THE OBSTRUCTION TO THE NAVIGATION OF RIVERS CAUSED BY THE PIERS OF BRIDGES.

BY J. W. SPRAGUE.

About a year ago, I was called on to survey a portion of one of the largest navigable rivers in the United States, in the immediate vicinity of a bridge, which had been erected over it. The object of this survey was to determine how much the navigation of the river had been obstructed by the piers of the bridge; and to procure data for testing the accuracy of the calculations of those engineers who had preceded me. A suit, of the nature of an injunction, was pending against the bridge. The affidavits, already taken in the case, were submitted to me, when I was surprised to find the singular errors into which some of the engineers (whose high professional position entitled their opinions to command the respect of all) had been led, by seeking to apply the formulæ of the books to a case to which they were totally inapplicable. All must admire the accurate precision with which a mathematical formula points out the steps that are to be pursued to arrive at the desired result; but experience has satisfied me that it is rarely safe to trust a formula to the hands of any one who, either from want of time or lack of ability, cannot first *retrace* the steps by means of which that formula has been drawn from well-known data. So rarely do bodies in the physical world present themselves to our notice under *precisely* the same circumstances as those assumed in the data from which the formula is deduced, that it is almost always necessary to make some allowance for the change in the condition of things. He who attempts to make such corrections, without a thorough understanding of the formula he is using, gropes in the dark, equally inclined to wander further from the right path or to stumble back into it.

In the case alluded to, the formulæ of the books were based upon the supposition that the line of the piers was parallel to the line of the current of the river. A survey of the premises indicated a considerable angle between the line of the piers and the line of the current. The formulæ of the books were used, but whatever corrections were applied carried the result further from the truth than would the simple formulæ. Even where the case that presents itself to us corresponds exactly with the one from which the formulæ are derived, there is liability to error, from not *entering* the formulæ with the correct units of time, space, or weight. Some formulæ require all distances to be expressed in inches, others in feet. After a formula has been developed, upon the supposition that an inch is the linear unit, we cannot always afterwards change that unit to a foot, without a complete revision of the formula.

The preceding remarks will, I trust, be deemed a sufficient apology for introducing to the readers of the SCIENTIFIC AMERICAN, a series of articles on "The Obstruction to the Navigation of Rivers caused by the Piers of Bridges," in which a simple method will be pointed out, by means of which the increase in the velocity of the current, and the hight of *remou* or back-water produced, can be determined with a considerable degree of accuracy by any engineer understanding the first priples of his profession. Perfect accuracy, however, is unattainable by any process. It is also proposed to discuss the additional power required to carry a steamboat up through the draw of a bridge over that required for plain steaming. Not to perplex the student with too many refinements of processes at the outset, some statements will be made as if they were strictly correct; and afterwards modifications will be pointed out. Unless expressly stated to the contrary, it will be understood that the line of the piers is parallel with the line of the current.

Suppose, at a certain stage of water, the cross section of the water prism of a river, just above the pier, to be 10,000 square feet, and the sum of the greatest cross sections of the immersed portions of the piers and abutments to be 1,000 square feet; how much greater velocity will the water have between the piers than above them? The contracted water-way will be 9,000 square feet; and as the same amount of water must pass each second through the 9,000 square feet as though the 10,000 square feet of uncontracted water-way, it is evident that the velocities at the two points must be to each other inversely as the areas, or that the increased velocity is to the original velocity, as 10,000 is to 9,000, or as 10 to 9. This would give the *increased* velocity 10-9ths of the original velocity, and the *increase* of velocity 1-9th of the original velocity. As a rule, then:—*Divide the uncontracted water-way by the contracted water-way; the quotient, less unity, will give the relative increase of the original velocity caused by the piers.*

To test the accuracy of the above rule, take any velocity, say 18 feet per second, as the original velocity. The *increase* of velocity would be 1-9th of 18 feet or 2 feet, and the *increased* velocity 20 feet per second. The number of *cubic* feet of water, discharged through any area per second, is evidently equal to the product of the *square* feet of the area opening, multiplied by the velocity in *lineal* feet per second, with which the water flows through the opening. The quantity of water discharged per second through the contracted water-way will be 9,000 square feet × 20 lineal feet = 180,000 cubic feet. The quantity of water discharged per second through the unconstructed water-way will be 10,000 square feet × 18 lineal feet = 180,000 cubic feet. The products being the same in both cases, as evidently they ought to be, proves the accuracy, both of the rule, and of the operation performed under the rule. In practice, it is always advisable for the engineer to apply such tests, since there he will seldom find ratios so simple as those here chosen.

The rule given above seems to derive itself from almost self-evident propositions, yet in the case already alluded to, almost every engineer was led into error on this point, probably by such reasoning as this:—If the uncontracted water-way is 10,000 square feet, and the obstruction is 1,000 square feet, then the obstruction is 10 per cent of the whole water-way, and requires an increase of 10 per cent, or 1-10th of the original velocity, to carry the water through the piers. This fallacy, stated in the form of a rule would read:—Any per-centage of obstruction to the water-way causes the same per-centage of increase of velocity. To show the absurdity of this, take a case where 50 per cent, or half of the water-way is obstructed. The rule would give an increase of 50 per cent to the original velocity; but it is evident, that if we would force the same quantity of water per second through half of any space, we must give the water *twice* the velocity that would be required, if the whole space was free. Doubling the velocity is giving it an increase of 100 per cent, not of 50 per cent, as shown by the rule. Yet again: suppose the whole water-way, or 100 per cent, obstructed; then, according to the rule, the velocity would be increased 100 per cent, or doubled; and we should have the peculiar phenomenon of a river discharging itself through no space at all, by merely doubling its velocity. The correct rule, already stated, would give for such a case an *infinite* velocity, indicating an absurdity in the proposition. The reason why these absurdities did not discover themselves to the parties in question was, that the per-centage of obstruction being only about 1-10th of the whole water-way, the error would not show itself without some calculation.

I will close the first article of this series, by giving the test applied to the calculations of one of the most distinguished engineers in the country. I speak of him as such, in order to show, conclusively, how liable *all* are to fall into error. The data are those given by him; I have only combined them in such a way as to produce what may be called a *reductio ad absurdum*:—

Uncontracted water-way	19,383 sq. ft.
Obstruction caused by piers, &c. (about 8½ per cent.)	1,667 "
Contracted water-way	17,716 "
Velocity in uncontracted water-way	6.74 per sec.
Velocity in contracted water-way	7⅓ "
Water discharged per second through uncontracted water-way, 19,383×6.74=	130,641 cu. ft.
Water discharged per second through contracted water-way, 17,716×7⅓=	129,858 "
Error of calculation, as shown by quantity of water accumulating each second above the bridge	783 cu. ft.

Adding 8½ per cent to 6.74 gives 7⅓, showing conclusively how the result was arrived at, and how the error crept in. The real error was, however, much greater than that indicated above, as will be evident further on, when certain necessary modifications are introduced.

[To be continued.]

ALL the rivets of the British iron ships are to be covered with cement, to prevent the action of bilge water.

THE LIME LIGHT.

Some recent improvements in the calcium light have been made in England, which are attracting a great deal of attention. The London *Journal of Gas Lighting* contains a long article on the subject, from which we make the following extracts:—

A light of great brilliancy was, some years ago, produced by combining a large volume of oxygen gas with a congeries of argand or other burners, supplied with oil, and known as the "Bude Light," but, like others, it was finally rejected, as disadvantageous in practice. For many years—even as far back as 1820—attempts were made to obtain a safe and intense light by the ignition or combustion of a ball of lime, in the united flames of hydrogen and oxygen gases. It was employed for microscopic purposes, and is stated to be equal to about 264 flames of an ordinary argand lamp (consuming the best spermaceti oil), each of which is equivalent to ten wax candles of four to the pound.

About the year 1826, Lieutenant Drummond, who was appointed to conduct the ordnance survey in Ireland and Scotland, first applied the lime light in the focus of a paraboloid, on lofty eminences, where the stations were usually placed, as it was of great importance in those operations to have certain and determinate signals, which could, almost under any circumstances of the weather, be seen at great distances; and by it he successfully connected the opposite shores of Ireland and England at or about Holyhead—a distance of about 64 *miles*. He used, on some of those occasions, oxygen gas, and alcoholic vapor, but ultimately substituted hydrogen gas for the latter. In Scotland he obtained a most successful result on the summits of Ben Lomond and Knock Layd—a distance of 95 *miles*, thus demonstrating the practicability of adopting the lime light for long distances.

It was found by Drummond that many substances were capable of producing light in conjunction with gases, but that, of all those which were available for the perfect combustion of the gases, chalk lime was the most suitable material for the purpose, and hence the name of "Lime Light." It was also the cheapest and most easily attainable in any locality. It was likewise found that several gases, compounds of hydrogen, might be successfully employed in combination with oxygen gas, as well as pure hydrogen. Pure hydrogen gas, obtained from zinc and diluted sulphuric acid, offers facilities in cases where carbureted hydrogen, as supplied by the gas-works, cannot be readily procured; but coal-gas, where available, is a most desirable substitute for the ordinary applications of the light.

The generation of oxygen gas, which plays so important a part in the production of this light, is one of extreme simplicity. It is obtained cheaply and easily from a variety of substances, each existing in great abundance, viz., peroxyd of manganese (black oxyd), chlorate of potassa, nitrate of potassa (familiarly known as saltpeter), and some other substances, the employment of which for this purpose is, however, precluded by their cost, as oxyd of lead and red oxyd of mercury; but it is probable that these will yield a residuum as the other substances, which residuum will become an article of ready and remunerative sale, by which the cost of the gas produced from them will be reduced to a mere nominal value.

The peroxyd of manganese requires simply to be placed in a retort raised to a red heat, when the oxygen gas is freely disengaged. So soon as the gas ceases to be evolved from the manganese (which can only be effected practically to the extent of about 11 per cent, although it contains at times 80 per cent), the residuum, the deutoxyd or sesquioxyd of manganese, may be drawn from the retort; and if thrown into water, or exposed at a high temperature to the action of the atmosphere, it will attract oxygen with great avidity, and thus this refuse becomes revivified, or resumes its former state of a peroxyd, fitting it by this operation for a repetition of the distillatory process. This peculiar property of the deutoxyd of manganese (of rapidly absorbing oxygen from the surrounding air or other oxygenated bodies brought into contact with it) gives to this substance a great commercial value as a material for producing oxygen gas; for since the actual consumption of the manganese is thus limited by the quantity necessary to provide for the supply of gas during the time required for the revivification of the exhausted material, a comparatively small stock only will be needed to compensate for the unavoidable waste consequent on this mode of operating upon it. In