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NOTE RELATING TO "WATER-HAMMER" IN STEAM PIPES.

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[A paper read before the American Society of Mechanical Engineers, June, 1883.]

The writer has been called upon during the past winter, in the course of his professional work, to examine into the systems of steam heating in use on so large a scale in New York city, and elsewhere, and to report upon the condition and capabilities of one of those "plants" which have been put in operation. In the course of this investigation he was compelled to examine into the peculiar methods of injury to which long lines of steam pipe thus used are exposed.

The action familiarly known as "water-hammer" had been long known to him, as to every engineer who has had much to do with steam power, and its singular effects had been often observed and commented upon by him, as by others; but, in this case, these effects were developed on so large a scale, and were so serious oftentimes in their consequences as to impress upon him the desirability of examining into the matter more carefully than had yet been done. He has not been able to make a systematic and thorough investigation, such as he would have liked to make; but he has been able to collect some facts, a few of which will be here presented, that may at least have the effect of calling the attention of engineers more generally to this matter, and may lead to further study of the subject.

When a pipe is filled with steam, and then has introduced into it a quantity of cold water, or when a pipe, itself cold, and containing cold water, even in very small quantity, and without pressure, has steam turned into it, the first contact of the two fluids is accompanied by a sudden condensation, which causes a sharp blow to be struck, usually at the point of entrance; and sometimes a succession of such blows occurs, which are the heavier as the pipe is larger, and which may be startling, and even very dangerous.

It is not known, so far as the writer is aware, precisely how this action takes place in all cases, or what conditions are most favorable to the development of the tremendous pressures which are often produced. Perhaps the action is as follows:

The steam, at entrance, passes over, or comes in contact with the surface of the cold water standing in the pipe. Condensation occurs, at first very slowly, but presently more quickly, and then so rapidly that the surface of contact between the two fluids is broken, and condensation is completed with a suddenness that produces a vacuum. The water surrounding this vacuum is next projected violently from all sides into this vacuous space, and crossing it, strikes upon the surface surrounding it. As water is nearly incompressible, the blow thus struck is like that of a solid body, and the intensity of the resulting pressure is the greater as the distance through which the portion of surface attacked can yield is less. In this manner enormous pressures are sometimes produced.

In some cases it seems certain that such pressures may be caused at points in the pipe far from either end, and from the point of entrance of the steam. For example, a pipe may lie in a nearly or quite horizontal line, and, if not fully drained, may contain a considerable quantity of water lying in the lower portion, while the steam may flow in above it. The passage of this steam along the surface of the water may cause some disturbance of the surface of the liquid, and this disturbance being gradually increased as the flow of steam becomes more rapid, may finally cause a break in the surface of the water, which disturbance may produce more rapid condensation and still further agitate the mass, until condensation occurs with such rapidity that a vacuum is formed at the point of greatest action. The next result is the rushing of steam from both directions towards this point, carrying with it, as it goes, masses of water which, coming from opposite directions with enormous velocity, meet at the intermediate spot at

which the condensation has been most rapid, and being stopped by instant collision, produce a pressure which may only have as its limit the strength of the pipe.

Where pipes are not burst by this action, it is common to see them sprung and twisted out of line, torn from their connections, and, when a succession of shocks occur, as is often the case, the whole line writhes and jumps lengthwise to an extent that is sufficiently serious to cause well-grounded alarm.

The writer had an opportunity, in the course of his work on the case above alluded to, to obtain some probably approximate measures of the intensity of this action in long and heavy lines of pipe. Four lengths of 8-inch pipe had been split by this action, and the writer desired to ascertain whether they remained, in their injured condition, strong enough to bear the ordinary steam pressure of the line from which they were taken. This never rose above fifty or sixty pounds per square inch. They were therefore subjected, in a proving-machine, to gradually increased pressures until the already fractured parts were still farther injured, the repairs, or rather the patching having been carefully done in such a way that they were not strengthened by it. This was done by putting on soft patches along the line of the split and securing them by bolts which were set in the line of the split. The patches thus served as simple stop-valves, preventing the exit of the water through the break.

The following are the results of the tests:

Pipe No. 1.—This pipe was split, near one end, for a distance of 15 inches, along the line of the weld. When placed in the proving-machine, it bore the applied pressure until it attained an intensity of 400 pounds per square inch, when the split suddenly extended about ten inches; the pressure could no longer be kept up, and the test terminated.

The pipe was then taken to a pipe-cutting machine, and the injured part cut off. It was then again subjected to pressure. It bore a pressure of 1,100 pounds per square inch,—the highest that it was convenient or customary to apply to that size,—and was taken out sound.

Pipe No. 2.—This length was cracked for a distance of 15 inches along the line of weld, not far from the middle of its length. The crack had opened a little and the pipe was slightly bulged. This piece bore 300 pounds and then gave way, the fracture extending just enough to let off the pressure.

At the opposite end of the pipe was another split, 8 inches in length. The part just fractured was cut off, and the remaining portion was again subjected to the water pressure. This time it bore 1,050 pounds per square inch, when the crack was started and ran about 15 inches. It began leaking, and showed plainly the effect of the pressure at about 800 pounds.

This was an unusually interesting specimen, as the pipe had been bulged considerably by the water-hammer along the line of the 8-inch crack. The pressure afterward borne, therefore, seemed to the writer to be likely to be a fair measure of that produced originally by the water-hammer. Such bulging as was here seen never occurs at usual pressures. The new break did not follow the weld, but ran irregularly, and apparently indifferently, through weld or solid iron.

Pipe No. 3.—This length was split for a distance of 22 inches, the end of the break being about 3 feet from the end of the pipe. It sustained a pressure of 250 pounds. The sound part of the pipe was then tested up to 1,050 pounds without injury.

Pipe No. 4.—This piece was split, like the last, and to just about the same extent, was tested similarly, and gave way at 300 pounds per square inch.

All of this pipe was 8-inch pipe, $\frac{3}{8}$ inch thick, and made with the usual form of lap-welded joint. The welds were not always perfect, as is probably the fact with all such pipe; but this pipe, butt-welded, would have borne very much higher pressures than those to which it was subjected in ordinary work by the steam carried on the line. It cannot be asserted that these lengths of pipe did not split under pressures less than those to which they were afterward subjected by the writer, as it is very possible that the first blow may have found a weak part of the pipe, and the split may, in some cases, have extended to stronger portions. Nevertheless, the writer is inclined to believe that this was not the case in all instances, and is convinced that, in one case at least—that of the 8-inch crack, which was accompanied by a decided bulge in the pipe—the water pressures, at the test, were, at least approximately, equal to, and are very likely to have exceeded, those obtained at the later test. It seems to him very certain that we may consider it as proven that the pressures produced by “water-hammer” are often enormously in excess of those familiar to us in the use of steam, and that they have in many cases exceeded 1,000 pounds per square inch. It is, then, evident that it is not often safe to calcu-

late upon meeting these tremendous stresses by weight and thickness of metal, but that the engineer must rely principally, if not solely, upon complete and certain drainage of the pipe at all times as the only means of safely handling steam in long pipes, such, especially, as are now coming into use in the heating of cities by steam led through the streets in underground mains.

The facts here presented have been, to the writer, something of a revelation, and have seemed to him to possess unusual interest and importance to the engineer using steam under such conditions as are here referred to. It is a fact which has long been well known, that these suddenly produced pressures are often very great. The writer has occasionally, for many years, known of serious and sometimes fatal accidents due to this cause; but that these stresses are often as great as is here indicated has probably been as little realized by engineers generally as by him.

Locusts in the Island of Cyprus.—The English government gives a penny and a half per pound for locust eggs. From July, 1881, to Feb. 1, 1882, 1329 tons of the eggs were brought to the English authorities and destroyed, each egg being much smaller than a pin's head.—*Rev. Scientif.*, Jan. 6, 1883. C.

Exploration of Greenland.—Nordenskiöld wishes to penetrate into the interior of Greenland, which, contrary to the general opinion, he thinks to be free from ice. This theory is based upon the fact that the *föhn* winds, or winds which are relatively dry and warm, must blow there. If such is the case, they cannot take into the interior of the country enough snow to feed a permanent glacier. He believes that vast regions covered with perpetual ice are a physical impossibility south of the 80th degree of North latitude. The illustrious voyager, with the energy and intrepidity which characterize him, does not hesitate to penetrate into the unknown deserts of the interior of Greenland, in order to test his theory. Among other studies, he proposes to continue those which he undertook in November last, upon the cosmic materials which the shooting stars bring to the globe. Those researches, in which he melted the snow collected at the surface of the ground, in order to examine its contents chemically, were not decisive; the residue consisted principally of feldspar and other terrestrial substances, without traces of metallic iron or nickel.—*Comptes Rendus*, March 5, 1883. C.