the centre of the Tunnel was becoming a problem, especially during rush-hour when vehicles would very often be stationary for long periods. The solution adopted in 1964 was the installation of extra booster fans at the Georges Dock Building.

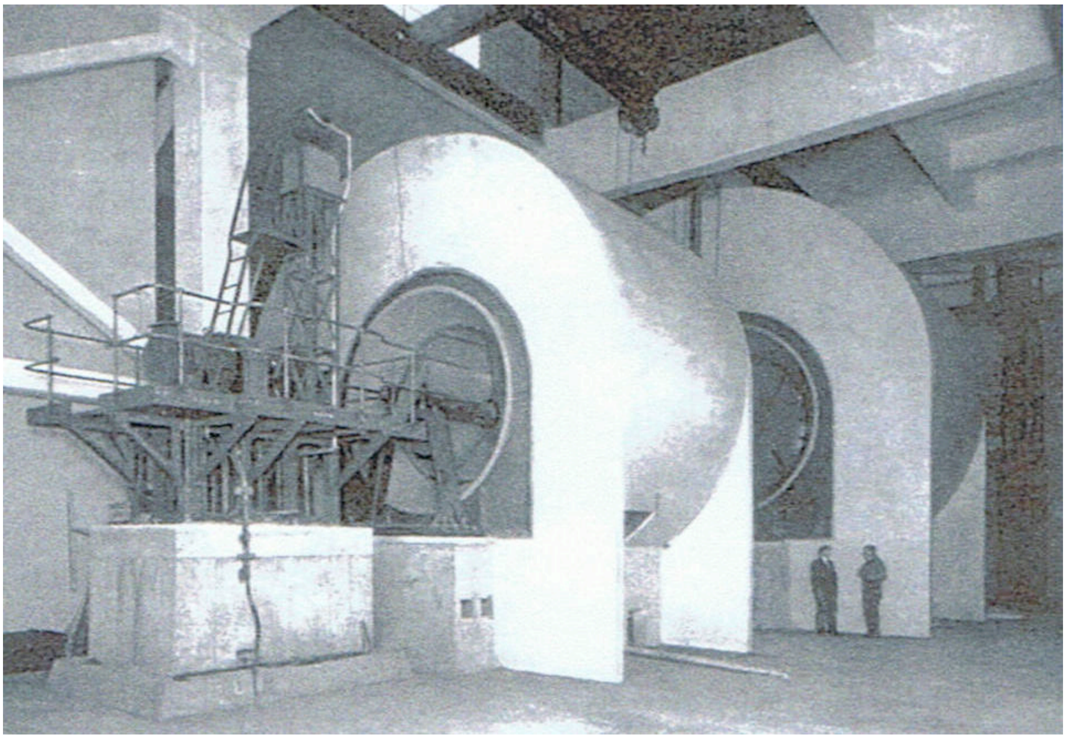
These 'Mid-River Fans' (one running and one stand-by) were installed just below ground level in what had been a workshop under the North piazza of the building. Two small air inlet towers were constructed at ground level to try to reduce the risk of contaminated, street-level air from being drawn into the system but, in fact, one of these towers is a dummy and air is only drawn in through the one next to The Strand. The architect of the original ventilation buildings, Herbert Rowse, insisted, quite rightly, that the arrangement was kept symmetrical. The fresh air from these fans is delivered to the mid-point of the Tunnel using the large space under the centre of the roadway and passes through openings in the support walls at this mid-point to provide extra air into the upper (roadway) level. Doors fitted in the quadrants upstream and downstream of the openings ensure that the air can only escape at the mid-river point.

There is great variation in the sizes of the fans both in diameter and in width with duties varying from 92,000 cubic feet per minute (45 cubic metres per second) right up to 641,000 cubic feet per minute (315 cubic metres per second). The largest fans are the extract fans at Woodside and Georges Dock, these are both 28 ft (8.4 m) in diameter and 9 ft (2.7 m) wide and the smallest fans, at 7 ft 6 in (2.25 m), are in the Liverpool dock branch (New Quay). All ventilating stations except Woodside operate one supply fan and one exhaust fan continuously. There are two parallel supply fans (plus two on stand-by) at Woodside.

The fans were supplied by two manufacturers, Sturtevant and Walker. The Sturtevant fans were an adaptation of their Grand Vitesse design and given the title ‘Grand Vitesse Mersey’. The Walker fans were their ‘Indestructible’ pattern. All fans in Georges Dock, North John Street and Woodside have only 4 blades but with some of the other, smaller fans there are as many as 16 blades. The maximum rotation speed with the largest fans, each weighing almost 19 tons, is about 90 rpm but some of the smaller ones (the smallest being just less than 6 tons) run at up to about 240 rpm.



Walker Exhaust Fan with oil reservoir tower for viscous coupling


Sturtevant Fresh Air Fans

The original system employed constant speed motors on all fans connected via a viscous coupling to a gear box. Some of the gear boxes, manufactured by David Brown of Huddersfield, have had to be reconditioned but a number of them are entirely original after almost 75 years use. The viscous coupling, in theory, allowed for the speed of fan rotation to be infinitely variable by the adjustment up and down of a weir between the oil reservoir and the coupling. In practice the weir system was not entirely successful.

Another problem of the original design was that some of the larger motors were cooled by a ducted supply of untreated outside air, leading to premature corrosion and rapid deterioration of the lacquer on the windings. A refurbishment programme is currently (2008) underway and the original motors and weir system are being replaced by modern, much smaller and more efficient, variable speed ones. The original gearboxes will still be used with the new motors.

The rate of ventilation was controlled manually but the controller was aided by three separate remote monitoring devices which were extremely sophisticated for their time. There was one device which measured the level of Carbon Monoxide, one which measured the speed of air movement in the Tunnel and one which constantly measured the numbers of vehicles entering and leaving. The controller thus knew at any particular time how many vehicles were actually in the Tunnel as well as what the CO concentration was and so could set the fresh air throughput rate accordingly.

Original motor with oil reservoir for viscous coupling is on left

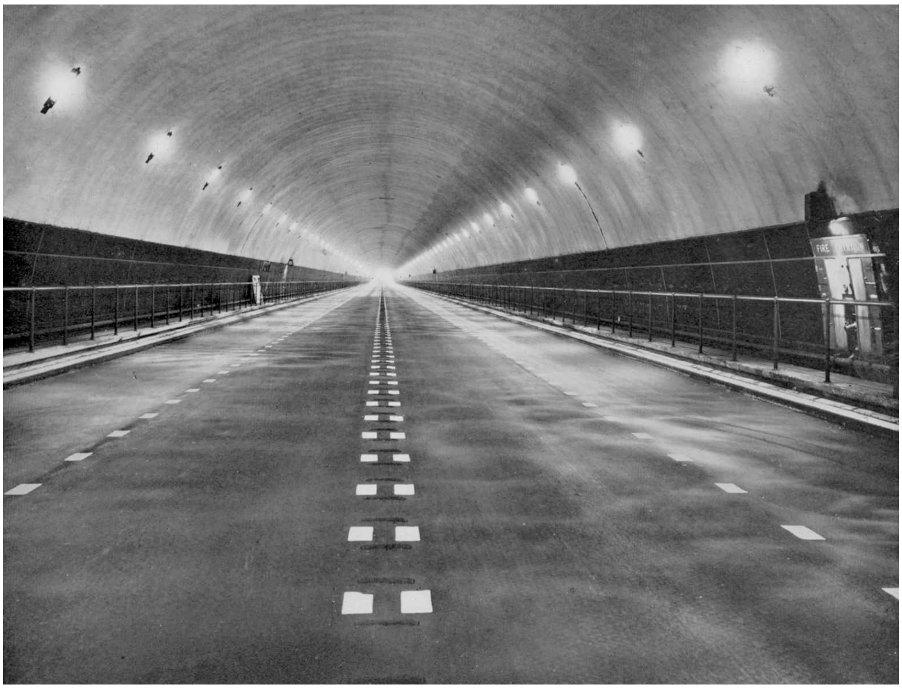
Since the opening of the Kingsway (Wallasey) Tunnel an the banning of vehicles over 5 tons (except buses) the Carbon Monoxide level has largely ceased to be a problem and is generally no worse than in any city street. So much so that the workers currently carrying out the motor replacement on the exhaust fans are able to operate quite safely in the extract stream.

Lighting

The original lighting was by means of 1600 x 150W tungsten lamps. The lamps were mounted in the curve of the roof immediately above the edge of the roadway. The fittings were approximately 15 in (375 mm) high by about 8 in (200 mm) wide and had a diffusing glass cover but appear to have had no reflector. They were designed by the City Lighting Engineer.

Original fitting still with glass diffuser, disused Birkenhead Dock Branch

The spacing of the fittings in the main sections of the Tunnel was 20 ft (6.0 m) but an attempt had been made to grade the variation of brightness at the entrances. At each entrance the spacing was 6 ft (1.8 m), this changed to 10 ft (3.0 m) a short way in and then 15 ft (4.5 m) after about another 50 yards (45 m). The standard spacing of 20 ft was achieved about 200 yards (180 m) from the entrance. Alternate lamps were extinguished at night in the threshold sections.



The original lighting installation, note black glass dado

In the main section of the Tunnel the lamps were supplied alternately from two separate circuits with one feed from Liverpool and one from Birkenhead so that a major outage on either side on the river would not create a total blackout. An extra safety feature was that every tenth fitting had an additional, third, supply. The original tungsten lamps were replaced in 1959 by 4 x 15W fluorescent lamps using the same fittings and in 1966 a number of additional fluorescent fittings were installed to boost the light level at each threshold. These each contained 3 x 125W 8ft (2.4m) lamps.

In 1982 the lighting in the Main Tunnel and the Liverpool Dock Branch was entirely replaced by fluorescent fittings running down the centre of the tunnel just below the roof. The standard fittings had twin 6 ft (1.8 m) tubes, rated at 75w each, housed in a 'broadspread' type reflector. These were, again, wired from two independently fed circuits alternately in a staggered manner such that on half power, when only one lamp in each fitting was illuminated, there was still an even spread of light. From just beyond the Dock Branch Junctions to the main entrances on each side of the river, the fittings housed three 6 ft (1.8 m) tubes and over the last 100 yards or so at each main entrance there was additional threshold lighting installed which was boosted by high-pressure sodium lighting. The intention here was to try to reduce the danger from drivers emerging into sunlight and having their vision temporarily impaired by the sudden change in brightness. (The standard 6 ft, 75w lamps were replaced in 2001 by 1500 mm, 58w units with HF control gear, giving an energy saving of about 36%.)

When the replacement system was installed it incorporated external sensors which were designed to vary the light level according to the level of natural light, not only at the thresholds but throughout the tunnel system. The design levels varied from 5000 lux at the threshold over 3 transition zones at 1750 lux, 700 lux and 240 lux to the central zone at 160 lux. There was the further possibility to reduce the Central Zone level to 80 lux at night if this proved to be acceptable. In theory there would be different levels for dull days, bright days and sunny days. In practice this seems largely to have been abandoned and the main section of the tunnel is illuminated to the same level (80 lux) all the time although during daylight hours the threshold boost still operates and there is always some extra lighting in the outer transitional zones.

As well as the safety feature of having electrical supply from both Liverpool and Birkenhead, there are now stand-by diesel generators as back-up

One final point on the lighting, which possibly represents another first, although this time in the Kingsway (Wallasey) Tunnel, is that the warning signs installed in the Tunnel soon after it opened in 1971, used fibre-optics. These signs incorporated two lamps, one to illuminate the word 'STOP' and one to illuminate the word 'ENGINE'. The intention was that, in case of emergency or hold-up, the second lamp would come on a few minutes after the first one, so that stationary vehicles did not increase the pollution level.

Fibre-optic warning sign now in the Tunnel 'Museum'

<u>Sources</u>

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