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CHAIN TOWAGE

WITH MAGNETIC ADHERENCE

BY

L. MOLINOS

Past President of the Society of Civil Engineers of France, President of the Lower Seine and Oise Towage Company

AND

A. DE BOVET

Director of the Lower Seine and Oise Towage Company

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CHAIN TOWAGE WITH MAGNETIC ADHERENCE.

I.

The traction on rivers of boats not individually provided with motive power is done either by means of chain-towing or by tug-boats.

The first method, taking a bearing on fixed points, gives much higher duty than the second, and has thereby an absolute, incontestable superiority over it. It is, however, necessary to give rational preference to the chain-towage over tug-boats, that the economy due to this higher duty be sufficient to cover the expenses chargeable to the chain and those incurred by the difference in cost of chain tow-boats over ordinary tug-boats. This is a question of relative, and not absolute, superiority, and depends only on the nature of the river.

It can be established, at least with sufficient approximation for practice, that the work required of the engines for drawing the same tow in still waters, with the same speed, is twice as great in the case of tugs as in that of chain tow-boats. In running waters, going up stream, if the speed of the tow with reference to the shore is in absolute value equal to that of the current, the ratio of power required of the tug to that furnished by a chain tow-boat equivalent thereto (as above described) would be as 4 to 1. This ratio would be between 2 and 4 to 1, when the speed of the tow with reference to the shore is greater than that of the current. It will be greater than

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4 to 1 when the speed is less, the ratio increasing rapidly as the difference in speed increases.

We know, on the other hand, what an amount of power is required to give an appreciable speed to a tow going up stream if the current is somewhat rapid, and that this speed is much below that of the current when the latter reaches from 4 to 5 kilometres.

It will therefore be understood why chain-towage is preferable as the current increases, and is finally the only method possible on streams having steep grades, either when in a natural state or where artificially regularized, and this even where the depth is sufficient to allow of powerful tugs. We might easily cite as examples large rivers, such as the Rhone, for instance, where, owing to the want of success up to the present time in establishing chain-towage, navigation is carried on by self-propelled carriers only. Such an example shows also that, as at present practised, chain-towing has not been developed successfully in many cases where it would be the most natural method.

On canalized streams, one effect of canalization being among others to reduce the current to a considerable extent, and that during long portions of the year chain-towage, during the seasons when the dams can remain more or less raised, loses its relative advantages, and the use of tugs, on the contrary, becomes more easy, and the struggle between the two methods is so intensified that one is forced to ask if both can possibly coexist. This is the case on the Seine. There canalization has been carried forward to a rare degree of perfection. The use of tugs therefore has found exceptionally favorable conditions, and has, in fact, been greatly extended during the last few years. It has thus shown that chain-towage was not, or was no longer, able to satisfy all the needs of navigation, but without, however, succeeding in showing that tugs alone could fulfil these needs, to a larger or to a better extent. It is not, however, probable that there are two equally good and sufficient ways of performing the same work; and one is forced to conclude that either one or the other method has not yet reached its highest perfection.

What is wanting in each of these methods? Nothing can show this better than the study of facts on a stream where both are in concurrent use; and the Lower Seine, with which we are specially familiar, seems very suitable for this comparison. It shows at the same time why chain-towage may have a hard struggle against tugs on canalized rivers, and why it is not always available in places where tugs are useless. We shall see that the cause is due to certain inherent defects in the apparatus in actual use for chain-towage, and we will show how we think these defects may be remedied.

II.

We will not insist on the origins of chain-towage and the experiments preceding its industrial application.

The first idea is attributed to Marshal Saxe. He proposed towing boats by means of a cable, one end of which was made fast to the shore. A horse-gin set up on the boat wound the cable on a drum. The cable was then unwound, and the end carried further ahead on the shore, and so on. But this was practically what had been done at all times on ships by means of the capstan.

We consider that chain-towage really began with the use of a submerged chain having the length of the whole route, the idea of which, we believe, is due to Messrs. Tourasse and Courteaut, who in about 1832 conceived the project of applying it to the Seine, from Paris to Rouen. The experiment failed. It was premature. In 1855 there was a short tow-line of submerged chain from the lock at the Mint to Port-à-l'Anglais, 6 kilometres long, used for clearing the empty barges from the docks in Paris.

It was this embryo application which caused the formation of the first large towage company, that of the Lower

Seine and Oise, which had a line 72 kilometres long, and had considerable traffic between the Mint lock at Paris and Conflans, at the mouth of the Oise.

At the time of its foundation, 1856, the canalization of the Seine was very imperfect, the *régime* of the river was very irregular, the current frequently violent, and the depth of water variable, being less than 1.50 metres in summer.

Owing to the absence of a lock at Suresnes, the shipping from the north, arriving with full cargoes at the Seine, were obliged at great expense to lighten their loads, in order to reach the Paris docks and the basin of the St. Denis canal.

Chain-towage, the object of which is to realize economically great traction power, rendered during this period incomparable service.

Substituted for horse-towing, or the use of the few rare and inferior tug-boats, it absorbed at the start nearly all the traffic except that down stream, which was mostly drifted; and its proportion amounted to 97 per cent. It lowered the cost of traction of a barge from 6 to 2 mills per kilometric ton;* and, although in the last few years its proportion of traffic has been much reduced, it has in thirty years towed from Conflans to St. Denis or Paris over 1,800,000 kilometric tons. It has consequently caused a saving to the Parisian commerce and industry that may be estimated at some $6,000,000, seeing that its influence was the cause of the reduction of rates. And this useful result was obtained without any subsidy or any other help from the authorities than the permission to lay a chain in the bed of the river.

But since its formation the navigation of the Seine has been greatly modified. The construction of new weirs with locks has carried the depth of water at all times to a minimum of 3 metres. The water section has been

* In 1856 the cost of traction of a 250-ton barge from Conflans to Grenelle was $100 in winter and $53.25 in summer. To-day, at the maximum, all included, it is not over $33.75.

thereby naturally increased; and the velocity, except in times of freshets, correspondingly reduced. These modifications, very advantageous to the shipping interests, reduced the relative advantages of chain-towage, as the necessity for it decreased with the reduction of the velocity of the current. On the other hand, the increased depth of water allowed improvements to be made in the tugs, which also profited by all the improvements made in steam-engines in the last twenty years as regards economy of fuel, whereas the chain tow-boats in actual use to-day are the same as those used at the outset. The consequence has been that, except during the three, four, or five months of high water, when chain-towage has the advantage, tugs compete successfully with it; and its traffic has been reduced. In the last few years its share of the total traffic has fallen off from 97 per cent. to about 50 per cent.

Moreover, the slackening of the current has rendered down-stream traction more and more necessary. Steam-tugs, that were better adapted for this work, came up, sure of finding employment. Once established, they naturally endeavored to procure loads for the down-stream trips, and thus gradually increased their power for service in this direction.

Hence the development of tug service on the Lower Seine, where there are to-day in use for regular or temporary service about 75 screw-tugs and screw-carriers. Of this number, besides those belonging to water transportation companies, 19 are employed at all seasons in towing barges; but in summer there are at least 28, of a total horse power of 4,450.

Is this condition of things to be final? Is chain-towage to disappear on the Seine? Is it not possible, on the contrary, to improve the appliances for chain-towage and the conditions of its service, so as to give to it decisive advantages over the other systems of towage?

This is the question that the Lower Seine and Oise Towage Company has been studying with perseverance for the last six years. It is of great interest from a general point of view, in regard to the best solution to be adopted for towage on canalized rivers. The common characteristic of these streams is to have necessarily a variable *régime*. In summer, the weirs being raised, the current is almost annulled, whereas in winter, during the rainy season, it is necessary to partially lower the weirs, and the current increases; and during flood waters the weirs are completely removed, and the natural *régime* of the river is re-established. Now, the usefulness of tugs diminishes considerably with the increase of the current. For instance, a tug of the "Wasp" type can in summer tow 7 barges, whereas during high water it can tow but 1 1-2, 3 for 2 "Wasps" coupled together, and only 1 during very high water. The proportion remains about the same for the large 300 horse-power tugs. In summer they can take 12 barges, but only 3 with high waters, sometimes only 2, and that at reduced speed.

It is thus seen that, in order to meet the requirements of traffic which is pretty regular, four or five times as many tugs would be required in winter as in summer; and, as they would not have employment for the greater part of the year, it is difficult to conceive how satisfactory service can be organized with the use of tugs only. There would naturally be either a dearth of means of towage in winter, an accumulation of barges, and excessive rise in prices, or else in summer a surplus of tugs (as we have stated above), and abnormal cuts in prices, thence, in short, a great latitude in the scale of rates.

Chain-towage, on the contrary, owing to its method of traction, is much less affected by variations in the current. In practice, the weight of the tow during high waters is reduced rarely in the proportion of 5 to 10 (very exceptionally 4 to 10). It should also be added that, whereas any variation in the current is of importance for the tug, only notable variations affect chain tow-boats. Consequently, with a given plant towage by chain can give much more regular service, and at the same time prevent large variations in the rates.

It is evident that a system of traction that has a crushing advantage over all others during from three to five months of the year, according to the conditions of the waters, will supersede all its competitors, if during the remainder of the year it equals them as to cost, security, and regularity of service.

Now, chain-towage does not at the present time fulfil this last condition; and, in order to explain the cause correctly, it is important to explain briefly how it operates and the defects inherent in the arrangement of its plant.

The method of hauling on the chain adopted at the origin by the Lower Seine and Oise Towage Company, was copied from the arrangements of the small tow-boat of Port-à-l'Anglais, and it has been universally adopted both in France and abroad. No other method was known; and, notwithstanding its defect, no French or foreign engineer has hitherto been able to propose a better one. It consists of two drums with five grooves each, with parallel axes set 3 metres apart, around which the chain is wound a sufficient number of times (generally 4 half-turns on each drum) for the adherence to equal the necessary traction effort.

This system is very defective with reference to the preservation of the chain. If the gauge of the grooves in the drums is not absolutely the same, the winding from one groove to the other becoming different, the chain is obliged to slip, which brings abnormal strains on the intermediate portions, that may considerably exceed the traction strain on the portion stretched in front of the bow of the boat. Besides, the chain is bent and straightened out eight times while under strain in passing around the drums, which, in presence of sand brought up by the chain, increases the wear. This apparatus is, therefore, in itself a cause of breakage of the chain. In fact, this usually occurs on the drums.

With regard to the general service, the inconveniences of this arrangement are not less serious. The length of chain wound around the drums is 37 metres. It therefore does not allow the use of boats having a propeller, which might cast off the chain at the end of the route; for at each trip it would bring up stream 37 metres of chain, and erelong all the chain would be accumulated at the upper end of the route.

It has been tried on the Lower Seine, and also on the Danube, to cut the chain in 100 metres lengths, which the tow-boat returns, to be added to the down-stream end; but this expedient, very unsatisfactory in many ways, has the serious inconvenience of displacing successively the chain in the whole length of the route. It cannot therefore be methodically repaired by placing new sections at the points the most strained or the most dangerous, such as bridges, etc., so that this arrangement consequently increases considerably the cost of maintenance of the chain, which is already quite heavy.

The consequence is that the towage service is done by relays, each boat remaining on the chain as well going down stream as going up, plying up and down with those preceding and those following it. If the traffic increases, if in consequence one or two more tow-boats are added to the service, there is no other way but to shorten the relays. But at the end of each relay the tow-boat must swap tows with the following one. This causes much loss of time, for it cannot be done at all points on the river. It is only practicable, without danger, at certain mooring places, so that the boats are obliged to wait for each other, absolute regularity being incompatible with all navigation service. The amount of this loss of time is so great that in winter, during the short days, when the traffic is usually most active, there is scarcely any advantage in putting on a fifth boat between Conflans and St. Denis, the loss of time taken up by these changes compensating for the advantages gained by an extra tow.

Another and more serious drawback to chain-towage is that, although an excellent system for going up stream, it is much inferior to tug-boats for down-stream work.

In the first place, especially in high waters, if the boat going down stream has a tow, its speed, limited by the winding apparatus, is not sufficient for the steerage-way of the barges. The operation of swapping tows is much more complicated, much more dangerous, and takes more time. Finally, if the chain breaks, the boat is stopped. Held by the chain rolled on the drums, the tow may collide with it, and more or less damage may result from it. Hence a certain repugnance among bargemen to chain-towage down stream. For the same rates they prefer tug-boats.

All the chain-towage companies established under the same conditions as the Lower Seine and Oise Company, such as the Upper Seine Company, the German companies on the Elbe, the Main, the Necker, the Russian company on the Tcheksna, are subjected to the same difficulties. All, or most of them, have had to give up down-stream towing. This is for them a loss of an important part of the traffic. It is also an avowal on their part of their inability to render to shipping all the service required. Towage down stream is convenient, even when the barges might float down. It is necessary on streams where the effect of the weirs is to frequently annul the current. Chain-towage has not, however, up to the present time been able to do this except by the means used by the companies from Conflans to Rouen and on the Danube,—means which we explained just now, but of which we also showed the serious inconveniences.

We may now formulate from what precedes the conditions to be fulfilled in order that the chain-towage plant yield a good service.

Instead of the present chain tow-boats, there should be used chain-towing tug-boats; that is to say, first-class propeller or paddle-wheel tug-boats, supplied with a chain-towing apparatus for use going up stream only. This apparatus should be simple, should not injure the chain, and should allow the chain to be removed and thrown overboard at any point on the route.

Then the relay service would be suppressed. The boats going up stream would take their tows to destination without any swapping. On going down stream, they would operate the same as free tug-boats. The service would be effected both ways, with a single chain. It would therefore gain in regularity, in speed, in traffic power, and in economy.

All depends, therefore, on the discovery of a system of hauling which would realize the conditions that we have just enumerated, and at the same time necessitate but a short length of chain over the apparatus, and sufficiently short so that it could be thrown overboard at any point without causing a dangerous amount of slack in the chain.

III.

Supposing the problem solved as far as the towing apparatus is concerned, there remains in a service organized according to the above programme one difficulty, which is to keep the chain in a good position on the bottom. When a chain tow-boat comes to a curve, as soon as the traction effort is applied to that portion of the chain placed on the curve, the tendency is for the chain to swing towards the centre. It places itself on a shorter line than the one previously occupied, and there is slack in the chain at the point where the boat is. If this slack could be retained on board, to be paid out gradually as the curve is passed over, the chain could be replaced in its original position. For this purpose there is needed, beyond the towing apparatus, an adjustable brake, by means of which, as needed, less chain could be paid out at the stern (at the beginning of a curve) or more chain (during the passage of the curve) than is taken in at the bow. For want of this brake, the slack falls back into the water at the time it is produced, and is not at hand when needed, so that each boat going up stream leaves the chain nearer to the convex shore than it was before.

This happens, for instance, on the Seine. When produced, the slack falls immediately from the stern. Sometimes it accumulates between the guide-sheaves on the chain-way, and the men have to draw it out. This also happens on the boats of the Elbe, the Main, the Necker. There, however, there is behind the towing apparatus a chain-well, reaching down to the bottom of the hold (the depth of these boats is nearly the same as that of the river), so that there is no piling up of the chain among the sheaves; but, the height which the chain has to rise on coming out of the well being comparable to that which it has to fall beyond the stern pulley, the well acts as a regulator. It does not, however, replace a brake, adjustable at will; and in all these cases, in the latter as well as in the former, the chain is displaced behind the boat going up stream, and the boats going down stream, acting both by their speed and their mass, have to be relied on to put it back into place.

On the Danube, with very rapid current, consequently under the action of very considerable traction efforts, the chain is still more displaced, but is, however, immediately replaced, without descending boats, by means of a large well at the rear of the towing apparatus and a powerful brake, consisting of two corrugated drums, similar to, but smaller than, the towing drums, on which the chain is wound several times, and which are held by spring breaks.

In all services organized with chain tow-boats going up stream on the chain and going down free, it will be necessary to have something analogous to this; and the brake will be all the more necessary and have to be all the more powerful for rivers with rapid currents.

A more or less complete system of brakes being necessary in the hypothesis we are considering, all that we have said in reference to the towing apparatus remains true of this brake. It must of necessity be able to act on a short length of chain, and will be acceptable only on the condition that it does not injure the chain and that the latter can be easily removed. In this last respect the system in use on the Danube, acceptable with the plant in actual use on that river, would not be a sufficient solution.

It is evident that the resisting effort required of the brake will of necessity be inferior to the traction effort, since these two are in opposite directions; and it is the difference between the two that alone causes the boat to advance, which is the final object in view. It is also evident that, the two operations being of the same nature, only in opposite directions, whatever arrangement is adopted for the towing apparatus may also be applied to the brake. In other words, the considerations that we have just presented add nothing new to the conditions that we mentioned at the end of Chapter II. as necessary for a good solution of the problem of chain-towage.

We will simply note in passing that these considerations show well one of the reasons why chain-towage has not been developed on very rapid streams, where its use would be the most natural. A chain tow-boat going down stream cannot run at full speed, as the chain holds it back. It runs at a speed less than the current; and the pull on the chain on curves displaces the latter in the same direction as when going up stream, and there is no method remaining to correct the effect produced.

IV.

From what precedes it would seem on the whole that, if chain-towage as practised up to the present time has defects that have interfered with its full development, all these defects are derived from one and the same cause; and, if means were found to obtain great adherence, using up but a small length of chain, which would not be overstrained, these defects would all be corrected. This being accomplished, chain-towage would regain, in most cases, its marked superiority over tug-boat towage.

The problem thus defined by Mr. Molinos, President of the Lower Seine and Oise Towage Company, this company has been trying for several years to solve the question.

Previous experiments had shown that all methods of gearing the chain by embossed pulleys, etc., should be put aside, owing to the impossibility of obtaining, or at least of maintaining, a uniform calibre in the chain.

Taking the chain up by a process similar to hand hauling, by means of projecting arms set at certain distances apart, was tried, but found to present many difficulties.

Trials in the shops were made, giving promising results, with a pulley having three prongs, which grasped the chain vigorously, operated by water under pressure. By means of a system of distribution, each prong or jaw seized the chain, and held it from the time it entered the groove of the pulley till it left it. This apparatus, however, was too delicate for rough towage work. The compression was liable to deform the chain; and, if the pulley was of small diameter, considerable water under pressure was required. Unless a small diameter is used, the speed of the pulley must be reduced; and this requires complicated gearing, heavy and massive parts.

Another suggestion was to press the chain on the pulley by means of friction rollers under constant water pressure, but here also the excessive pressure required was destructive to the chain.

At this point Mr. de Bovet suggested magnetizing the groove of the pulley, hoping thereby to get considerable power, adding the attractive force of the magnet to the effect due to winding a flexible organ through a large angle. Experiments alone could determine whether the results obtained would be sufficient, or in what measure this effect would permit of educing other mechanical devices, if any were needed in addition.

A first trial on a small scale having given encouraging results, it was decided to build a pulley of the size that would be used in practice. We have just said that it was desirable to keep to small diameters. This was fixed at 1.25 metres.

The plan was to place the chain in contact with two magnetic poles, set quite close to each other, so that, being of soft iron, it would short-circuit any magnetic current that might be developed in the magnet by an electric current. To obtain the maximum effect with the least expenditure of current, it was necessary to make the electro-magnet — that is, the towing-pulley — of soft steel, using a large mass of metal, an extra weight in this case not being objectionable.

A drawing of the trial pulley built by Messrs. Sautter, Harle & Co. is shown in Figure 5. The groove is smooth, turned on a lathe, and made so that the links of the chain will fit into it alternately in a vertical, then a normal, plane to it with the least possible play, in order to reduce to a minimum the distance between the chain and the lips of the groove. The dimensions taken were those of the heaviest chains used on the route. Consequently, it was expected that the adherence would be much reduced at those points where the chain, being old and worn, weighed less per metre, and would give more play in the groove; but, as the oldest parts of the chain are always in those sections where the resistance of the current, and consequently the traction effort, are the least, it was hoped there would still be sufficient adherence at these points, if there was on the new parts of the chain, situated on the more difficult portions of the route. For these portions we did not estimate that the traction effort would ever exceed 6,000 kilos, and we thought we should be in safe conditions if we could reach these figures with the new chain.

The total angle encompassed by the chain on the pulley would necessarily be less than 360 degrees. Owing to constructive necessities, 270 degrees was determined upon as a maximum.

Figure 5 gives all the dimensions of the trial pulley, made of 2 flanges of cast steel. The space reserved for winding the wire is enclosed by a bronze ring with rubber joints (for extra precaution the induction coil may be enclosed in a sealed casing). The bolts of the outside flanges are also of bronze. If of iron, there might be loss of current. The feed-wires pass through the centre of the shafting, and terminate on 2 insulated rings, on which are applied 2 brushes.

As can be seen, the apparatus is strong. The lips alone are liable to wear out. For pulleys in constant use the lips should be made in separate pieces, easily removable. The maintenance of a pulley of this style would be quite simple. Figure 6 shows this arrangement.

The pulley shown in Figure 5 was tested in the shops of the makers, being set up stationary; and, without insisting on the details, we will rapidly give a summary of the principal results obtained.

At first an experiment was made to determine the limit of current that it would be best not to exceed. This was done with a portion of new chain (an old worn chain would naturally be saturated by a weaker current), formed of one whole and two half links, placed against the bottom of the pulley, and sustaining a box in which weights were placed till the chain was pulled off. It was found that this sustaining effort did not exceed 300 kilos, and that the current above which no greater adherence was obtained was 48 amperes, corresponding to 37,000 ampere-revolutions and an expenditure of 4.5 horse power.

This maximum current corresponds to the saturation of a new chain of 26.5 millimetres, weighing 15.5 kilos per running metre; and we were not able to measure the slip of this chain when wound 3-4 around the pulley, as the appliances at hand did not allow over 7,000 kilos to be applied, which was not sufficient to start the chain.

With old chain, out of service owing to excessive wear and deformation, and reduced in weight to about 9 kilos per metre, the limit of adherence, when wound 3-4 around the pulley when dry, was found to be about 6,000 to 6,500 kilos, and this with an expenditure of only 3 horse power. Of course with new chain, this same power would carry more than 6,500 kilos.

With the chain wet in clear water, or soap and water, which we consider would give the same slipperiness as the slime brought up by the chain, the loss was about 10 per cent.

Even when twisted, new chain carried all the load we could get on without any slipping; and, when twisted as much as possible, badly placed on the groove, and oiled as much as possible, with 3-4 turn on the pulley, it carried more than 4,000 kilos. The adherence is good; and, with sufficient current, it is maintained even where there is back lash produced. When the limit of weight for a given current is reached or exceeded, there is a more or less rapid slip of the chain, according to the load. In fact, the pulley itself limits the stress.

We will add a last remark. We have shown how we measured the power necessary to pull the chain off in the direction of the radius with but 2 links. If we call f the shearing stress, or normal attractive force per centimetre of chain, the same conditions of current and chain which give for the total length wound 3-4 round the pulley sum $f =$ 4,000 will give for the effort necessary to produce slipping of the chain in the groove 6,000 kilos. This abnormal result seems to us to show plainly that the mechanical effect of winding enters for a large part in the results obtained.

All these experiments were made in place, but in service the speed foreseen, at the circumference of a towing-pulley of the diameter of the one experimented with, is about 1 metre; and every one knows that with such speeds the coefficients of friction are the same as at rest. At most the loss would only be that corresponding to a few less degrees of winding, and due to the retardation of the links of the chain in motion in reaching the maximum state of magnetization. There does not seem to be anything to fear on this head, as the results obtained were far beyond practical needs; and, the experiments being concluded, the Lower Seine and Oise Towage Company decided to build a boat with a magnetic pulley, the same pulley used in these experiments.

We will note that the pulley might be built in some other way, as long as the chain could short-circuit the magnetic current applied.

Thus electric cores might be placed along the radii of the pulley, as in the armatures of an alternate current Gramme machine, or along the rim, normally to the plane of the pulley, as in the armature of an alternate current Siemens machine. With the addition of a properly fitted collector, these arrangements would allow of suppressing the current at the point where the chain leaves the pulley, and thus detach it without any effort. But the construction of the apparatus would be complicated, the maintenance more delicate; and it has seemed preferable, if only on account of its rusticity, to use the arrangements just described, although the chain has to be forced off of the pulley, and a small amount of energy applied for this purpose. This is quite small, however. If we turn back to the figures given above for the shearing force per centimetre of groove, and if we admit that, after a separation of, say, 2 centimetres, no more effort is necessary, it is easy to figure that for the speed required only about 1-2 horse power is needed.

V.

In a report presented to the fifth congress of navigation (Paris, 1892), from which has been largely extracted what proceeds, we gave a description and a plan of the boat that the Lower Seine and Oise Towage Company was then building for applying the system we have just described.

The boat was not then completed. The work was well under way, and was to be completed according to the description that we then gave; but we could only surmise as to its working capacities.

Now it is completed and in regular service,* experience has caused us to make but few modifications to the arrangements first adopted, as can be easily seen by comparing the description given at that time and the following one.

The boat built by Mr. Sâtre, of Lyons, is shown in Figures 1, 2, 3, and 4.

It is 33 metres long, 5 metres wide amidships, with 2.70 hold, and a mean draft, when towing on chain, of 1.90 metres.

Advantage was naturally taken of the fact that there is a great depth in the Seine in adopting a rather large propeller.

The engine is of the overhead, compound type, placed near the centre of the boat; and, by means of two clutches, it can, as may be required, drive the propeller by direct action or the towing apparatus by means of bevel gears.

When working on the propeller, it is intended to develop 150 horse power, with 150 revolutions per minute; when working on the chain, 60 to 80 horse power and 90 revolutions.

At the rear are 2 boilers of 50 square metres of heating surface each; near the bow the towing apparatus, the transmission to which is clearly shown on the drawing.

The two rudders have been maintained as in ordinary chain tow-boats. The forward one is placed in such a way that, when it is set at rest, while the propeller is in use, there is no tendency for it to turn. The two wheels are set near together, by the side of the captain's stand, the forward one at G, the aft one at G′.

Instead of the ungainly-shaped hulls of the boats in

*We have sent to the Chicago Exposition to be shown in class 31: (1) Plans of the boat just as it was built; (2) Photographs of it as used in service. We also added drawings of the towing-pulley and a photograph of the old style boats used by the Lower Seine and Oise Towage Company.

actual use, this one has been moulded so as to give satisfactory speed when used as tug-boat. When drawing on the chain, the boat will set practically level longitudinally. In this position the bow widens out suddenly, in order to insure sufficient steadiness, even when drawing obliquely on the chain. When using the propeller, the stern must set down lower, and the raised bows show finer lines. In order to obtain this difference of water lines, there are 2 water-ballast compartments, W, W′, one forward and the other aft, with a pump for shifting the water from one to the other, as may be required.

The general form of the deck remains the same as usual. Forward and aft the chain passes over needles F, F′, similar to those on the company's other boats, then over the vertical blocks E, E′. (Figures 8, 9, 10, 11, and 12 show details of the needles and blocks.)

From the forward vertical block the chain follows the chain-way D to the towing-pulley A, around which it can make a 3-4 turn. It is guided on and off of the pulley by 2 sheaves B, B′, set symmetrically on either side of the vertical axis. If the boat is only going up stream by chain power (when going for any distance down stream on the chain, the boat is turned about), it is sometimes obliged to work backwards for a short distance in shunting, etc. The 2 guide-sheaves are set on carriages, and can be pushed back to put the chain in place or cast it off, or in order to reduce the encircling angle of the chain.

As to the towing-pulley, it is mounted at the end of the shaft; and 20 or 30 centimetres play between it and the iron portions of the deck and engine, are sufficient to prevent all loss of current.

After leaving the towing apparatus, the chain follows the chain-way, D′, beyond which, before reaching the vertical blocks, is a well, L, and a brake, M, for the purpose already described.

As chain-towage presents no great difficulties on that portion of the Seine where this boat was to be used, and does not necessitate any very great strains, we considered best to give to this well a size sufficient only to hold from 20 to 25 metres of chain. The shape, an inclined plane from fore to aft, is to prevent the accumulation of the chain on the outgoing end. The brake-pulley is built similar to the towing-pulley, only smaller, 50 centimetres. (The details of this brake are shown on Figures 16, 17, 18.) Set loosely in the boxes supporting its axis, as long as it is not magnetized it acts simply as a supporting sheave; but a roller firmly set on the same standard and just behind it obliges the chain to cover at least 90° of the sheave. So that, when a current is sent through it, the magnet always acts on a sufficient length of chain to insure its action, which would not be the case if the chain was in contact with the brake-pulley only at one point.

On the lower quarter of this same pulley there is a shoe, encircling the groove at a small distance from it, free to be drawn into it by magnetic attraction when the current is turned on, and falling back by its own weight when the current is cut off. The operation of the brake is easily understood. Turning on the current attracts the shoe, which prevents the pulley from revolving. At the same time the chain, which becomes slack on the side towards the well, is drawn on to the upper quarter of the pulley. It then covers half the circumference, and can resist a strain of 1,000 kilos in the case of a new chain with full current. The result can be varied by graduating the intensity of the current; and the paying out of the chain is the result of its weight, the tension of the chain falling at the stern, and the variable resistance of the brake. All that is needed for operating is a commutator and a rheostat placed at the captain's stand.

As to the sheaves, B, B′, that guide the chain on and off of the towing-pulley, we at first thought it might be well to make the entering one, B, of non-magnetic metal, in order not to affect the field on this side. This precaution seems superfluous. The other sheave, B′, was, on the contrary, made of magnetic metal, with a very thick rim, in order that, when in contact with the large pulley, it would present less resistance than the chain to the passage of the current, and the chain, being almost indifferent, would leave the pulley more easily. For safety and to insure this separation, a pawl, H, of non-magnetic metal, was added, fitting into the groove and overhanging it, but also supported by 4 bronze rollers resting on the pulley and transferring all the stresses to it, either from the pressure of the chain on the end of the pawl or from its tendency to raise it. (Figure 7.)

As the chain-way is but slightly inclined between the sheave, B′, and the well, in order to make doubly sure of the paying out of the chain, we placed a sheave with rough surface at the end of the chain-way, that in case of need could be operated by a receiving dynamo.

As a matter of fact, the action of the sheave, B′, which is quite massive, though somewhat effective, is insufficient to insure for a certainty the easy detaching of the chain, which has a tendency, as soon as the tension of the outgoing end is reduced, to jam in between the pulley, the sheave, and the pawl. The first trials showed that the arrangements we had made were insufficient, and that it was necessary to maintain a constant tension on the outgoing end, to make sure of detaching the chain from the pulley.

The figures from experiments referred to in the previous chapter showed that this tension need not exceed 300 kilos. It could therefore be easily obtained by a slight winding on a small pulley lightly magnetized, on the condition that the pulley was constantly revolving with a circumferential speed equal to or slightly superior to that of the large pulley.

It was best to operate this pulley by a mechanical transmission taken directly from one of the shafts of the towing apparatus. This is shown in Figure 1, at J, K. As to the details of the apparatus set up at the entrance of the chain-well, they are found in Figures 13, 14, and 15. Two guide-sheaves pressing on the chain oblige it to make a quarter turn around the magnetized pulley. Sometimes it happens, however, that the chain is under considerable tension at the rear of the boat, as well as at the bow. Then the use of the magnetized pulley at the entrance of the chain-well is unnecessary, but the supports of the 2 small guide sheaves may be considerably strained. In order not to have them made too heavy, they are mounted on springs, which allow them to rise when the general tension of the chain exceeds 300 kilos, so that they never are submitted to excessive stresses.

In the engine-room a small receiving dynamo runs a centrifugal pump that supplies water for washing the decks and chains and for operating the water-ballast.

The current for the different electric appliances is supplied by a special motor, acting directly on a dynamo set up at T. This work could not be done by the main engine, thus leaving the production of current dependent on the manœuvres of the boat.

The distributing board and resistance boxes are in the engine-room. The commutators, which regulate the current for the towing-pulley, the brake, and pulley, P, are enclosed in a box placed on the bridge near the rear rudder wheel. This is a closed box, from which the handles only protrude. A plate glass set over the keys shows these up, and at night they are illumined by 2 incandescent lights.

On the bridge, which is raised slightly above the deck (it is placed over the shaft of the large pulley), the captain has under his hand the wheel of the rear rudder, which he operates, and the different commutators, thus allowing him to control all the machinery connected with the passage of the chain on the boat without having to call on the crew. He is so placed that he can see perfectly how the chain is acting on the pulley and also give orders to the man at the forward wheel.

Everything that might interfere is carried on the port side of the deck, the starboard side being kept clear for handling the chain and shipping it on or off. The only obstacles, and these present no great difficulty, are the cleats for making fast the tow-ropes.

When the boat acts as tug-boat, it draws its tow by a single line, as usual. This can be made fast to a hook at the base of the chimney at a short distance from the plane of the thrust-bearing of the propeller. It is supported on rollers at the stern, which can be removed when the chain is used.

There are also fastenings on the deck for snatch-blocks, used when necessary for handling the chain.

VI.

Such as we have described it, this boat was put in service on the Seine at the beginning of this year. Alone of its kind at present and operating concurrently with the old style boats, it has, of course, not transformed the methods of operation; but it has completely filled all the conditions for which it was built.

It has proved that there was a satisfactory solution of the problem, as we described at the beginning of this report. We have not sought for greater traction power than that of the old style boats of this company, for this was sufficient. It takes as large tows as the others going up stream, with the same current and equal speed. The chain may be thrown off at any point with the greatest ease (it takes at most from 5 to 10 minutes) without displacing it longitudinally or forming any slack that might interfere with boats following. The necessary 3 or 4 metres of slack are obtained by one turn of the engine, by tightening the chain forward.

Going down stream, free as any other tug, it tows very correctly.

It realizes, in fact, all the advantages that we could only foretell in our report of 1892, which we then summed up thus: —

First, as compared with the system of chain-towage in general use.

Considerable less wear of the chain, suppression of the principal causes of breakage, and the service of relays, better utilization of plant, increase in traffic power, decrease in running expenses.

Possibility of towing down stream same as ordinary tug-boats.

Second, as compared with tug-boats.

Equal to them in shallow waters.

Incontestable superiority to them in high waters.

This whole amelioration, so important from different points of view, will bring about a real transformation of towage as practised up to the present time by bringing to it that which it lacked, in order to give by itself complete satisfaction to the different needs of shipping.

We will remark that a steamboat supplied like the one described, with a propeller as well as an apparatus for chain-towing, will be well adapted for use on certain rivers, such as are to be found in different parts of the world, where long stretches of easy navigation are separated by rapids almost impassable with the present means at hand, whether it be for purposes of towing freight boats or for self-propelled carriers.

We studied the apparatus described for purposes of chain-towage, the only one we have referred to up to the present point.

We are aware that trials have been made in different places to substitute a cable for the chain. All these have failed except that on the Rhine. This latter success is due, we think, simply to a local particularity. The bottom of the river where it is applied is covered with points of rock that prevent the cable from dragging around the curves, and hold it so well that sometimes it escapes only just a short distance ahead of the boat, with a vertical whip-lash motion which a chain would hardly resist. This special circumstance, therefore, obviates the principal objection to the use of a cable, and justifies it in this case. But otherwise and in a general way we consider the cable inferior to the chain for towing.

Owing to its short duration, it is not more economical. On the contrary, as it can only be rolled on large diameters, it necessitates much larger and cumbersome apparatus.

Being too light, it is displaced much more in the curves by the tractive effort, and thus renders the passage of a boat much more difficult, notwithstanding the much easier steering facilities attributed to a cable tow-boat, but which we consider very doubtful.

It breaks less frequently, but it is harder to fish up and much more complicated to splice together.

It winds more smoothly and evenly, it is true; but we do not think that this single advantage compensates for the inconveniences we have enumerated.

We can but point out these different facts, as to discuss them would necessitate an additional report; and we refer to it only to explain why, in searching for improvements in the towing industry, we have considered only chain-towage.

We would, however, note that in the rare cases where cables could be used with advantage magnetic pulleys, similar to the one we have described, might well replace the one with much more delicate jaws, more expensive, and one that exerts a most destructive action on the cable.

The twisted chain passes on the pulley, as we have described it, with sufficient adherence; but sometimes it is straightened out when in the groove, this giving rise to a jerk. It is best in all ways to see that it is kept free from twists, as thereby it is much better preserved. This is all the easier to do with a few hand spikes, as the whole towing apparatus has a tendency to untwist the chain when it has been poorly placed.

It might be possible to have a pulley with a single groove instead of the double one we have adopted, through which the links would pass x-wise. From a few experiments made, we estimate that with a good construction of this shaped groove the loss of adherence would be about 1-3 as compared with the double groove system. The former arrangement seems to us the best.

The total adherence increases with the weight of the chain. For streams with rapid currents a much heavier chain is necessary than on the Seine, so that even in this case there will be sufficient adherence without need of exaggerating the size of the pulley. Besides the 2 sheaves, B and B′, might be magnetized and made to revolve by power (Figures 1 and 7), and thus increase the length of active chain, and consequently the total adherence. In this case, if care were taken to give to the sheave, B′, a less amount of magnetism, it would play the part of the pulley, P; and the apparatus at the entrance of the chain-well could be dispensed with.

VII.

VARIOUS APPLICATIONS OF THE MAGNETIC PULLEY.

In closing, we would note various applications of the magnetic pulley that we have been describing.*

Mechanical Traction on Canals.— It appears to us that it might give a satisfactory solution to the question of mechanical traction on canals. A pulley of but 40 centimetres in diameter would be sufficient with a light chain, 3 to 4 kilos per metre, to give the necessary effort to propel a dumb-barge, which is the heaviest boat to draw in a canal. In these conditions the proposed solution would be to rig up an apparatus consisting of a towing-pulley with accompanying guide-sheaves, a driving dynamo, and

* See these different applications in the bulletins of December, 1892, and of January, 1893, of the International Society of Electricians.

the necessary connection transmission. The whole, of small volume (about 1.25 metres by 1.20 metres by 0.80 metre), and weighing not over 1,500 kilos, would be enclosed in a box, and set on the boat as it reaches the canal and unloaded from it as it leaves it, to be used on another boat for the return trip. There would be one or two submerged chains in the canal, according as the traffic was or was not of such importance as to allow the necessary time for shifting the chains on passing boats. The current would be taken from an overhead line, as in the case of electric tramways. A commutator handle projecting from the box would allow of running faster or slower or of stopping. This would be done by the boatman himself, without any outside help, so that he would remain entirely independent, to stop or go ahead as he pleased, as he might at any time take on, or throw overboard the chain. We intend shortly to make a trial of this system, in accordance with a wish expressed by the fifth international congress.

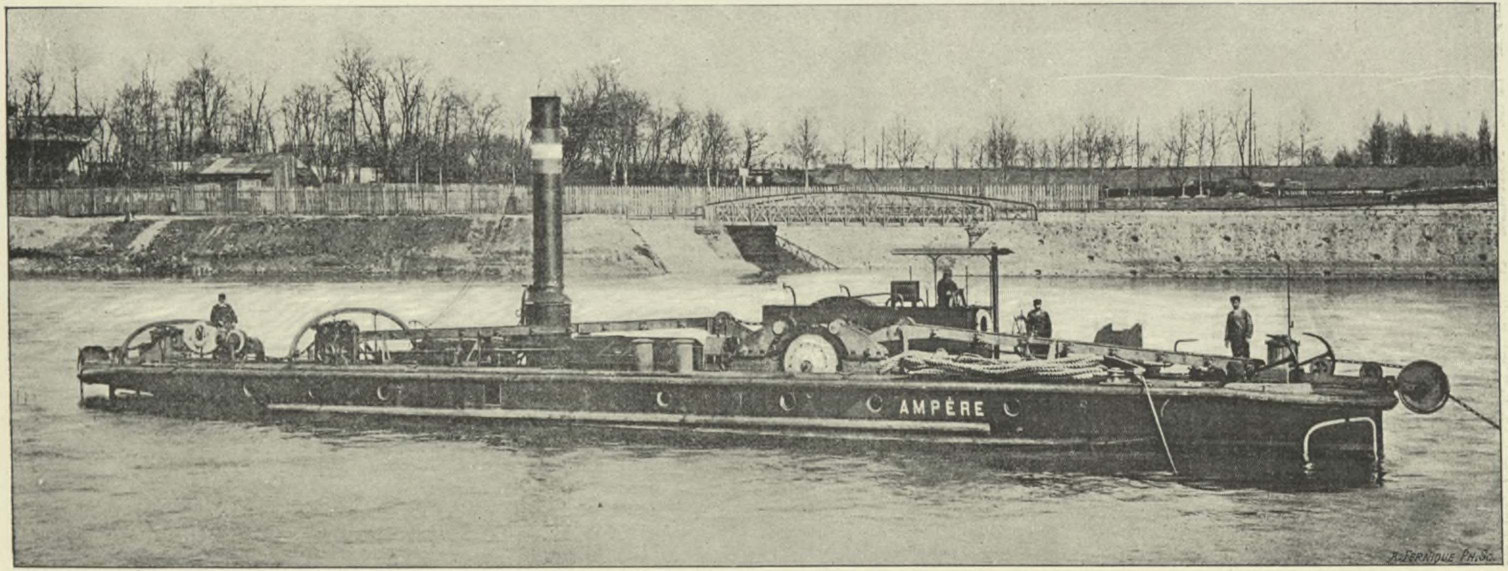
Hauling by Floating Chain. Transmission by Chain.— In a different line of thought, it is clear that the magnetized pulley could be applied with success in cases of mechanical hauling by means of a floating chain. It would also apply to transmitting movement from one shaft to another without all the difficulties due to variations in the thread, which are so vexatious in all systems of chain-gearing.

Carriage and Car Brakes.—With the same construction of pulley, but with a different-shaped groove, and replacing the chain by a flexible blade or sheet with shoes, we obtain a brake at once simple, strong, and easily moderated. Here the widening of a flexible organ again intervenes in a very efficacious manner, that certain measures that we were able to take make quite evident. It is shown by this fact that the curve constructed by referring the total slipping stress to the exciting of the electro-magnet still remains very much inclined on the line of ordinates in that portion where, if the magnetic attraction acted alone, it would be almost parallel to it. From trials made at the shops we believe that we may conclude that with a pulley of 40 centimetres diameter, the heaviest brake effort that need ever be applied to the axle of a heavy wagon at high speed needs but 40 Watts per axle. Such a brake would have the advantage of absolute simultaneousness. It could easily be made automatic.

Couplings.— By slight modifications in the shape of the pulley, and replacing the chain or blade by a ring of magnetic metal, we lose the advantages of a flexible organ; but we get an excellent utilization of the field, and arrive at forms giving good mechanical working couplings, from which we have obtained very good results. In many cases they constitute very good limiters of power (for instance, on dredges). With very slight expenditure of current, considerable power can be obtained. Coupling is rendered possible at full speed, or the transmission of any power without shock, by allowing any length of time desired from the first setting in motion to the full coupling up. We think we can obtain with this apparatus even the power necessary for reversing the run in rolling mills: the possible applications are evident either as couplers or brakes.

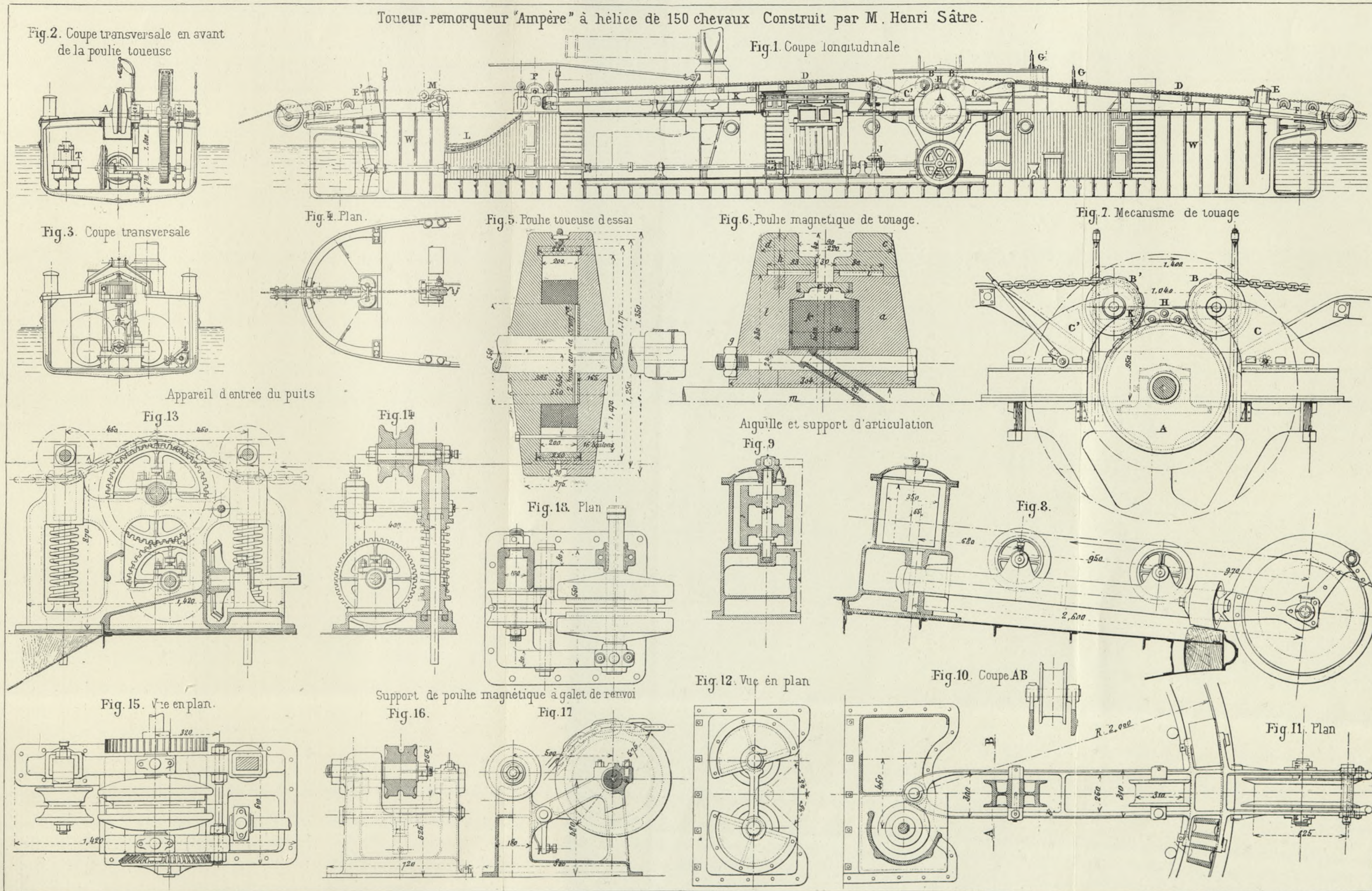
To return to our subject, we will mention as example the following case. On a river with rapid current the necessary manœuvres to keep the chain in proper place going up stream may require for a time the use of the propeller, or paddle-wheels, at the same time that the towing apparatus is in operation. This happens, by the way, on the Danube. Well, nothing would be easier on a boat such as we have described than to arrange the coupling of the propeller in such a way that going up stream it could be stopped at will, while keeping the arrangements so that in going down stream by the power of the propeller it could be coupled without the use of the current.

PARIS, May, 1893.



VIEW OF THE CHAIN TOW-BOAT AMPÈRE.

CHAIN TOWAGE BY MAGNETIC ADHERENCE.—DeBovet's System.



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