

PNEUMATIC TELEGRAPHS FOR LONG DISTANCES.*

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[Continued from Vol. lxx, page 285.]

In the present state of the question it seems evident that, even taking into account a postal service already well developed, the diameter of a pneumatic tube should never exceed one-tenth of a meter; under these conditions the limit of remunerative cost has been reached, beyond this limit the cost becomes greater than that of a railway. If such a tube is worked by engines of sufficient power, it can transmit as many as 100 boxes per hour, representing nearly 100 kilograms weight of messages, which, divided into letters of 20 grams each, would equal 5000 of such letters per hour.

It is evident that a traffic of this kind would be far in excess of the amount of work possible at the present time.

We have just seen by what has been previously stated on the subjects of pressure and diameter, that these two elements in the establishment and working of a pneumatic tube, cannot, practically, be extended beyond certain limits; we now proceed to examine the influence of the length itself. We again revert to the fact that all the advantages of a pneumatic telegraph consist in its compensating, by its capacity, for its relative slowness as compared with electricity. It is necessary therefore, if we wish to go far, to go at a high speed; we have just seen within what limits we can avail ourselves of increased pressure and diameter, and the result of our examination is, that a solution of the problem must be sought in some other direction.

The first investigations of the subject date from 1857; they were made by Mr. Latimer Clark, who brought forward the question of the necessity for a mechanical arrangement to allow of the working of lines of comparatively great length. A kind of opening was arranged which was closed by means of special mechanism at the moment a train passed, when a train was being impelled by compressed air, and was opened upon the passage of a train in the opposite direction, drawn inwards by the vacuum.

The advantages of a plan of this kind were indisputable, and we find in the journal *Engineering* of the year 1869 the description of an apparatus proposed by Mr. Sabine, which affords a satisfactory solution of the problem.

* Extracted from the *Telegraphic Journal*, London.

Mr. Sabine has taken the case of a line similar to one of the principal line radiating from the Post Office in London, and constituting a line of communication with a point more or less distant by means of trains alternately driven forward by pressure of air, and afterwards drawn back again by a vacuum applied at the end of the tube terminating in the central station.

His arrangement consists of a valve acted upon through a hinged rod by a sort of diaphragm of leather or india-rubber, the latter being influenced through a special tube by the vacuum or pressure at the central station. This diaphragm opens the valve, and when sending by pressure the air, by escaping through the opening, allows the train to traverse the first section as if the line consisted merely of the length between the starting point and the valve. The moment the train passes the opening, it detaches the valve from the rod which connects it with the diaphragm, by the action of a spring; the valve then closes, and the train passes through the second section with the speed proper to a line having the length of the two first sections, and so on.

If the central station draws a train from the extreme end, the apparatus acts in the following manner: by means of the vacuum actuating the diaphragms through the special tube, all the valves are closed, the line can then be exhausted of air in front of the train which, as it passes the valves, acts upon the bolts, and thus disconnects them, so as to allow the air to enter behind the train at the end of each section; the same advantage is thus obtained as when sending by pressure.

The table given below shows the advantage gained by employing this apparatus; a line of ten sections is taken for example.

No. of Section.	Time of transit in each section.	Total time of transit.			Percentage of gain.
		With Valve.	Without Valve.		
1	1	1	1		
2	$\sqrt{2}$ 1.41	2.41	$2\sqrt{2}$	2.82	17
3	$\sqrt{3}$ 1.73	4.14	$3\sqrt{3}$	5.19	25.4
4	$\sqrt{4}$ 2.00	6.14	$4\sqrt{4}$	8.00	30.3
5	$\sqrt{5}$ 2.24	8.38	$5\sqrt{5}$	11.20	33.7
6	$\sqrt{6}$ 2.45	10.83	$6\sqrt{6}$	14.70	35.7
7	$\sqrt{7}$ 2.65	13.48	$7\sqrt{7}$	18.55	37.6
8	$\sqrt{8}$ 2.83	16.31	$8\sqrt{8}$	22.64	38.8
9	$\sqrt{9}$ 3.00	19.31	$9\sqrt{9}$	27.00	39.8
10	$\sqrt{10}$ 3.16	22.47	$10\sqrt{10}$	31.60	40.6

From this table it is seen that the percentage of gain goes on increasing as the line becomes longer; the gain which is 17 per cent. for a line of two sections, with only one apparatus in the middle, increases to 40 per cent. upon a line of ten sections provided with nine of the apparatus distributed throughout its length.

The remedy is, however, far from being a radical one, for, if it allows pneumatic lines to be extended in length, it limits this extension, and the same table which shows the advantage of the apparatus, shows also very clearly the limit of the same extension; for we see that even with the proposed improvement it takes 3.16 times the time to traverse the tenth section that is necessary to pass through the first, and that averaging the gain over the whole length, the mean time occupied is represented by 22.47 instead of 10, which would be the figure were all the sections traversed at the same speed as the first. The mean speed after the tenth section has been passed is less than one half; the time occupied is nearly three times what it ought to be.

The solution of the problem of a line of unlimited length with a constant speed required a more complete apparatus, and it is this apparatus to which I have given the name of *relay*, that I am about to describe. Its object is to perform in the most complete and exact manner the operations which would be carried out by an attendant who, under conditions about to be described, would have to act in the following manner.

The pneumatic line of extended length has been, as in the case of lines established within the limits of cities, divided into sections of about one thousand meters in length; each of these sections is furnished at its commencement with reservoirs in which is stored up the compressed air, having the pressure and volume necessary for performing the service of the section. The case is exactly the same as that of an intermediate station in a city, provided with means for compressing air; the two lines up and down are arranged in a straight line, end to end, in such a way that a train received on the up line can pass without impediment into the down line; the attendant, whose presence we assume, would await the arrival by the up line of a train which was being sent to him, allowing to the air to escape freely at the end of the section. At the moment when the train passes from the up line into the down line he closes the former behind the train, and opening a cock communicating with his own reservoir of compressed air, by this means drives the train forward along the next section;

he keeps the cock open whilst the train is passing to the next station, and closes it when informed of its arrival at the latter point by the attendant there in waiting.

Such are the various operations which must be performed automatically by the relay; the first apparatus used and giving certain results was tried in the month of May, 1873. The trials were made in Paris, upon the direct line from the Central Station to the Bourse; and in London, in the engine-room at Telegraph-street.

At Paris the apparatus was placed under a cast iron plate, and was connected by special pipes with the reservoirs of compressed air in the station at the Théâtre Français.

This apparatus fulfilled exactly all the operations above described as having to be performed by the attendant supposed to be placed at the intermediate station. The escape of the air took place in front of the relay, where a portion of the tube was perforated on all sides so as to give a passage to the air equal to twice the section of the tube. The closing of the line behind the train, and the opening of communication with the compressed air reservoirs were governed by a kind of trigger, and acted upon by the train directly it had passed through the relay. The duration of the blowing was determined by a piston rising in a cylinder through the effect of the internal pressure; the rising of this piston was regulated by the counter-pressure in such a way that the blowing continued somewhat longer than the time necessary. The moment a train arrived at its destination or entered a further section the pressure being destroyed in the line the weight of the regulating piston caused it to fall and remain in position to await the arrival of another train.

The success of this apparatus was complete; it enabled a certain number of trains to be passed to and fro between the Central Station and the Bourse with a saving of more than half the time. The return journey was equally rapid, for the trains were sent by pressure as far as the relay, the escape of air taking place through the perforated part of the tube; the rest of the journey was accomplished by means of vacuum from the Central Station.

The objection made to this apparatus is its delicacy; it contains within it a piece easily broken, this piece is the valve employed to close the line; if a foreign body hinders, even partially, its action the relay becomes nothing but an obstacle preventing, in the most absolute manner, the passage of the trains.

To remedy this objection it becomes necessary to do away with this valve which, after the description which has just been given, would seem to be the essential feature of the apparatus, since it is that which separates the outlet from the inlet. It could only be removed by suppressing the outlet, and to enable the latter to be dispensed with, the counter-pressure must be taken away.

It is this chain of observation which has guided me to the formation of the plan which I now proceed to set forth, and which completely solves the problem. The line is double acting; by means of special apparatus which are also relays, it is kept constantly exhausted of air and there is consequently no longer any counter-pressure nor are there any valves in the pressure relays.

By the side of the line, which we may assume to be of unlimited length are laid two secondary tubes connecting the reservoirs of vacuum and compressed air for the supply of the relays, which are placed in convenient positions along the course of the line. These relays are of two kinds; those destined to exhaust the line of air are placed five kilometers apart where it is intended that trains shall be sent along the line at intervals of a quarter of an hour. The reason for their being placed at this distance apart is, that a rather less space of time is needed for exhausting five kilometers, and there is, therefore, no advantage gained by placing them nearer together. They are of a very simple form, a piston rising in a cylinder carries with it a valve closing the line, and a slide opens the communication with the vacuum reservoirs; the piston is raised in the cylinder on the passage of a train, by the counter-pressure which follows the moving power, it closes the line behind it, and at once starts the exhaustion of the section of line which has just been traversed by the train. The valve of this relay has none of the objections attaching to that of the former relay, seeing that it opens of itself after the exhaustion of the section appertaining to the vacuum relay has been completed, an operation which is generally accomplished in half the time prescribed for the interval between the passage of two trains. Moreover, as these relays are placed every five kilometers, and at least one half of them are in places provided for compressing and exhausting the air, they are under the eyes of the attendants. The pressure relays placed one kilometer apart become simple blowers, opening on the passage of a train, and blowing all the time the train is traversing the section;

they merely consist of a piston pushing a counter-weight acting upon a slide, which is the pressure slide, and the regulating piston which stops the admission of air after the blowing has lasted the proper time; the compressed air enters the line by a kind of grating which uncovers openings having twice the sections of the line, and the blowing is governed by the train itself which, acting upon a trigger, lets fall a counter-weight placed upon the piston working the slide. The blowing is instantaneous; it is stopped by the action of the regulating piston which closes the communication leading to the line, and shuts up the compressed air in a small chamber between the point where the communication is thus closed and the slide. The effect of this compressed air at the moment when the pressure is lost in the line, that is to say, at the moment when the train has passed through the section, is to raise the piston acting upon the slide, and to restore everything into position for the arrival of another train. This apparatus, which is the main feature of the new system, is extremely simple, and does not require personal supervision in its working. It is accompanied by a reservoir of compressed air of sufficient capacity for the section.

I need not here discuss in detail the means by which the compressed air and vacuum are to be brought to the reservoirs serving the relays. Any of the methods usually employed for this class of work can be made use of, but the most economical process would, of course, be selected. In a populous country the engine stations might be numerous, and the power employed small. In thinly inhabited countries they might be 20 or 25 kilometers apart, and the power would then have to be greater.

I now proceed to the consideration of the speed with which the boxes will travel in a pneumatic line of unlimited length, in which, by the methods described above, the vacuum will be kept at 0·5 meters of mercury, and the pressure, admitted by the relays at intervals of 1000 meters, equal to 0·76 meters of mercury; the tube to be one-tenth of a meter in diameter.

My point of comparison will be the speed in the tubes of the Paris system, where a pressure of 0·4 meters of mercury gives a speed of 20 meters per second, in a line 1000 meters long, and 0·066 meters in diameter.

The increase of diameter will increase the speed in the proportion

$$\sqrt{\frac{100}{65}} \text{ or } \frac{10}{8}$$

say 25 meters per second.

The fact that the line if kept exhausted of air will reduce the friction in each length of 1000 meters to an average equal to that of 600 meters at most, for at the beginning of each section, that is to say, at the moment when the train passes the pressure relay, there is no column of air traveling with it; at the termination of the section only, will the column of air which drives the train have a length of 1000 meters. If the vacuum were perfect, the average friction length of the column of air would be but 500 meters. The diminution in the frictional length of the column of air gives an increase of speed in the proportion

$$\sqrt{\frac{1000}{600}} = \frac{33}{24}$$

The speed, raised to 25 by the increase of diameter, now becomes

$$25 \times \frac{33}{24} = 36 \text{ meters.}$$

We have then the increase of the differences of pressures, which is also in the ratio of the roots

$$\sqrt{\frac{26 + 50}{40}} = \frac{115}{65}$$

The application of this last ratio indicates a speed of nearly 70 meters per second.

This is an enormous speed, and would in all probability be attended with some inconveniences, but it is evident that we should work with the highest speed possible.

Now, observations made with trains running under similar circumstances at speeds of 40 to 50 meters, have shown that these practical speeds are quite admissible in regular working. It is only necessary to employ a very strong material, arranged in such a way that it alone shall wear without wearing the line; this end is attained by fitting the rubbing parts of the boxes with a softer metal than that composing the line.

The two ends of the line are provided with apparatus suitable for sending and receiving, in which precautions are taken to secure a

considerable slackening in the speed of the train when approaching its destination.

This effect is obtained by causing the air in front of the train to be compressed in the last hundred meters leading to the receiving apparatus; this compressed air is allowed to escape slowly in such a way that the train rises slowly into the apparatus.

Pneumatic lines with relays would certainly be a valuable means of communication for correspondence between distant places. The facility with which trains can be multiplied upon these lines without considerable expense, the speed which they can attain, and even the small net cost of the system, if too large a diameter be not employed, would make it one of the greatest utility to the Postal service.

The speed of transmission is three times that of the fastest railway train, if the stoppage of the latter are taken into account, and the establishment of the system upon lines where several days are required for exchange of letters, would evidently be of immense service.

A line of this kind has been proposed for establishing rapid communication between the Assembly at Versailles and the Ministerial offices in Paris; its execution would be a first step in this path, which is little known and which has been but little explored.

Useful Effect of Gunpowder in a Cannon.—M. De Saint Robert, in an article from his pen in the *Revue Scientifique*, gives the following calculation of the efficiency of a rifle cannon, the diameter of the bore of which is 7.5 centimeters = 3 in.—the shell of which weighs about 3.7 kilograms = 8.3 lb.—and the firing charge of which is 0.55 kilogram = 1¼ lb. It may thus be estimated:—Experiment has shown that the velocity of the shell when it leaves the mouth of the cannon is about 400 meters = 1300 ft.—per second. The height from which the projectile would have to fall to acquire this velocity is 8158 meters = 26,800 ft. Consequently the work actually done by the powder is equal to 30.185 kilogrammeters = 219,000 foot-pounds. On the other hand, Bunsen and Schischkoff have found by direct experiment that the heat evolved by the combustion of a kilogram of gunpowder is equal to 619.5 calories. Hence the heat evolved by the above charge of 0.55 kilogram is equal to 340.7 calories. The mechanical work corresponding to this amount of heat is 144,798 kilogrammeters = 1,050,000 foot-pounds. Comparing this, which is the possible mechanical work, with the actual work done on the projectile as given above, the ratio is 0.208 for the effectiveness of the cannon; that is to say, about 21 per cent.