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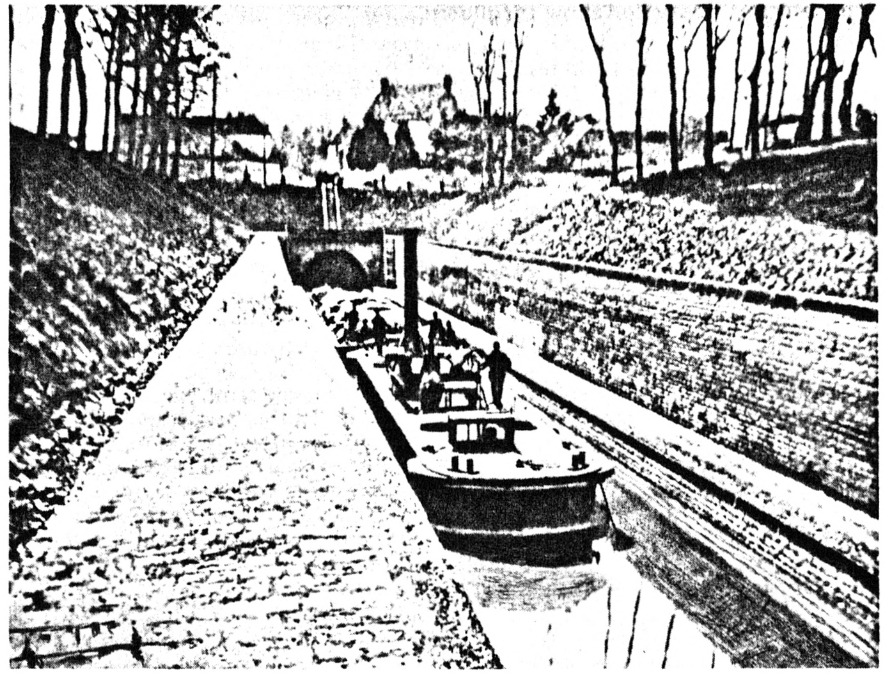
Fireless Steam Tugboats for Canal Tunnels

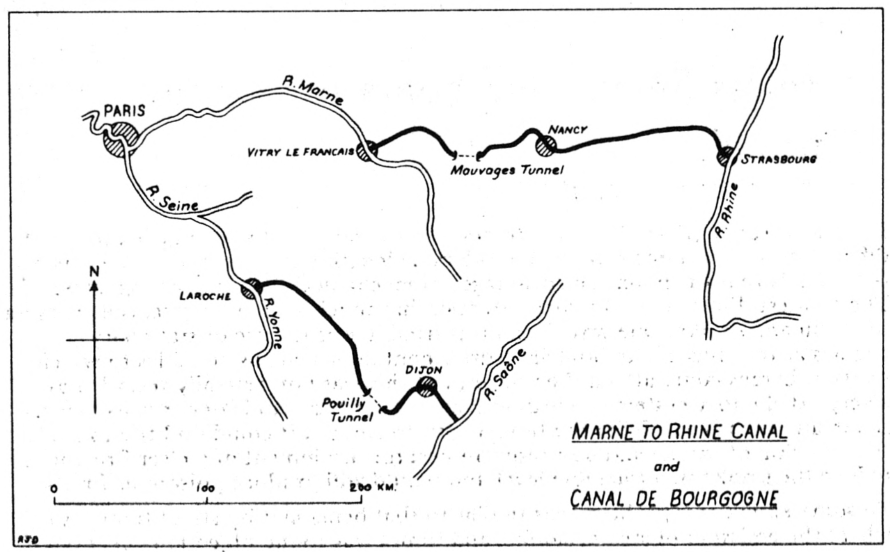
BY D. GORDON TUCKER

The use of steam power for canal traction in the nineteenth century led to difficulties where tunnels of any considerable length were involved; yet it was in the tunnels that the potential advantages of mechanical traction were greatest. The greatest disadvantage of steam traction in tunnels was, of course, the emission of steam and smoke. One way round this trouble was the use of stationary engines at the ends of the tunnels to drive continuous chains or cables to which boats or barges could attach themselves, but this was not generally regarded as a very satisfactory system. A steam-driven boat or tug could condense its exhaust steam and thus avoid filling the tunnel with steam; but it could do little to avoid the emission of smoke and poisonous fumes; the attainment of a clear fire might reduce the smoke to a tolerable level, but would still produce poisonous fumes.

To some extent this problem was similar to that being met by street tramways, where the emission of steam, smoke, and fumes was found objectionable, even if



Fireless Steam Tugboat, leaving the tunnel at Pouilly, late 1880s.



less dangerous than in tunnels. One of the solutions adopted in America, and even more on the Continent of Europe, from the early 1870s, was the use of the fireless steam engine on tramways. The principal inventor of this system was Emile Lamm, a French-born American dentist, whose ideas of 1870–1872 were taken up vigorously in Europe by Léon Francq.[1] The principle finally standardized was to obtain the steam on the vehicle from an insulated vessel containing water which had been superheated (i.e. raised well above normal boiling point and at very high pressure) by the injection of high-pressure steam from a stationary boiler at the terminuses and possibly also at intermediate stations. This type of fireless steam locomotive although eventually abandoned on tramways, remained in use in many industrial situations where smoke or sparks might be objectionable for almost a century.

It does not seem to be well known that Francq also applied this principle to tugboats for long tunnels on two French canals. This application was specifically covered in his French Patent of 1879:[2]

> 'Dans la navigation des canaux, l'application des chaudières sans foyer sera journalière pour la traversée des tunnels et évitera ainsi tous les frais d'une aération indispensible et des dégradations provenant de l'emploi de la chaudière ordinaire.'

The first tugboat on what was called 'le système Lamm et Francq' or merely 'le système Francq' was built for use in the Mauvages tunnel on the Marne-Rhine canal[3] (see map). This tunnel, which is 5 km long, already had a steam tug using normal boiler arrangements, winding itself along a chain which normally lay on the canal bed but which was raised by the tugboat to run over its steam-driven winch and thus propel the tug and its convoy of barges. In spite of numerous ventilating shafts, much trouble was experienced with smoke and fumes, and there were some fatalities. Francq's tugboat of 1881 operated on the chain in the same way. It could tow 20 to 25 boats carrying 4000 to 4500 tonnes of cargo, and took about four hours to traverse the 5 km of the tunnel itself, then continuing, on its stored steam still, for the remaining 4 km of the summit level. So successful was this tug that a second one was built for the canal administration in 1885.

These tugs were driven by two-cylinder compound steam engines, through gearing to the winch. Two 'receivers' contained the superheated water, and an expansion-valve of what was called the 'Francq-Mesnard' type distributed the steam from these vessels to the engine at a constant pressure. Such a distributing valve was obviously necessary, for the steam pressure in the 'receivers' would naturally fall from a high initial value to quite a low one at the end of the run. The system of charging the receivers with superheated steam differed from that used on tramways in that no stationary boilers were provided at the ends of the tunnel or at the ends of the summit level. Instead, the tugboat carried its own boiler and firebox. In starting out in the first open-air section of the summit level, the fire would be operated with sufficient vigour to provide not only enough steam to drive the engine and tow its load, but also to charge the receivers to the required degree of superheat. Then, as the tunnel entrance was approached the fires were damped completely, and the traverse of the tunnel and of the open-air section at the far end made on the stored steam.

The pressure in the receivers at the beginning of the tunnel traverse would have been about 250 lb/in^2, and it would normally fall to about 100 lb/in^2 by the end of the traverse of the tunnel. The expansion valve supplied steam to the engine at about 60 to 70 lb/in^2, to which value the pressure in the receivers would have fallen by the end of the open-air section.

The operation was the same in both directions of traverse.

Measurements of tractive effort on the tow-rope (i.e. the rope connecting the tug to the boats being towed) showed that the work done was about 1200 to 1300 kg-metre per second, corresponding to about 16 to 17 horse-power.

In 1886, a similar, but smaller, tugboat was made for working the Pouilly tunnel on the Canal de Bourgogne (see map). Table 1 summarizes the characteristics of the Mauvages and Pouilly tugs. The photograph shows the Pouilly boat, and the traction chain can be seen at the bows. The Pouilly tunnel had been operated by an ordinary steam tug since 1867, which covered the 3.3 km of the tunnel itself and 2.1 km of approach cuttings.[4] The submerged chain principle was used here too, and was found very satisfactory; and although in 1892 it was proposed to substitute electric towage for steam, it was not proposed to do away with the chain.

The use of the Francq tugboat was found very satisfactory from the operational point of view, and the reason it was thought desirable to introduce an electric tugboat was entirely economic. The Francq tug cost 20,000 francs a year to operate, whereas it was estimated that the electric tug, using cheap electricity generated from the streams that fed the summit level and distributed by trolley wire, would cost only 16,000 francs a year. It was proposed to keep the Francq tug as a reserve in case of failure of the electric system.

The later history of these interesting 'fireless' steam tugs has not yet been elucidated, nor has it been discovered if any others were built.

The author must gratefully acknowledge the helpful assistance of the staff of the Library of the Institute of Civil Engineers.

PARTICULARS OF FRANCQ TUGBOATS

	MAUVAGES	POUILLY
Total length of boat	29.00 m	25.00 m
Width over ribs	4.65 m	3.50 m
Total depth	2.30 m	2.20 m
Draft	1.10 m	1.00 m
Diameter of high-pressure cylinder	0.32 m	0.28 m
Diameter of low-pressure cylinder	0.56 m	0.475 m
Stroke	0.40 m	0.48 m
Steam pressure admitted to engine	4 kg	4 kg
Rating of generators (primary boilers)	17 kg	17 kg
Rating of receivers	17 kg	17 kg
Heating surface of the two generators	92 m^2	56 m^2
Volume of water in the two generators	5 m^3	3 m^3
Volume of water in the two receivers	10 m^3	6 m^3
Total work produced by the steam stored between 15 and 4 kg drop, allowing 1500 kg-m per kg of water superheated, on engine shaft	22.5 x 10^6	13.5 x 10^6
Engine rev/min	50	50
Speed of boat in tunnel	0.35 m/sec	0.35 m/sec
Speed of boat outside tunnel	0.60 m/sec	0.60 m/sec
Effective power of engine	28 horse-power	24 H.P.

N.B. This table is a direct translation of that given in ref.3. Where pressures are given in kg, it must be assumed that what is meant is kg/cm^2. Work is in kg-metres.

REFERENCES

1. A reasonably full account of the process of invention of the fireless boiler and its applications to tramways (including those by Francq) in the 1870s is given in D.G. Tucker, 'Emile Lamm's self-propelled tramcars of 1870–1872 and the evolution of the fireless steam locomotive', *History of Technology, 5* in course of publication.
2. French Patent No. 128,671, dated 27 Jan. 1879. An English translation of the passage quoted is: 'In the navigation of the canals, the application of fireless boilers will become normal for traversing tunnels and will thus avoid all the costs of the ventilation necessary, and the damage caused, by the use of the ordinary boiler.'
3. This account is based on a section of a brochure 'Traction et Moteurs à Vapeur sans Feu, Système Francq et Lamm', published by the Compagnie d'exploitation des Locomotives sans Foyer of Paris, c1890; copy in Library of Inst. of Civil Engrs. There are no ambiguities in the technical part of the French account, but it is not absolutely clear whether the remarks about the previous tugboat and the fatalities do apply to the Maugaves tunnel, or are more general.
4. See report by M. Galliot, 'Touage électrique des bateaux', also 'Rapport de la Commission d'Examen sur le Canal de Bourgogne: Avant-Project d'établissement d'un touage électrique dans le souterrain de Pouilly', both in *Communications of the 5th International Congress on Inland Navigation,* Paris, 1892, pp. 1–11 and 13–18 respectively.

From J.Railway & Canal Hist.Soc., 27, July 1981, p.36

Fireless Steam Tugboats for Canal Tunnels

Sir, – Mr Rodney Weaver's letter in the March *Journal* on the subject of my article in the November issue raises some interesting points. I do not know if the Mékarski compressed-air system was ever tried for traction in canal tunnels, but the papers cited in my reference 4 state that a compressed-air system was seriously considered as a rival to an electric one when it was decided to replace the fireless steam tugs on the Canal de Bourgogne.

I think Mr Weaver has been rather hasty in using words like 'ludicrous' and 'ridiculous' in regard to Francq's design. The paper cited in my reference 3 states unambiguously that the engines were of condensing type, so that compounding would be reasonable. The charge of 'ridiculously low' engine speed is based on Mr Weaver's assumption that the engine speed was lower in the tunnel when the boat speed was lower; but I would have thought my table, coupled with the fact that the drive to the winch was through gearing, makes it quite clear that the engine speed was maintained constant.

The 'strange inconsistencies' in the figures I quoted are, I feel, due to Mr Weaver's own assumptions. The 16–17 hp quoted for the tow-rope traction was, of course, at the open-channel speed of 0.6 m/sec. In the tunnel, with the speed reduced to 0.35 m/sec, the resistance to traction would have been far less than half, and the hp well below 8. Thus, as the tunnel journey took 4 hours and the open journey 1 hr 51 min., the total hp-hours were about 60 at the most. Now in stating the stored energy in his plant, Francq did not say (as Mr Weaver implies) that his engine achieved only 1hp-hr for every 401 lb of water in the receiver. He said that, allowing this (conservative) figure, the stored energy would be 82 hp-hr. Thus, since the stored energy is at least 82 hp-hr, and the traction requirement does not exceed 60 hp-hr, there is some margin for the loss due to friction and the propulsion of the tug itself. So, where are the 'strange inconsistencies' mentioned by Mr Weaver?

So far I have only been defending Francq, to see fair play, so to speak. Now to defend myself over that 'absurdity' of the traction chain being at one side of the tugboat. Maybe it is absurd, but it may nevertheless be true; for in the report by Galliot cited in my reference 4, it is clearly stated that in the design of the proposed electric replacement tug, 'the chain-driving wheels are even placed on the boat's axis so that it may be more stable and easier to manoeuvre'. (Les roues à empreintes sont placées sur son axe même, de manière à ce qu'il soit plus stable et plus facile à manoeuvrer.) The implication that this was not the case in the previous boats is clear. D. GORDON TUCKER