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CHARACTERISTICS OF FIRE STREAMS

By Harry J. Corcoran

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THE IOWA STATE COLLEGE is annually host to the fire fighters of Iowa, in the Short Course for Fire Fighters held under the auspices of the Engineering Extension Department.

The meeting is really a conference of firemen, municipal officials and others interested in fire fighting and fire prevention; a conference at which they can discuss with experts, both from within the state and from other places, the important problems connected with their work. Here, the firemen and representatives from each community can learn new and better ways of meeting their problems through contact with speakers and counselors, many of whom are nationally known in their fields. Practical demonstrations of first aid and fireman training are features of the program.

This publication contains two of the more general papers presented at the 1926 Fire Fighters' Short Course. Several others will be published soon, and can be secured by writing to the Engineering Extension Department of the college.

CHARACTERISTICS OF FIRE STREAMS

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The characteristics of fire streams have been discussed so often and written about so much that no attempt will be made to present anything new at this time. Several books have been written about the subject and almost every issue of fire department magazines contains the solution of some fire stream problem. There are several different phases which could be discussed. We might take up the use of small streams, or the use of heavy streams; or we might spend considerable time in talking about the placing of fire streams. The question of the hydraulics of fire streams is always open to discussion, however, and this paper will be pretty much along that line.

The introduction of automobile pumping engines has opened up new opportunities in handling fire streams to small towns as well as to cities. Much can be learned by tests and drills, and much information will also be gained at actual fires. Previous study of pressures, of the behavior of water under pressure, and of the way in which pressure is changed when water is moving or flowing, will always make the results of actual pumping tests more easily understood. Only a small percentage of fires call for extensive use of hose, consequently experience with unusual layouts is limited. It is under such conditions that knowledge of fire streams is most useful. Such knowledge requires a thorough understanding of the reason for everything that happens. After you know how water under pressure acts it will not be difficult to use the tables which are sent out by apparatus manufacturers and underwriters. The only mathematics needed will be simple arithmetic. The tables referred to are compiled very accurately as they are intended for use in making tests of pumps where careful and exact results are wanted. For fire fighting exact results are never used, and an approximate idea is all that is needed. Some of the figures used cannot be changed a great deal without materially affecting final results. One thing to remember is that all the factors and numbers used have been arrived at by tests. They are the best way we know of expressing the laws of nature.

There are several things which can affect the stream, the most important being; the condition and type of nozzle, the quality of the hose, and the pressure supplied. The pressure at the nozzle, which is the important pressure, depends to some extent upon the quality of the hose. The elevation of the nozzle with reference to hydrant or engine may have an important bearing on a stream too. The condition of nozzle and the hose can be taken care of before the apparatus ever rolls to the fire, and in a well managed department they are.

Experiment and experience have both demonstrated that the smoothbore nozzle is best suited to form the fire stream. The function of the nozzle is to convert pressure into velocity, and that nozzle which causes the least disturbance in the water will produce the best stream. The bore must be a true circle; rough spots or obstructions such as a poorly fitting shutoff valve or gasket cut down the effectiveness of the stream; a sudden choke in the taper of the nozzle will set up whirls and eddies, and thereby waste pressure.

The shutoff nozzle has so much merit that it is coming into general use for hand lines, and the best quality makes are carefully ma-

Demonstration in Fireman Training Work at the Second Fire Fighters' Short Course, Iowa State College, October 26–29, 1926.

chined to leave a smooth inner surface when the valve is wide open; hence if the valve sticks and does not open fully the stream will be poor. I have seen a stream go into spray within twenty feet of the nozzle from this cause. The larger size nozzles have metal vanes fastened inside to keep the water flowing straight toward the tip; if these vanes become bent or broken the stream naturally will be damaged.

An assortment of tips, ranging from 3/4 to 1 1/8 or even 1 1/4 inches, is usually furnished with the best nozzles; the taper will not be the best for all sizes, and is usually designed for the larger sizes; the choke on smaller sizes isn't bad. Some departments still use the ring

tip, which has a metal plate with hole bored thru it set in the end. The claim is made that these tips will throw the water farther than the same size smooth bore. This is not true. Each bore of ring tip will give a stream of water about 1/8″ less in diameter than the hole in the plate, or equal to the next size smaller smooth bore tip. If we are using the same engine or hydrant pressure, we naturally get more distance with the smaller tip or stream. There is absolutely no advantage in using the ring nozzles, and a department is mistaken if it thinks there is a benefit.

The function of the hose is to carry the water under pressure from the engine or hydrant to the nozzle. If the inner surface of the hose is rough an unnecessary amount of pressure will be used up to overcome the frictional resistance, and thus leave less pressure at the nozzle. Friction losses are high enough at best, and good quality lining will keep these losses at a minimum. When large tips are used it is often necessary to supply water through two or more lines of hose, and a "Siamese" coupling or deluge set is used. In many small departments a coupling is used which is called a "Siamese" coupling, but which in reality is not one; it is used to split a single line into two lines, and the correct name is a "wye" coupling. It is generally used where the department lacks enough hose to lay two lines from the hydrant to the fire and keep it from spreading. Needless to say, the pressure is always low under such circumstances. If a true "Siamese" is carried, there is often enough hose for a double line at least part of the way and the pressure will be much improved. A long single line of 2 1/2 hose will carry only enough water for two small nozzle tips; it is not advisable to use over 100 foot lines of 1 1/2″ hose however. A 1/2 inch bore tip is the largest suitable for use with 1 1/2 inch hose.

The only remaining consideration is the pressure, but it is a mighty important one, and is, in fact, the most variable factor affecting a fire stream. Water pressure acts according to very definite natural laws which have been pretty well understood for centuries. Practically all of our difficulties in solving fire stream problems arise because we must use odd numbers and fractions to express the laws of Mother Nature. At least one method of avoiding a lot of trouble has been advocated; it is a plan to stop designating streams by their diameter and set up a new system of calibers, similar to gun sizes. The plan has much merit and would certainly simplify computations. The chief obstacle to its adoption is the confusion it would cause; it can nevertheless be applied immediately to many problems. However, if we understand where it is necessary to be exact and where we can use approximate whole numbers in our arithmetic, a lot of time can be saved in using present methods without a practical difference in the fire stream.

But to get down to pressure. Just what do we mean when we speak of water pressure: We say water is under so many pounds pressure. We mean that there is a pressure of that many pounds upon each square inch of surface of the thing which contains the water, whether it be pipe, hose, or tank. Our pressure gages are built so they will show what the pressure is in pounds per square inch. In order to understand pressures it is necessary to keep two of the laws regarding water in mind. The first is that water cannot be compressed; you all know that as it is common experience. If we fill a small cylinder with water and try to force a piston into it, we are unable to do so; if we fit a lever to the piston and attach a gage we can raise the pressure with a very little movement of the piston, because a little of the water goes up into the gage. The second thing to remember is that pressure is carried thru water with equal effect in all directions, because it is a liquid; in other words, if we connect a long pipe to the cylinder and fill it with water, a pressure gage at the far end will show the same reading as the one near the piston; and gages anywhere in between will also be the same. There is only one condition which will cause differences in the readings of the gages along a closed pipe filled with water under pressure; that is the elevations of the gages with respect to each other.

If we build a tube one inch square, set it on end and attach a gage at the bottom, then begin to fill it with water, the gage reading will increase with the depth of water. When the water is 2.34 feet above the gage, the reading will be one pound, and the weight of the water in the tube will be one pound. For each additional 2.34 feet depth, the pressure will increase one pound. If the pipe were larger the pressure per square inch would be the same as with the small tube, but the weight of all the water would be greater. The depth of the water is called the head; for ordinary use 2.3 feet or 2 1/3 feet in elevation is equal to one pound pressure. This difference in height acts the same thru a slanting pipe as through a vertical pipe. The only time when a fire department needs to consider the head is when working on a hill or when hose is carried to upper floors of buildings; allowance must be made then for the effect of head.

Up to this point we have been talking about water that is not moving. When water begins to move thru a pipe or hose, the above rules or laws seem to change; pressure does not remain equal at the same elevation. Every one of the laws just named acts exactly the same whether water is still or moving. An additional factor enters, however, and it is more complex than any of the others. Ordinarily it is called friction; if you can think of it as resistance to the flow of water, the effects produced may be more easily understood. Although the roughness of the inside of hose, the actual diameter of the hose, the length of the hose and the amount of water flowing thru it, all have a bearing on the friction resistance, the two latter are particularly important from a fireman's point of view. I believe the reason many men become confused about fire stream friction is that it doesn't seem reasonable.

You all know that it takes force to push a brick along a rough board; that it takes less force to push the same brick along a polished steel plate, but still quite a little force. And if the board is tilted, gravity helps to move the brick. If the brick is ground to powder and mixed with water to about the consistency of syrup, and the board is made into a trough, the entire brick will slide or flow down the incline from the force of gravity alone. And if the dust is all strained out, the water will flow down the trough faster, tho there is still a resistance. This is also true when the water is flowing thru a hose. The only way possible to determine how much this resistance

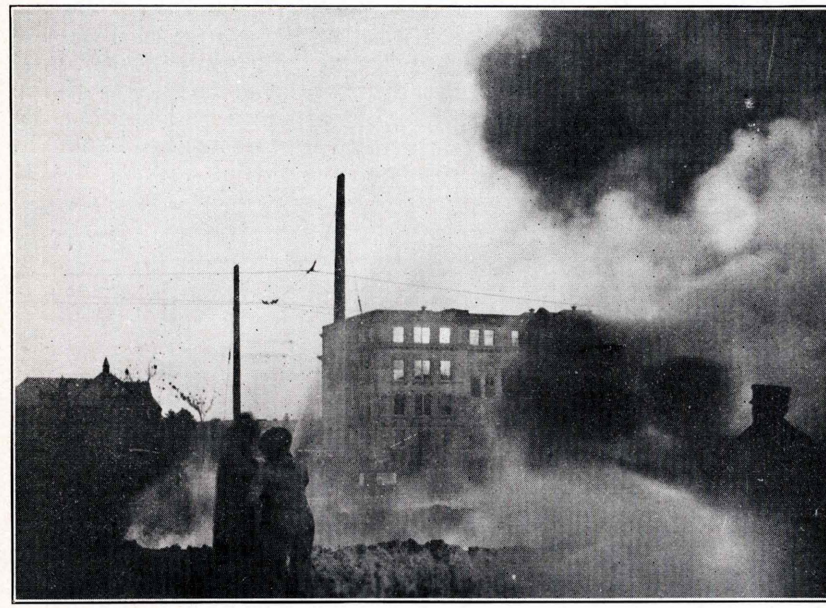
Demonstration of Oil and Gasoline Fire Extinguishment at the Second Fire Fighters' Short Course, Iowa State College.

amounts to is to measure it. The rougher the hose lines the greater is the resistance. The lining is roughened when high pressure forces the rubber into the weave of the jacket. Hose will stretch when filled with water under pressure, and the resistance will become less as the diameter increases. These two actions tend to offset each other. It is utterly impossible to make hose exactly uniform, and equally impractical to test each length of hose. Fortunately for the average fireman who cannot carry a laboratory around with him, the mean of the results of several tests on first class hose will not differ greatly from the mean characteristics when several sections are connected in one line, even though two sections may be far different. In any case we must use these averages or make a guess and I prefer to use the results of tests. Tables showing these figures are published by underwriters and apparatus companies, and they are the most convenient tables available. These tables are merely averages and very few pieces or lines of hose will give exactly the same results.

The amount of resistance is in direct proportion to the length. This means that the resistance for 200 feet of hose is twice that for 100 feet, and for each additional hundred feet the same amount can be added. Figures in the tables make allowance for bends and turns in the hose as it is generally laid at a fire. The fourth factor, the amount of water flowing thru the hose, is the most variable factor encountered, and it therefore causes the greatest variation in its effect. The losses and variations from this cause are not uniform changes such as those frictional losses varying directly with the length of the hose. Doubling the amount of water flowing thru the hose will increase the friction resistance almost fourfold. The simplest way to determine the change in friction loss due to the quantity is to refer to the tables mentioned.

All of the things which affect pressure have been outlined, and we now come to the pressure at the nozzle. In almost every case this is the thing which we must know or find out. The solution of any stream problem will be easier if we know the nozzle pressure. This is the pressure which throws the water and all that has been said before this time concerns those things which produce nozzle pressure. Only by test can we determine exactly what the nozzle pressure is. Tests are entirely out of question at a fire so some approximate method must be used. It is possible to tell within 10 pounds if we know how far the water is being thrown and the size of the tip, providing a strong wind is not blowing. But there is difficulty in measuring distance, and still air is seldom found. The easiest way is to compute the nozzle pressure from other things which are known. The things which we generally do know are: the size of tip, length of hose, and engine or hydrant pressure. If we want to find the engine pressure required, we must of course estimate the nozzle pressure.

A formula has been developed which makes use of these things we do know and which gives as accurate results as are needed. This formula is: Nozzle pressure is equal to the hydrant or engine pressure divided by 1.1, plus a constant multiplied by the number of sections of hose. The constant changes with the size of the nozzle tip. It also changes with the size of the hose and for double or triple lines of hose into one nozzle. If we confine ourselves to a single line of $2\frac{1}{2}$ inch hose we will avoid confusion and the other constants will be easily learned after we understand the way in which one is used. The Underwriters' red book, or engine test book, gives a table with these constants for nozzles of 1 inch in diameter and larger. The constants for single line of hose are: one inch tip, .105; one and one-eighth inch tip, .166; one and one-quarter inch tip, .248; one and three-eighths inch tip, .341; and one and one-half inch tip, .505. A suggestion on the use of these constants may help some of you. Instead of multiplying the number of hose lengths by the constant, change the constant into a fraction and divide the number of sections by the lower number of this fraction. For example, the fraction for .105, the constant for a one inch tip, is about one-tenth. The list would be changed as follows for the above size of tips: 1/10, 1/6, 1/4, 1/3, and 1/2. In other words you can divide the number of hose lengths by a small number and get the same result as you would if you multiply a large number.



Demonstration of Oil and Gasoline Fire Extinguishment at the Second Fire Fighters' Short Course, Iowa State College.

If the thing wanted is the engine pressure needed to give a certain kind of stream, the nozzle pressure will have to be known first. This can be determined better from judgment than any other way. And the best judgment is always the result of close observation backed up with some study. For fire fighting it is generally sufficient to know that a fair or a strong stream is needed, which permits a leeway of 10 to 15 per cent in nozzle pressure.

For example, if a fair stream from a $1\frac{1}{8}$ inch tip is desired the nozzle pressure should be somewhere near 50 pounds. This can be used to estimate the required engine pressure by adding to it the necessary allowance for loss from friction in the hose and any head between the engine and nozzle. The operator or officer should know what nozzle pressures correspond to fair and strong streams with different sized tips.

All of the essentials necessary to solve any fire stream problem have been discussed. If they are thoroughly understood, and their relations to each other are known, no difficulty should be encountered in correctly handling any fire stream problem. One prominine fire chief has covered the ground pretty well when he states that, "Knowledge can be developed during leisure hours by selecting buildings worthy of note from a fire department standpoint, imagine fires therein, and make calculations as to what would be done, the size of nozzles and hose layout needed, and the pressures that would be required." Not only will one acquire a good knowledge of fire streams by such use of leisure time, but a person will develop the ability to quickly size up any situation and devise means to handle it.

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