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Electric Propulsion on Canals

BY

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ELECTRIC PROPULSION ON CANALS.

The solution of the canal problem depends largely upon the construction of a compact portable motor, adapted to any canal boat, whatever its shape or size, and capable of being shipped on board when the boat enters, and removed when it leaves the canal.

In order to meet the demands of trade, canal traffic should be provided for by the establishment of a system of mechanical haulage, with a speed of at least from 0.5 to 0.7 metres per second (the speed of horses); or, better, 1 meter per second,—*i. e.*, 3.6 kilometres per hour (2¼ miles).

The production of a large amount of power in one place, and its subdivision and distribution, has been proved by experience to be economical, as has been shown in cable haulage. As the power used in propulsion (from 2 to 5 horse power) would be too expensive if produced separately on each boat, the idea presents itself of making use of electricity, so applied as to dispense with any addition to the boat's crew.

Storage Batteries.—The first application of electric power to navigation was made in 1839, by Professor Jakobi, on the Neva. He used a galvanic battery, and since his day electric boats have been driven by storage batteries. In this system the motive power is exhausted after working a few hours, and the boat must stop for a fresh supply at a special station. But the same objections to the equipment of every boat with a steam or petroleum engine, have still greater weight against electric accumulators, which are still more troublesome and expensive, and for this reason no further allusion to them will be made in this report.

Transference of the Electric Current by means of Wires.—The first known use of the transference of the electric current by means of wires, as applied to canal boats, was made by R. Hunter, of Philadelphia, in 1888, and his patent, No. 403,193, for an electric boat, bears date of May 14, 1889.

Büsser's Invention.—A proposition differing from Hunter's was offered to the Royal Prussian Government for its consideration, by the author, in 1891. He starts with the idea of furnishing every boat traversing a canal with a portable motor, shipped on board when the boat enters, and removed when the boat leaves the canal. Electricity drawn from a conducting wire running along the shore, was proposed as the motive power to drive a screw, a paddle wheel, or a chain drum. This project was also described, in 1892, at the Fifth International Congress on Inland Navigation.

BÜSSER'S SYSTEM OF ELECTRIC CHAIN TOWAGE.

The complete establishment of the system requires: First, storehouses to contain the motors to be placed on the boats. Second, the motors and their accessories. Third, a chain with its anchor fixtures. Fourth, a power house. Fifth, a conducting wire and appropriate transformers.

The general arrangements of the system are shown in Plate I., figures 6 and 7.

The boat F, carries the motor M, at its bow, over which the chain K passes. M is connected with the conductor L, by the wire Z, and the trolley C, which the boat carries forward as it moves.

Storehouses for the motors are established at the various ports on the canal. These are provided with traveling cranes and railway connections to the bank, where other cranes are placed for loading and unloading the motors. These cranes may be worked by electricity.

The Motors.—Of all the appliances requisite for electric towage, the motor alone merits a detailed description.

Position in the boat.—The most available position of the motor in respect to the efficient working of the chain, is in the bow. Figures 1 and 2, Plate I., represent the motor in

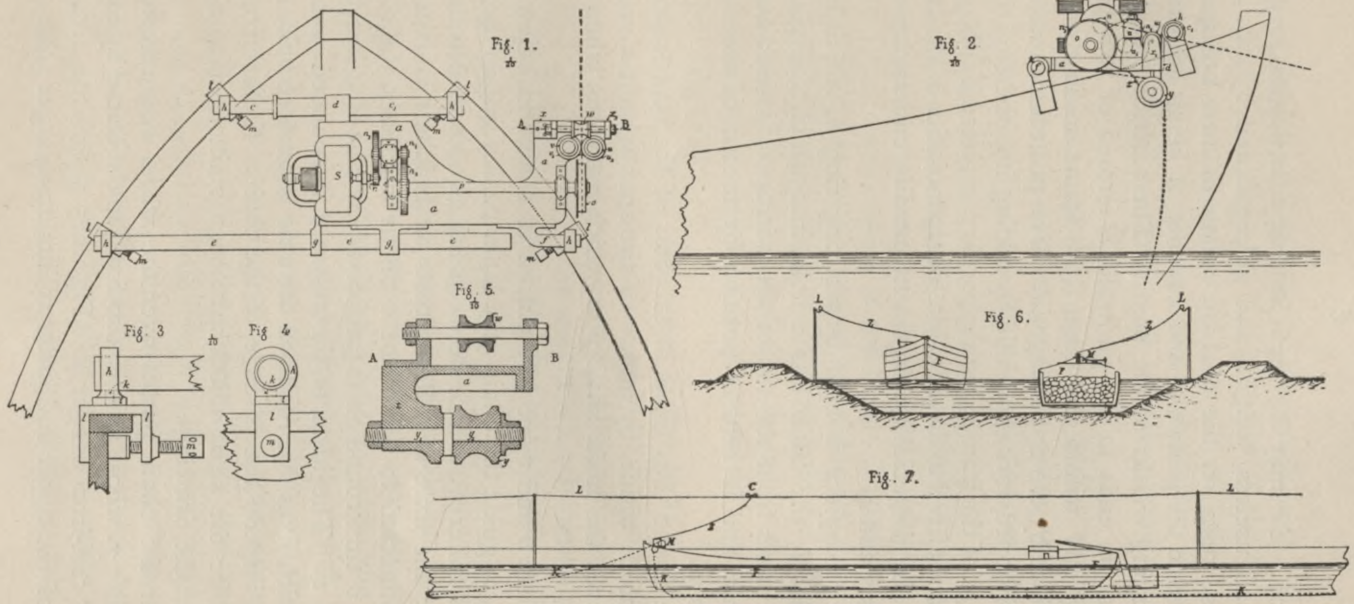
Fig. 1.
1/10
A
B
a
c
c₁
d
e
f
g
g₁
h
l
m
p
S
w
z
Fig. 2
1/10
S
a
d
f
y
Fig. 3
1/10
A
k
l
m
Fig. 4
A
k
l
m
Fig. 5.
1/10
A
B
a
w
y
z
Fig. 6.
L
Z
Fig. 7.
L
C
K

Plate I.

question. As may be seen, its frame, hollowed so as to avoid all useless weight, and strengthened by ribs and flanges, rests on the boat by means of two crosspieces fastened to the gunwale, and capable of being adjusted to the varying widths of the boats. The anterior crosspiece fixed at its ends to the gunwale, is formed of two parts, sliding one within the other; the frame resting on this crosspiece by the appendage, d. The posterior crosspiece is partly openwork, and held by sliding into the two rings, g and g_1 of the frame; the support is completed by the part, f, which is fixed to the side, like the extremities of the crosspieces, by a special arrangement, readily understood from figures 3 and 4.

The crosspiece is held by a strong ring h, which has a shoulder l; the latter has a hole, into which the pivot k fits, k arises from the top of the stirrup l; l rides on the gunwale, and is held in position by means of the clamp screws m.

The frame thus fixed at the bow of the boat, carries a dynamo S, which, by means of the spur wheels n, n_1, n_2, n_3, drives the main shaft p to which the chain wheel o is keyed.

Rollers u and v are also placed in front and below this wheel, to guide the chain; the latter passes first on the horizontal roller w, thence between the two vertical rollers u and v; the axle of roller w rests on brackets x, x, which are connected to the frame a of the machine; the rollers u and v turn round axles supported by cast-iron bearings, u and v. The head of the roller u is rounded, and the nut which fixes this roller on the axle is countersunk, so as not to impede the passage of the chain. Other arrangements for the same object have been omitted, so as not to confuse the drawings.

After the chain passes over the wheel o, it returns on the roller y, whose axle is also fixed to the frame by means of the cast-iron hanger z. Figure 5 shows the arrangement of the upper and lower rollers on a larger scale.

The electro-motor chosen is the machine S, 3 of the "*Berliner Maschinenbau Aktien-Gesellschaft*" which makes 600 revolutions per minute, and weighs 235 kilogrammes. It is a 3-horse power machine, having an efficiency of 75 per cent. It absorbs, therefore, 2,940 volts.

The main shaft bearing the chain pulley revolves 50 times a minute; as this pulley has a radius of 155 millimetres, the length of the chain developed per second is 974 millimetres.

The motor is completed by a commutator, for putting the machine in and out of circuit, and a resistance coil, which regulates the speed of the boat. The electrical apparatus is protected by a casing omitted in the drawing.

Finally, the trolly takes the current from the conducting wire and carries it by the wire Z to the motor on the boat. This connection is effected in the same manner as for the electric railroads.

The Chain.—The thickness of the links is 10 millimetres, which gives a resistance of 975 kilogrammes, while the actual stress never exceeds 300 kilogrammes, allowing a factor of safety of 3; its weight is 2.2 kilogrammes per running metre; it is raised from 25 to 30 metres in front of the boat using it.

In order that boats going in opposite directions may pass each other, the chain is double at the locks; the two chains are interrupted and united transversely, so as to have an endless chain, for the following reason: when the boat is moving, it carries the chain forward as much as the difference in length between the taut chain and the slack chain; instead of having to carry back this excess, it is carried across the canal to the other chain; thus the chain will have passed the whole length of the section, up on one side and down on the other, whereby the irregularity is obviated by subjecting every link to the haul of the boats; besides preventing the formation of kinks, as the moving boat has no superfluous length of chain in front of it.

In the straight part of the canal the chain rests freely without anchors; in the curves, anchors or guiding posts are necessary; at each extremity the chain passes through a simple ring, solidly fixed, which serves as an end anchor. It is not absolutely necessary to interrupt the chain at every lock; on the contrary, it can very well be carried

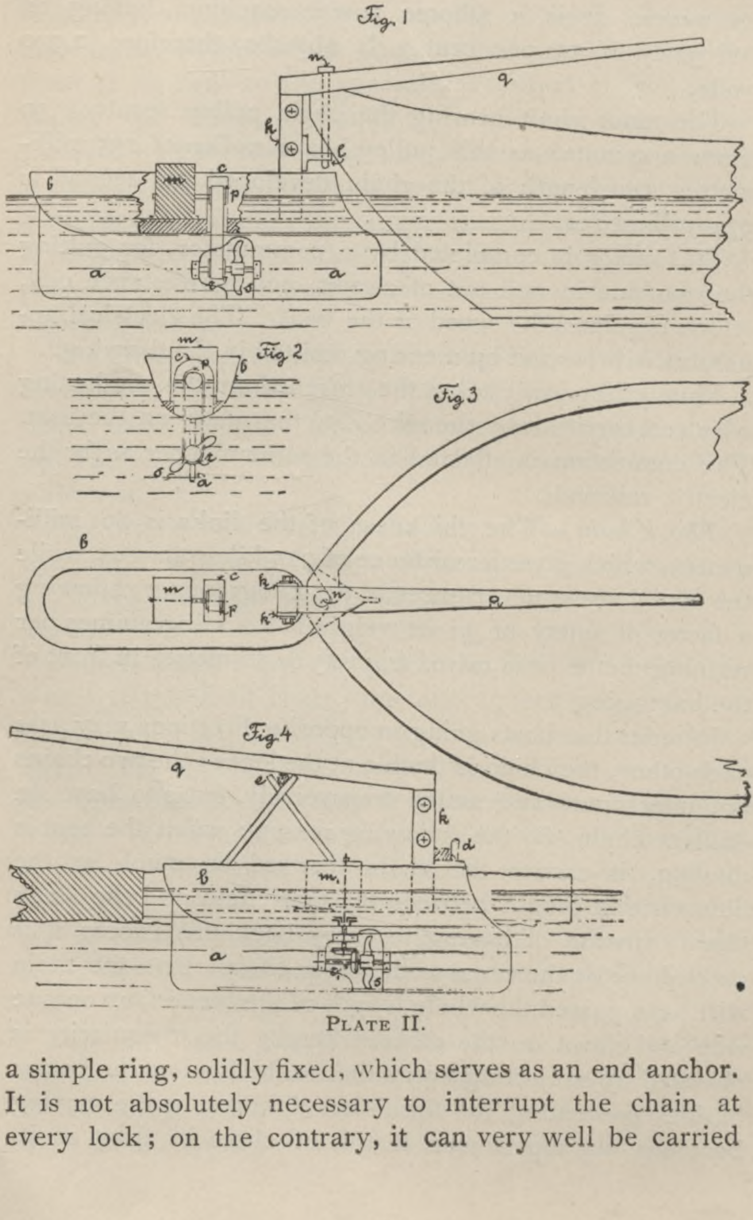

PLATE II.

over: the places of its interruption must be determined by the practical necessities of the case.

The Power House, and the system of distribution.—We shall not consider here the source of power, the details of the power house, or the plan of distribution; we may simply remark that the high-tension electric current leaves the power house requiring only a small conducting wire; but as this current cannot be used for driving the motors, it must be transformed, in special stations erected for that purpose, a short distance from each other into one of lower tension, and it is only this secondary current, thus obtained, which gives the available motive power. For this working current a second wire is necessary, but no addition to the *personnel* is required.*

The electric motor-steering boat is a small craft used for propelling and steering both boats and rafts; it is not intended to go independently, and, therefore, has no arrangement of its own for steering, and no room for a steersman, but is fastened to the boat or raft in place of its rudder, which is temporarily removed and laid aside during the passage through the canal. This steering boat is operated from the craft to which it is attached.

Description.—The motor-steering boat consists of a small boat of wood or iron (figs. 1–4, Plate II.). Its keel is enlarged so as to have the shape of a rudder blade, *a*. *m* is an electro motor, keyed to a horizontal or vertical driving shaft, figure 1, which is carried through the side wall of a well *c*; *c*, being water-tight, is raised above an opening in the bottom of the boat, and closed with a lid. The end of the driving shaft projecting into the well *c*, carries a pulley *p*, from which the belt is carried to a second pulley *r* keyed to the screw shaft.

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*An article by Professor Fischer on the "Introduction and Development of Steam Navigation on the Elbe," in the Kingdom of Saxony, published in the *Civil Ingenieur* for 1891, page 233, contains a statement of the cost of chain towage as compared with steam towage, together with Mr. Büsser's comments; but as the discussion has been superseded by M. de Bovet's report, it has been thought best to omit it.—ED.

In the vertical position of the driving shaft, figure 4, the latter is carried downward, through a stuffing box, in the bottom of the boat. The transmission of the motion to the screw shaft is effected by a pair of bevel wheels, *r;* the well naturally is omitted in this case.

The propeller screw *s*, mounted on a horizontal shaft in the midship section, half way up the blade *a*, rests on two bearings fastened to *a;* the latter is hollowed out, so as to allow the revolution of the screw. The tiller *q*, has the usual form of those of river boats, but is not permanently fastened to the steering boat, and, therefore, ends with a knee.

The fastening of the tiller *q*, to the boat is effected by two flat rails *k*, fastened to the bottom of the boat and braced. The knee of the tiller *q*, fits into the space between these two rails, and is fastened to them by two screw bolts. The tiller *q*, has a different position when fitted to a boat than when fitted to a raft. On a boat it is turned forward, and fastened to it by means of a pintle, in the usual way. In order to counterbalance the upward pressure, which tends to lift the pintle, *n*, there is a plate, *l*, on the knee with a hole in one end, through which the lower part of the pintle passes.

For rafts, the motor-steering boat is used somewhat differently. A free space corresponding to the size of the boat is left in the head of the raft when the logs are fastened together, and a simple footbridge *d*, figure 4, is put across this space at such a height that the rails, *k*, can be pinned into it just above the gunwale of the boat.

The bridge, *d*, is here either cut out, or provided with two pintles, in order to prevent the rails from sliding sideways. The tiller, *q*, is fastened in the opposite direction, so that it projects backward over the steering boat, and can be handled there for steering the raft.

The downward pressure on *q*, caused by the working motor, is counteracted by a wooden crosspiece, *e*, pushed under *q*. The accessory pieces of machinery belonging to the motor, *m*, are not indicated in the drawing, because their arrangement, as well as the fastening of the tiller to the steering boat, and the attachment to the boat or raft, can be varied indefinitely. The motor has a rheostat, by which the velocity of the screw can be varied within certain limits; this regulator is placed upon the boat itself. The flow of electricity is regulated by a commutator fastened to the tiller; the working of the commutator and the rheostat is limited to the handling of two levers by the steersman. The trolley pole is attached to the end of the tiller.

Remarks.—First, electricity from a central station can be used to drive tugboats provided with electric motors, as the boat invented by Hunter, and mentioned above. Second, we may also have electric funicular traction. In this case electricity is used instead of steam to drive the cable. Third, Wollheim's Electric Railway. A system of electric haulage has been proposed by Leonhard Wollheim, of Vienna, in which a boat is provided with a storage battery, and the current from this, used to drive an electric locomotive running on a railroad laid along the shore, and drawing the boat by a tow line. The experiments already made with steam locomotives for this purpose are not very encouraging. The weakest point in Wollheim's system is the necessity for storage batteries.

Financial Conditions.—The use of electricity for the propulsion of boats allows the production in *one* place of an amount of power required for the propulsion of a great number of boats. Besides, the consumption of motive power is more easily adapted to the exigencies of the situation than is the case with steam, and it can, therefore, be supposed that electricity will have the advantage of cheapness. This supposition might be proved by careful calculation, but as long as practical experiments in electric towage are wanting, the financial advantages can only be ascertained by computation, and that only for chain towers and the motor-steering boat, as even the necessary data for an estimate are wanting for the others.

Suppose a stretch of canal 100 kilometres in length: let the boats be of 200 tons capacity, to be moved as fast as they could be towed by horses,—*i. e.*, at the rate of 0.667 metres per second (2.4 kilometres, or $1\frac{1}{2}$ miles per hour). The dimensions of the boats, if laden to 80 per cent of their capacity, are as follows: length, 38.32 metres; width, 5.11 metres; draught, 1.54 metres. If the ratio of the cross section of the canal to the maximum cross section of a boat floating on it be as 5 to 1, the canal will have a cross section of 39.27 square metres. Therefore, the power necessary for the propulsion of the boat, calculated according to Bellingrath's formula, will be: P[*] $= 20.387 V^{33} \frac{C^2 Q}{(C-Q)^2} =$ 0.990 horse power with a full cargo, and 0.244 horse power with one fifth of a full cargo. In the formula, V equals the velocity in metres per second; C equals the cross section of the water in the canal; Q equals the largest submerged cross section of the boat. The traffic is supposed to be such that the boats always carry a full cargo on their first trip, and only one fifth on their return trip. The highest rate of traffic may be found as follows: Let the boats follow each other in the canal at a distance of 300 metres, both up and down stream, this speed being 0.667 metres per second. One boat up stream and one boat down stream will pass a certain point in the canal every 450 seconds. At 15 working hours per day there will be a traffic of 240 boats a day; of these, 120 carry each 200 tons, making 24,000 tons; 120 carry each 40 tons, making 4,800 tons; making in all 28,800 a day, or, with 300 days of traffic a year, 8,640,000, or 864 million kilometric tons. The actual average traffic may only amount to 45 boats at 200 tons, *i. e.* 9,000 tons; 45 boats at 40 tons, *i. e.* 1,800 tons; total, 10,800 tons a day, making in all 3,240,000 tons per year, or 324 million kilometric tons per year.

In the former case, *i. e.*, with the heavier traffic of 864,000,000 kilometric tons, there would be in the canal at the same time: $\frac{100 \times 1000}{300} = 334$ boats with full loads,

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[*] $P = 74.35$ k. m. $= 0.990$ H. P.

requiring each 0.990 horse power = 331 horse power; as well as 333 boats with partial loads, requiring each 0.244 horse power = 81 horse power. The propulsion of all these boats consequently requires 412 horse power.

At an average traffic, there are to be propelled simultaneously: 120 boats with full loads, at 0.990 horse power = 119 horse power; 120 boats with partial loads, at 0.244 horse power = 29 horse power. For ordinary traffic, this would be 148 horse power.

The expenditure of establishing the system is supposed to be based on the first sum of 412 horse power; the expenditure of carrying on the traffic, on the sum of 148 horse power.

The total amount of power necessary for propelling two boats separately is greater, as is well known, than the power required for both when the second is towed by the first. Assuming this to be the case, and that the locks of the canal are capable of accommodating two boats at a time, we should only require $\frac{334+333}{2}$, say 350 motors.

The average traffic would only require 130 motors; but in order not to overrate the capacity of the system, this item of saving will not enter into our calculations. The total propelling power of marine engines, according to Weisbach's formula ("Engineering and Machinery"), is rated at from 0.30 to 0.50 for a screw or paddle, and at 0.65 for chain boats.

In transmitting the motive power by electricity different conditions arise, and so we may estimate it at 0.50; so that it would hardly be overrating if we estimated the degree of power of the screw at $0.30 \times 0.50 = 0.15$, and that of the chain machine at $0.60 \times 0.50 = 0.30$.

The 412 horse power calculated above for the haulage of boats gives the following: $\frac{412}{0.15}$ for the screw motor = 2,750 horse power; $\frac{412}{0.30}$ for the chain motor = 1,400 horse power. And the average traffic requires $\frac{148}{0.15}$ for the screw motor = 1,000 horse power; $\frac{148}{0.30}$ for the chain motor = 500 horse power, which would have to be supplied by the steam engine from the central station.

The cost of the plant, including the steam engines, may be estimated as follows :—

	Screws Marks.	Chains Marks.
Central Station (dynamos, transformers, etc.)	400,000	400,000
Poles and wires for 100 kilometres, with transforming stations	900,000	900,000
350 motors at 2,000 marks	700,000	700,000
100 kilometres double chain, at 5,000 marks		500,000
Cranes, storehouses, etc.	200,000	200,000
Total	2,200,000	2,700,000

THE ANNUAL EXPENSE OF MAINTENANCE.

Interest on the cost of the plant, at 4%	88,000	108,000
Sinking fund, 10%	220,000	270,000
Wages in excess of those paid under the present administration	30,000	30,000
Motive power (interest, sinking fund, attendance, maintenance, at a price of coal of 2 marks for 100 kilogrammes), par effective horse power, is 0.04 per hour x 2,750 horse power x 15 x 300 =	495,000	
1,400 x 0.04 x 15 x 300 =		252,000
Expenses for the heaviest traffic	833,000	660,000

For the average traffic these sums would be reduced by a smaller consumption of coal, the expenses of which, calculated at 1.05 kilograms per horse power, per hour, for the difference of

2,750—1,000=1,750 horse power, amounting to	236,000	
1,400—500=900 horse power, amounting to		121,000
Consequently the yearly expenses=	597,000	539,000
The average yearly traffic amounts to 324,000,000 kilometric tons, the cost of 1 kilometric ton is	0.001,843	0.001,664
For the heaviest traffic which would cost yearly	833,000	660,000
Which corresponds to 864 000,000 kilometric tons; hence, the cost of propulsion would amount to	0.000,964	0.000,764
Per kilometric ton.		

The cost of haulage by horses is from 0.0025 to 0.0030 marks, and, in comparison with the electric system, would afford the following noteworthy savings :—

At an average traffic for the screw	0.0007 or 26%
At an average traffic for the chain	0.0008 or 33½%

With an increase of the average traffic, these savings would also increase, and if the canal were used to its full capacity they would amount to:—

For the screw	0.0015 or 61.5%
For the chain	0.0017 or 69.5%

Although practical experience will necessitate many corrections in these numbers, yet it is evident from the foregoing calculation that electricity used as motive power for navigation on canals has financial advantages, and that the chain motor, in spite of higher cost of plant, affords cheaper haulage per kilometre than the motor-steering boat; besides, it may be noticed that the chain has been assumed about three times as strong as necessary, and consequently the sinking fund would hardly amount to the sum calculated.

CONCLUSION.

1. The use of electricity for the haulage of boats on canals offers a fair prospect of financial success, and that in a higher degree than steam power.

2. For the development of these projects, practical trials are absolutely necessary.

3. The theoretical and practical solution of the problem is so elaborate and expensive that practical results could only be attained by spending a considerable amount of time and money.

4. This improved haulage of boats on canals must be followed by an improvement in the traffic on water ways, and consequently an increase in trade and industry. The profits arising from this increase would not accrue to the benefit of any individual, but to the whole community; therefore the State should be called upon, in the first instance, to provide the necessary means for the realization of these projects.

ODERBERG-IN-THE-MARK, May 9, 1893.

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