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Water Works

... AND ...

Pipe Distribution

BY

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WATER WORKS

AND

PIPE DISTRIBUTION.

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—PREFACE.—

In preparing this pamphlet it has been my aim to collate, in condensed form and by systematic arrangement, such important information regarding water-works and street mains as is usually to be found scattered throughout the pages of extensive treatises on hydraulics and water supply, whose authors generally and, perhaps, naturally give more attention to domestic service, potableness, etc., than to fire service.

Technical phraseology has been, as far as possible, avoided, in order that the property-holders of a city may understand its recommendations when considering the introduction or improvement of water-works. Impressed with the value of a thorough canvass for the criticism and opinions of others, such as was made in the case of the Universal Mercantile Schedule, the writer decided to send the pamphlet "in proof" to Hydraulic Engineers, Fire Chiefs and other experts throughout the country, with the result that he is under obligation not only to the gentlemen quoted throughout the pamphlet but, also, to many others and especially to Mr. Freeman, to whom he has been largely indebted, as numerous references throughout the work indicate. Indeed, so wide has been the writer's canvass for criticism and so materially has the article been improved by drafts made upon the wisdom of others that he feels more like a compiler than an author. Whatever he may lose in credit for originality, however, will be compensated by the gratification of an honest desire to furnish valuable and reliable information, in a concise form, and by the conviction that those who make use of the treatise will rely more thoroughly upon its statements, for the reason that it involves the consensus of judgment of many able experts, rather than the individual opinions of one man.

F. C. M.

New York, April 1, 1895.

WATER WORKS

AND

PIPE DISTRIBUTION.

The best system of water-works for fire-extinguishing purposes is a gravity system, with the reservoir at a sufficient elevation to ensure, with full draught, an effective head or pressure *at the hydrants* of 80 lbs. to the square inch or not less than 40 lbs. to the square inch at the base of the nozzle with 250 feet of hose.

The force of gravity acting with an ample reservoir differs from pump pressure for forcing water through pipes, in the important respect that it is always ready for instant use without notification by means of electric wires, telephones, etc., and is not liable to break down or get out of order like pumps or other direct pressure appliances. It, moreover, exerts, at all times, a steady pressure on the pipe system, reducing the liability of breakage to a minimum. A gravity system has a decided advantage over a direct pressure pumping system in that (if pipes are of proper size) the full volume of flow is instantly available without waiting to fire up extra steam boilers.

To secure an effective head or pressure, the reservoir should be elevated about 200 feet above the general level of the city and near enough to prevent serious loss of head. Such an elevation is, of course, not often found near a city; where it is, no other system should be considered as a substitute for pressure purposes. There should be two force or delivery mains of heavy cast-iron pipe leading into the general network of pipes within the city, so that one pipe at least will always be available in case workmen are repairing the other or cutting branches upon it; and these mains should be of such ample size that not more than twenty feet head will be lost by friction even when the full number of hydrant streams are in play. A single line of supply main is especially objectionable if of the so-called cement lined variety, which consists of a thin sheet of wrought iron, covered with cement mortar, and which after ten or fifteen years is liable to be broken by rust and is, at any time, liable to be instantly ruined by a stroke of lightning.

Any discussion of water-works for fire-extinguishing purposes would waste time in treating of those matters which usually, from the standpoint of potableness, occupy so much space in engineering works on hydraulics, such as filtration, etc., etc. It makes little difference by what means, natural or artificial, by springs or rainfall on water-sheds or pumps, the water is impounded at the elevation needed. If ground at 200 feet elevation is not available, or if the elevated reservoir is necessarily at considerable distance from the centre of the town, so that but 50 lbs. pressure, from the gravity supply, for instance, is available, then it may happen to be a decided advantage to have the supply pumped to the reservoir from some neighboring river or lake, for then, in case of a great fire, the pumps can supplement the reservoir supply by direct pumping at a higher pressure. The pumps being connected with the street mains with a check-valve to prevent backward flow to the reservoir, a combined "gravity" and "direct-pressure" system would be secured. Where drainage or water shed area is relied upon, the impounding reservoir should be of sufficient capacity to supply the maximum domestic demand and fire draft during a season of drought. The distributing reservoir, also, should be large enough for several days' domestic consumption, and with a sufficient reserve in addition for fire purposes. In some instances distributing reservoirs are large enough only to supply a day's average demand for domestic purposes, and a break in one or both of the supply mains, or stoppage for necessary repairs, may leave the city without water.

Where a gravity supply is insufficient and the system is reinforced by direct pumping from a neighboring river or lake, it should be remembered that while this reserve may be excellent for purposes of domestic supply it may prove unreliable in case of an extensive conflagration unless such pumping system is so arranged and managed as to bring the reserve plant into full action whenever needed—a feature of such duplex systems which should always be carefully investigated.

Where the lay of the land does not permit of an elevated reservoir and reliance is necessarily placed upon direct pumping systems and standpipes, direct pumping or the so-called Holly system, has given excellent service in many cases; in other cases it has failed to respond properly, and since of necessity it must depend upon some device to transmit the alarm of fire and a notification that extra pressure is needed, and relies moreover on there being a surplus of steam and a pump capacity available instantly, it cannot compare with first-class reservoir service in point of security.

If the pumping station on the Holly system is in close proximity to the city (but not liable to be destroyed by a conflagration) it is more reliable than when several miles distant. There should be duplicate pumping engines—three would be better still—with at least three force mains.

The pumping station should be connected electrically with the Fire Department, so that when an alarm of fire is received at the engine-house the intelligence will reach the pumping station at the same moment.

There should be a liberal distribution of relief valves to prevent water-hammer.

Head or Pressure. The weight of a cubic foot of water, ($7\frac{1}{2}$ gallons*) the equivalent of a column of water 12 inches square and 12 inches high, would be 62.4 lbs. This divided by 144 (the number of square inches in the base of the column) would give a pressure of .43 lbs., or nearly $\frac{1}{2}$ lb. per square inch of base surface for each foot of vertical depth, which, if the loss by "frictional head" hereafter explained, be say 15 feet, would yield, for a "static head" of 200 feet, an "effective head" or pressure of 185 feet at the hydrant, or say 80 lbs. to the square inch. The effective head for fire purposes in the absence of steamers, whether reliance is placed upon the "direct pressure" system or a gravity reservoir system, should be at least from 40 to

*One cubic foot of water=7.48 U. S. gallons.

50 pounds per square inch *at the base of the nozzle* and the static hydrant pressure must be enough greater to allow for friction in the pipes and for friction in the hose.

This pressure of 40 or 50 lbs. will force a 1 $\frac{1}{8}$ inch stream for effective work to the top of a four-story building of usual height—say 60 feet—and from 230 to 300 gallons per minute will be discharged. A 1 $\frac{1}{4}$ inch nozzle under like pressure would discharge 20 % more, but a 1 $\frac{1}{8}$ inch nozzle is generally regarded as the most practical for general use. To force the main body of a 1 $\frac{1}{8}$ inch stream 80 feet vertically would require a pressure of the main body of 55 pounds per square inch or a head of about 130 feet *at the nozzle.* The extreme drops may go 40 % higher, but could not put out any noteworthy fire at that elevation. And we may here remark that the height and distance reached by fire streams as measured at firemen's musters, are sometimes wholly misleading as applied to practical work, for in such cases they measure the extreme point touched by the farthest drop.

Among firemen and engine men pressure is commonly stated in pounds per square inch. The following table gives the equivalent in pounds per square inch of pressure stated in feet head or vertical height of an equivalent water column in feet. It will be observed that the popular estimate that two feet of head are equal to one pound of pressure will lead to serious error; for instance, on that basis 80 pounds hydrant pressure would call for only 160 feet head, whereas it would actually need an elevation of 185 feet of water column to produce the same pressure. Eighty pounds or 185 feet head *at the hydrant* may be regarded as the least pressure giving strictly good fire service, and with this head it is still imperative that the pipe be large enough so that this pressure will not be drawn down greatly when fire streams are flowing. A few feet less would make the difference between a good fire department and an inefficient one.

The friction in 300 feet length of the best and smoothest hose will absorb about one-half of the available fire pressure at the hydrant.*

*This loss may be reduced by Siamesing two lines of hose into one nozzle, which would save a large proportion of the pressure usually wasted in friction between the hydrant and the nozzle.

TABLE FOR CONVERTING PRESSURE GIVEN IN FEET HEAD OF WATER INTO PRESSURE IN POUNDS PER SQUARE INCH:

Feet Head,		Pounds per Square Inch.
1	Ft.	0.43
5	"	2.17
10	"	4.33
15	"	6.50
20	"	8.66
30	"	12.99
40	"	17.32
50	"	21.65
60	"	25.99
70	"	30.32
80	"	34.65

TABLE FOR CONVERTING PRESSURE GIVEN IN POUNDS PER SQUARE INCH INTO FEET HEAD OF WATER:

Pounds per Square Inch.		Feet Head.
1	Lbs.	2.31
10	"	23.09
20	"	46.18
40	"	92.36
50	"	115.45
60	"	138.54
70	"	161.63
80	"	184.72
100	"	230.90

Test of Water Pressure. The head exhibited by a pressure gauge attached to a hydrant or to a fire pipe within a building may often be very misleading as to the pressure available for projecting a fire stream from a hose nozzle. There are towns where the static pressure, or pressure with the water at rest, may be 90 pounds per square inch, but if two hose streams be put in play the pressure will be pulled down to 15 or 20 pounds per square inch or scarcely sufficient to send water into a second story window. In one such instance the town had a gravity supply from a reservoir about five miles distant, and it was the friction in this long line which made the hydrant pressure practically worthless when sufficient water for one or two good fire streams was added to the domestic consumption. In many towns the result of drawing simultaneously half a dozen fire streams from the public mains is never found out until a disastrous conflagration occurs. Both citizens and underwriters, relying upon the static pressure without taking the trouble to investigate what the flowing pressure will be when a large number of streams are drawn, learn of the inadequacy of the fire department only after millions of dollars have been destroyed.

No general statement can be made as to the amount of the loss of pressure by friction per mile of pipe, although it can be readily computed for any particular case. At the present day there is little excuse for ignorance of these matters, when a practical test by a number of fire streams at once will answer the whole question in so certain and satisfactory a manner. Engineering science is competent to answer questions as to pressure when a diagram showing the length and diameters of the pipes and their condition regarding rust is at hand, but the practical test is more convincing and reliable. The best test, therefore, of effective pressure of hydrants for any city level is to *attach lines of hose and turn on the water;* and this is the test which inspectors of water-works and underwriters fixing rates and hydrant deductions for any section should, in my judgment, rely upon.

Frictional Head. What is known as the "static head," or the head of a body of water at rest in the reservoir, is diminished by the "frictional head" or loss of pressure from friction in flowing through the pipes, which increases proportionally to the square of the velocity of the water and is increased greatly, also, by the smallness, roughness or tuberculation of pipes. For a similar reason pipes, where located in undulating ground, causing the collection of sediment should be "blown off" frequently. "Dead ends" should be avoided, if possible, by completing the parallelograms and connecting the ends by an additional sub-main or pipe—a comparatively inexpensive precaution in the line of a true economy, since the growth of a city would eventually require such additional pipe. It is not always possible to connect dead ends by cross sections of pipe to complete parallelograms, since the uneven growth of a city may carry one main for blocks beyond parallel mains, and there must of necessity, therefore, be some dead ends in such a system. In the city of Detroit an admirable system is followed, that of placing a cistern at the end of each street where water pipes are laid. This reservoir serves not only as a "blow off" for the main, but enables the engines to do effective service by pumping from the reservoir, which they could not do from a hydrant on such a dead end, as with the latter they would soon "run away" from the water in the main.

There is a material loss of "head" where the water main is not of proper capacity and where the water has to travel great distances. The loss of head for each thousand feet of travel, in a new, straight, clean water main 14 inches in diameter, is about $7\frac{1}{3}$ feet per thousand feet of length of pipe, the velocity of flow being 5 feet per second, or say a loss of 40 feet head per mile. Pipes are seldom or never laid straight, and they do not long remain new and free of rust, and where the reservoir is, say, two miles distant from the operating hydrant it may safely be assumed that if the domestic draft, plus the fire draft, amounts, at any moment, to 2400 gallons per minute, then even with a nearly new pipe the pressure at the hydrant will be at least a hundred feet less head, or fully 43 pounds less pressure, than at the reservoir.

"*The rule that the loss of head by friction is proportional to the square of the velocity*, applies not only to a simple pipe, but is substantially true for combinations of pipes of different sizes joined either by taper reducers or by sudden contractions, or for pipes containing obstructions and curves. It is also useful to keep in mind that for cases of a pipe system in combination with a discharging orifice or with a series of discharging orifices, so long as all the discharging orifices lie at substantially the same elevation, the opposite of the above proposition is true and of wide application:

viz., *the quantity discharged through a given pipe system and the orifices in connection therewith is very nearly proportional to the square root of the pressure* measured at any convenient point anywhere along the pipe system, providing the pressure be reckoned from the level of the orifices."

There is a popular misunderstanding among mechanics in supposing that the carrying capacity of a pipe increases exactly in proportion to its area or to the square of its diameter. Really the carrying capacity increases faster than this, by reason of the lessened influence of skin friction in a larger pipe, or, stated in mathematical language, *the capacity to convey water is proportional to the square root of the fifth power of the diameter.*

TABLE SHOWING CAPACITY OR DISCHARGE OF PIPES OF DIFFERENT DIAMETERS FOR VARIOUS VELOCITIES OF FLOW AND FRICTIONAL HEAD IN FEET PER 1000 FEET OF LENGTH,

for new, clean, straight pipe.

DIAMETER OF PIPE IN INCHES.	VELOCITY OF FLOW IN FEET PER SECOND.	LOSS BY FRICTIONAL HEAD PER 1000 FT. L'TH.		CAPACITY OR DISCHARGE	
		IN FEET HEAD.	IN LBS. PER SQ. INCH.	IN GALLONS PER MIN.	IN GALLONS PER DAY (24 HOURS).
4	3	10	4.33	113	165,000
	4	17	7.31	150	215,000
6	3	7	3.01	260	375,000
	4	11	4.76	340	485,000
8	3	5.4	2.32	490	700,000
	4	9	3.87	640	915,000
10	3	4	1.73	750	1,075,000
	4	7	3.01	975	1,450,000
12	3	3	1.29	1,050	1,500,000
	5	9	3.87	1,800	2,600,000
14	3	3	1.29	1,500	2,150,000
	5	7.3	3.14	2,400	3,500,000
16	3	2.5	1.07	1,875	2,700,000
	5	6	2.58	3,200	4,600,000
18	3	2	.86	2,400	3,500,000
	5	5.5	2.36	4,100	5,925,000
20	3	1.7	.73	3,000	4,300,000
	6	7	3.01	6,000	8,600,000
24	3	1.3	.56	4,125	5,900,000
	5	4	1.73	7,125	10,240,000
	6	5.5	2.36	8,625	12,340,000
36	3½	1	.43	11,250	16,150,000
	6	3	1.29	19,000	27,200,000
	8	5.6	2.40	27,250	37,500,000

N. B. The number of streams which a pipe would supply can easily be determined by dividing the quantities of above table by 200 or 250, according to the size or number of gallons per minute of the stream, it being remembered that under the gridiron system, or where the pipe is supplied at both ends, double the quantity of water in the above table may be secured.

The above table and those commonly given in the text-books for friction loss in pipes are apt to be misleading for the reason that they state the friction loss per hundred feet *in new, clean pipe.* The actual loss in practice will often be found double the loss as tabulated for new, clean pipe, by reason of the bunches of rust which forms on the interior surface even of the best pipe with nearly all waters. Careful experiments on corroded pipe as compared with clean pipe have shown that a very moderate amount of corrosion will nearly double the frictional loss, and to prepare the table below, the frictional loss as stated in the excellent and convenient table prepared by Mr. Edmund B. Weston, Civil

Engineer in charge of the Water Supply of Providence, R. I., has been doubled.

FRICTION LOSS PER ONE THOUSAND FEET IN LENGTH OF ORDINARY WATER-PIPES **after corrosion by 10 to 20 years** OF AVERAGE PRACTICAL USE.

GALLONS PER MINUTE DISCHARGED.	DIAMETER OF PIPE IN INCHES.						
	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.	16 in.
	PRESSURE LOSS IN POUNDS PER SQUARE INCH.						
250	41.	5.	1.	.37			
500	168.	20.	4.6	1.45	.58		
750		44.	10.8	3.3	1.3		
1000		76.	19.	5.9	2.3	1.1	
1250			29.	10.	3.6	1.7	.8
1500			42.	14.	6.	2.7	1.2
1750				19.	3.	3.3	1.6
2000				25.	10.	4.3	2.2
2250					13.	6.	3.
2500					15.	7.	4.
3000					22.	10.	5.

The number of 250 gallon fire streams supplied can be determined by dividing the quantities of the first column by 250.

It may be assumed that 3,000 population, at their hour of maximum draft (as at 10 A. M. Monday), will draw for domestic purposes the equivalent of one fire stream.

It is not generally understood how great is the loss of head by reason of roughness in the pipes or of sharp, right angle bends. By the use of curves of moderately long radius, the loss caused by elbows may be made practically insignificant. Pipers do not commonly use them, because they cost a little more.

If the diameter or capacity of the main should be increased the loss of head would be less; a 16-inch main, for example, would show a loss of not much more than half the frictional loss of a 14-inch main, the number of gallons per minute carried being the same in each case.

We have thus far been speaking of variations between the carrying capacity of pipes of different sizes. Another problem is the variation of friction loss with the same pipe when different quantities are drawn through it. Then the friction loss varies as the square of the velocity.

Taking a 6-inch pipe for our unit, this being the smallest that should ever be used for a hydrant main, and comparing pipes on the basis of their carrying capacity, we find:

One	8-inch	pipe	is	equivalent	to	2.05	6-inch	pipes.
"	10 "	"	"	"	"	3.58	"	"
"	12 "	"	"	"	"	5.65	"	"
"	14 "	"	"	"	"	8.32	"	"
"	16 "	"	"	"	"	11.60	"	"

If we compare the pipes on the basis of cost complete, as laid in large quantity (with cast iron and lead at the low prices of to-day) the relation will stand as follows:

DIAMETER.	COST PER LINEAL FOOT COMPLETE.	COST COMPARED WITH 6-INCH.	CARRYING CAPACITY COMPARED TO 6-INCH.
6	$0.52		
8	0.70	1.35	2.05
10	0.90	1.73	3.58
12	1.20	2.30	5.65
14	1.45	2.79	8.32
16	1.65	3.18	11.60

In other words, an 8-inch pipe costs 1 ⅓ times as much as a 6-inch pipe and will carry two times as much water; or, again, a 16-inch pipe costs three times as much as a 6-inch and will convey eleven times as much water.

STAND-PIPES. In the absence of a sufficient elevation to secure a gravity head, a "stand pipe" of the tank kind is used to secure needed pressure and also a supply in case the pumps should break down. A stand-pipe of the tank form, 24 feet in diameter by 100 feet high (and there are some larger ones throughout the country), would hold a quarter of a million gallons of water which, providing the last drop could be drawn out and give good pressure, and providing all was used for fire and none for domestic supply meanwhile, would supply five hydrant streams of 250 gallons each for 3 ⅓ hours. A good ordinary steamer would average 500 gallons per minute, and one-quarter million gallons would supply two steamers about four hours; but while such a supply would be, in many instances, sufficient for extinguishing an ordinary fire, especially if the stand-pipe or reservoir could, in an emergency, be fed by reserve pumps—in which case the supply could be regarded as margin enough to cover the interval while starting the reserve pumps and boilers—it must be borne in mind that stand-pipes are seldom of sufficient diameter to afford an ample fire supply. Their capacity to supply a number of hydrant streams is a subject of widespread popular misapprehension. It takes *volume* of water to put out a fire—*pressure* alone will not do it, and it does not follow that a stand-pipe 20 feet in diameter which exhibits say 80 pounds static pressure on a gauge when full will afford good fire service. Ten feet in depth of a stand-pipe 20 feet in diameter, will supply five hose streams only 18 minutes, and a single fire stream will draw off as much water as the *average* domestic consumption of 6,000 people.

It should be remembered that the water in the lower part of a stand-pipe is practically useless for fire purposes so far as pressure is concerned, and serves only to fill mains for suction by steam engines, if there be any.

In small towns stand-pipes are often supplied by pumping for a few hours during the morning or even on alternate days, after which the fires are banked or extinguished and the water allowed to draw down under domestic draft. It is unnecessary to suggest that if a fire should happen to break out when the pipe has been drawn down, the boilers cold and the engineer asleep or absent, a conflagration is not likely to be extinguished.

Air and Vacuum Valves, Blow-off Valves, Etc. When water is forced into delivery mains more or less air is taken along with it, and where the pipes undulate to conform with the contour of the ground this air accumulates in the summits, and in the course of time interferes seriously with the flow. As a means of relief, air valves should be located at such points. These valves are now combined in the same piece of mechanism with vacuum valves, which are required at the same points for the reason that when the pipes are drained for repairs or other purposes there is a tendency to form vacuums at the summits, which will cause collapse unless relief is given or the pipes and joints are strong enough to stand the pressure. It may be added that hydrants when properly located can be made to perform the offices of both air and vacuum valves.

Caution must be exercised when filling the pipes to see that air valves are opened and the water admitted no faster than the air can escape, as otherwise the compressed air sets up an aggravated form of water hammer causing the water to rush back and forth violently and the weak parts will suffer.

Attention is again called to the desirability of providing Blow-off valves at suitable points. Sediment will accumulate at the low points of the pipe system and, after a while will seriously impede the flow unless removed. By having blow off valves at these points the proper remedy is provided.

An essential condition which is sometimes overlooked is the necessity of keeping the elevation of the mains below the Hydraulic Grade Line. Often the contour of the ground is followed without regard to this all important feature. Where this point is not considered, not only is there a tendency towards the formation of air pockets at the summit but the pressure conditions in the pipe are entirely changed. The water in that part of the pipe between the reservoir and the point of elevation above the hydraulic grade line has a velocity due only to the head given by their difference of elevation. Beyond that point if there is a greater difference of elevation to the point of outlet the velocity will be greater and hence the supply from the first part will not be equal to the capacity of the other part, and the water in the latter part will not be under pressure at all but will flow as though in a gutter.

It is sometimes necessary because of the nature of the ground to go above the hydraulic grade line. In this event, the diminution of flow caused by reduction of velocity in the section between the reservoir and the point of elevation above the hydraulic grade line, may be compensated for by making the pipe larger in this section than beyond it.

High and Low Service. In the case of cities having different levels and consequent "high and low service," such as Kansas City, Albany, Brooklyn, Cleveland and others, it is important that the two systems should be connected by means of check and gate valves, which can nearly always be arranged at slight additional cost so as to make the high service available for the lower levels in case of fire. They can be disconnected at any time when the exigency is removed.

The difference in elevation may be so great in a town that while the service in the lower part is entirely satisfactory the pressure in the higher portion is so reduced as to become practically valueless. It is desirable in such cases to provide, by some means, for increasing the pressure at the higher elevation. When this district is small and will not permit of the introduction of a high service system, or even the maintenance of a steam pump, a device which is now in successful operation in the city of New London, Ct. may be introduced with advantage. This consists of a tank, having sufficient elevation to give the requisite pressure, which is supplied by a hydraulic water motor. While it is not the intention to describe this motor in detail it may be stated that it is operated by the water consumed in the lower part of the town. It is located on a supply main, and receives the power to operate it from the passing water, which, after performing its work, is carried on, with but slightly diminished pressure, to be used in the low service system. By ingenious automatic arrangements the two systems are made communicating as occasion arises. It is claimed for the motor that it possesses advantages of cheapness, of consuming no fuel, of working day and night, and of requiring but little attention. The reduction in pressure above the motor and below it is inconsiderable, the figures in the one to which we refer being found from actual test to be 34.62 lbs. above the motor and 31.46 lbs. below. Its cost was $5000 and it has proven amply sufficient for the needs of a district requiring from 100,000 to 150,000 gallons per day. It may be remarked again that it is claimed the cost of maintenance is very small, that it requires but little care and that the initial cost is practically all that has to be considered.

A full description of this motor will be found in a valuable paper read before the New England Water-Works Association Dec. 14, 1892, by Mr. Walter H. Richards, C. E., Junior Editor of the Association.

Water Mains and Pipe Distribution. That system of pipe distribution is best where the street mains run at right angles to each other throughout the city or town *connecting at every street intersection*—"gridironed", so to speak. This arrangement insures that each pipe will be fed practically at both ends and will double the feeding capacity.

SIZE. The subsidiary mains passing through the various streets should, in the business or compact portion, be not less, in any case, than 8 inches in diameter, and in the dwelling section not less than 6 inches in diameter. The size should be liberal in the compact mercantile portion, for the reason that existing conditions of low or small buildings may, with the growth of the town, be radically changed by the subsequent erection of more dangerous structures. It should be remembered that faults in the placing of hydrants may, at any time, be remedied, but mistakes in the size of street mains are not easy of correction and, keeping in mind the fact that the cost of excavation, leading of joints and labor is very nearly as great in the case of small mains as in the case of larger ones, it is poor economy to lay an inadequate pipe in the first instance.* Where the district is a large one, containing large buildings and values, 12-inch mains should be used, at intervals of say a thousand feet, as feeders. The Boston engineers are at present working toward a system of 12-inch mains, about a fourth of a mile apart, crossing by gridiron distribution between these with 8 and 10 inch pipes, in the business section, and 6 and 8 inch pipes in the outlying district.

Boston already has 28 % of its service in 12 inch mains and New York 25 %.

The feeders or larger mains should supply the "gridiron" from the outside, instead of extending through the centre. Not only will this insure better service, but the arrangement

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*Cast-iron water-pipe may be purchased at $19.50 per ton, freight added. Four-inch cast-iron water pipe weighs 20 pounds to the foot, 6-inch 30 lbs., 8-inch 45 lbs. and 12-inch 80 lbs. The difference in price, therefore, between 6-inch and 8-inch pipe would be, roughly, about 15 cents per foot, and the cost of laying 5 cents more, in all a difference of 20 cents per foot, or $20 per hundred feet. (See page. 10)

The difference in insurance rates in favor of property on the line of 8-inch mains as compared with 6-inch mains, in the Universal Schedule, (see Nos. 155, 156, 190, 192) is 7½ % on buildings and 5 % on stocks. There would be eight 25-foot buildings, counting both sides of the street, on 100 feet length of pipe. It would be a low estimate of value to assume $50,000 insurance on each lot, or $400,000 in all. If the average insurance rate should be 80 cents per $100 on a 6-inch main, it would be 5 %, or 4 cents per $100 (40 cents per $1000) less on an 8-inch main, making *an annual saving to property-owners in insurance premium of* $160 for the extra cost of $20 in a pipe which would last for fifty years and which the property-owners would save eight times over in a single year. Could any civic policy be more stupid or shortsighted from an economic standpoint than the laying of 6-inch pipes in the compact mercantile portions of cities!

There is a greater difference still between 8-inch pipe and 4-inch pipe, the insurance rate being 15 % higher on buildings and 10 % on stocks on the line of 4 inch mains as compared with 8-inch mains.

will respond to future demands upon it as the city increases in size—an important consideration.

In a seaport city the water main on the water front should be at least 16 inches with numerous hydrants.

I quote from one of the many valuable treatises on water supply by Mr. John R. Freeman, of Boston, the well-known and able engineer, as follows:

"*Within a crowded and valuable metropolitan district, a diameter of eight-inches is the smallest that can be recommended for the general net-work or gridiron of intersecting pipes,* having in view the deterioration in water carrying capacity which occurs in time with nearly all waters.

For valuable metropolitan districts a pipe so small as eight inches is suitable only when forming part of a general net-work whose intersections are not far apart, say not more than 300 feet in one direction, by 800 feet in the other. When the cross connections are smaller than eight inches or farther than 800 feet apart, a ten inch pipe may be needed. Along the borders of the gridiron the size should be larger. This reinforcement by cross-connections, is of the utmost importance and if absent it may require a 16 inch pipe to afford the same delivery as a gridiron of six-inch pipes.

Within almost any suburban residence district where there are frequent cross connections, also within compactly built cities of medium size and even those of large size and of medium hazard, excellent protection may be afforded by a gridiron of six-inch pipes along each of those streets running in one direction, intersecting, at 500 feet intervals, with pipes eight inches in diameter, in each transverse street. The maximum of economy in pipe will be secured *if the six-inch pipe runs lengthwise of the blocks.*

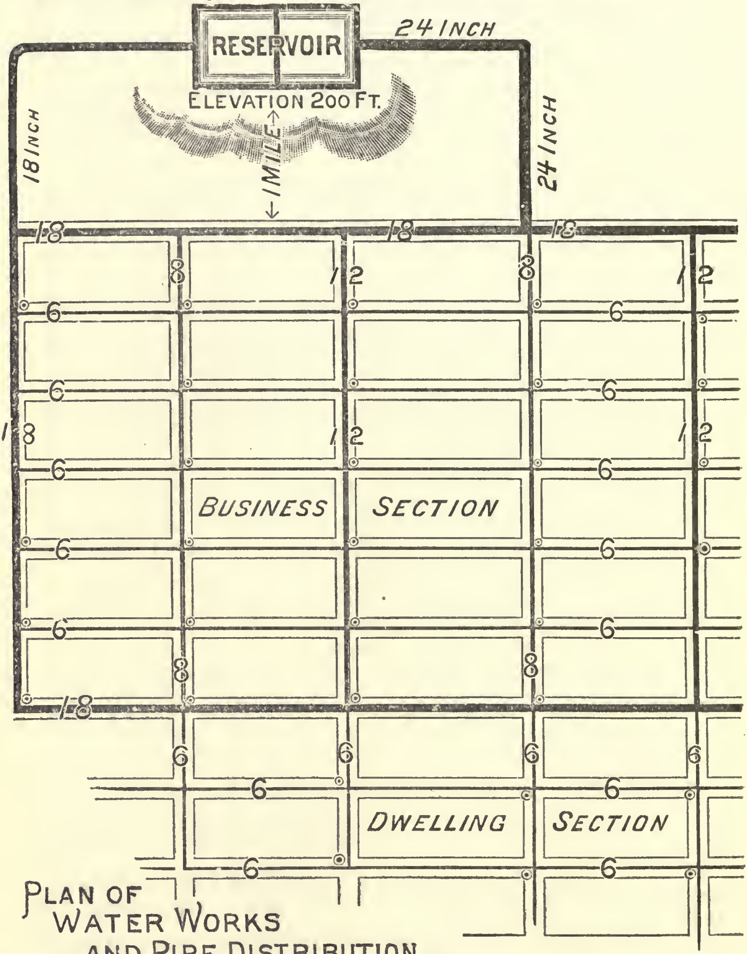
For small cities in which the streets run so that frequent cross-connections are possible, very satisfactory protection can be had by a net work of pipes none of which exceeds six inches in diameter; but along the margin of the gridiron there should be a few main arteries of larger sizes and the size of a few of the pipes near any large hazardous building, as a valuable factory or warehouse, may need to be increased.

This use of six-inch pipe, however, *presupposes that the six-inch pipe makes a complete circuit about each street block which is to be protected, so that the water will flow in toward the point of heavy draft from nearly all directions.*

A block located in the midst of a net-work of 6-inch pipes may sometimes be much more efficiently served than one past which runs a single line of 12-inch pipe.

Four inch pipe should never be used for a hydrant main, unless it be to protect scattered, detached dwellings in situations similar to a country village or where the closest economy of first cost must be practiced in order to get any general water works pipe system at all, and in these cases it should be clearly understood that starting with say 75 lbs., a line of four-inch pipe one-half mile long so soon as it becomes old and roughened by rust can only deliver water enough for a single 100 gallon fire stream three-fourths inch in diameter, which is too small to extinguish anything more than a dwelling house fire or to do more than protect the neighbors, while the original fire is left to burn itself out.

In many New England towns the hills and valleys have compelled a growth radiating outward in narrow strips or in ways which forbid any such reinforcement of the flow as we have here been considering, and in these cases much larger pipes will, on computation, be found necessary to give an equal delivery at the hydrants."



PLAN OF
WATER WORKS
AND PIPE DISTRIBUTION

Where a city is unwilling to pay for 8-inch mains they should be supplied, at least in part, to carry water from the outside feeders, the 6-inch being used only for lengthwise of the blocks, as shown in the foregoing diagram.

It will be observed that in the gridiron form of distribution shown in the accompanying diagram, every pipe is supplied at both ends and, in case of fire and a draft upon any hydrant, water would run to it from all directions.

Concentration of water for fire at a given point is of the utmost importance, and under the gridiron system this can be secured no matter where that point may be.

It may safely be assumed that while hose lines 500 feet in length can be used with steamers to force the water, it is preferable to have short hose lines, not exceeding, in any case, 300 feet in length. An examination of the preceding diagram will show that with the gridiron system and a "2-way" hydrant at each corner, and street blocks 500 by 200, it would be possible to supply, in case of a fire in the middle of any block, 12 streams, each with less than 350 feet of hose, and a still larger number with 600 feet of hose. Boston can place 52 steamers within 500 feet of a fire and supply them with water.

Siamesing Hose. The loss by friction through greater lengths of hose, as already stated, may be largely saved by connecting the two lines of hose, through a Siamese coupling, into a single line at a point 50 to 100 feet back from the nozzle. Strange as it may seem, it has been demonstrated that there is less friction and a greater supply of water can be secured in this way than by the use of two steamers, one pumping into the other. In this way, a Siamese placed 50 feet back from the nozzle so lessens the loss by friction that with the same steamer pressure a jet will be thrown with exactly the same force through a thousand feet of hose as if the steamer were only 287 feet from the nozzle on a single line of hose. So important a fact should be understood by Fire Departments.

The reason for the difference in results is obvious. Where the water is carried through two lines of hose instead of being forced through one the velocity will be only half as great, and the loss of pressure only one-fourth as much, as where a single line of hose is used; and it is unfortunate that fire departments so frequently over-look the use of a Siamese coupling to connect two lines of hose from a single steamer, especially where the steamer has to be distant from the fire. Two steamers may be frequently seen endeavoring to do with great difficulty what a single steamer with a double line of hose could easily accomplish.

Cast-iron pipe, well tarred is preferable for fire protection to wrought iron, which is sure to rust, or to steel, which will probably rust. The tar should be applied by the best hot process.

It is important to have smooth throatage. The mere roughening of the inside of a pipe will double the friction loss even where there is no noteworthy deposit of rust bunches or tubercles. One great objection to cement-lined pipe is the thinness of the iron (for cast-iron pipe the iron shell is commonly eleven times as thick as the wrought iron shell used in cemented pipe) in addition to the danger of rusting which, as stated, may be regarded as a certain expectation in the case of wrought iron.

Cement-lined wrought iron pipe, as already stated, is not only certain to become leaky after fifteen or twenty years of use, whereas cast-iron will last for fifty years or more, but it is liable to be destroyed by lightning—a casualty which has happened in Arlington, Woburn, Lynn, Fitchburg and Winchester, Mass., and other places. The cities of Fitchburg, Worcester, Manchester, Spencer, Somerville, Malden, and others, have found it necessary to take up the cement-lined pipe and replace with cast-iron. In Rome, N. Y., several years ago, the bursting of a cement-lined pipe during a fire led to a property loss of upwards of $200,000. The objection is to the thinness of the iron, not to the cement lining, which is in itself an advantage. It would improve cast iron pipe, by saving frictional head, but the extra expense, makes its use prohibitory with cast-iron.

The size of mains and pipes should be carefully gauged by competent experts to insure that too much head is not lost by friction, taking into account the supply needed for domestic (household and manufacturing) purposes and fire extinguishing purposes.

Supply. While the amount needed for fire service, *per annum*, is not large, the amount required for a fire will often exceed, for a few hours, that for all other purposes. Twenty hose streams, for example, would require, for each, estimating only 150 gallons per minute, 3,000 gallons per minute, (estimating 250 gallons, would require 5,000 gallons per minute) while the domestic supply for a town of 25,000 population, estimating 75 gallons maximum per capita (a large estimate) per diem, would not exceed 2,700 gallons per minute.

On this basis, Mr. Freeman says:

A single good 1 $\frac{1}{8}$ *inch* × 45 *pounds* × 250 *gallons fire stream takes as much water as would be needed on the average for the ordinary domestic supply of a population of* 6,000 *at* 60 *gallons per day to each person.*

A sufficient fire supply should be provided in addition to the maximum domestic consumption, and double the average draught (or whatever ratio of increase the actual record, if there be a record, may show of the district under consideration) should always be kept in view as the *basis over and above* which the fire supply is to be secured.

The average domestic consumption for household and manufacturing purposes, per capita, is safely estimated in small cities with little manufacturing at 50 gallons per diem, but at certain hours of the day and on certain days of the week, particularly on Monday, a larger supply is needed, and a common experience is that, at times, the maximum draft will be double the average draft. An average of 110 gallons per capita daily would probably be sufficient for both domestic and fire service. In manufacturing cities a much greater amount is often used. The daily consumption in Boston is over 100 gallons per inhabitant per day. The same is true on the other hand of Nashua, N. H. The use of water per capita is steadily increasing. Making allowance in planning new water-works for a growth of a prosperous city or town of 40 per cent. in a decade, it would probably be found economical to gauge the reservoir and supply-mains accordingly, unless an additional reservoir can be constructed afterwards at pro rata expense, which is not likely. To supply a city of 25,000 population, using 365 cubic feet of water per minute for domestic service and, in the emergency of a conflagration, possibly 400 feet more per minute for fire service, would require a 24-inch supply main from the reservoir. Two of these as already stated, would be better, and insure against breakage. To insure protection, the reservoir should always (even at 4 o'clock Monday morning) hold a reserve for fire of at least two million gallons for any closely built city up to 75,000 inhabitants, and more if the city is much larger.

The following figures are based on estimates of Mr. J. T. Fanning, in his "Treatise on Hydraulic and Water Supply Engineering"—a work well worthy of the study of underwriters.

With a static head of 150 feet and pipes 1,000 feet long, a 6 in. pipe would supply 40 cu. ft. per min. or 300 gallons.

8	"	"	"	80	"	"	600	"
10	"	"	"	120	"	"	900	"
12	"	"	"	220	"	"	1,650	"
18	"	"	"	480	"	"	3,600	"

All of these figures as to frictional head and discharge are for *new, clean pipe;* if the pipe is old and rusted the loss of frictional head may be doubled, as hereinbefore explained.

If the subsidiary pipe relied upon is six inches in diameter and supplied at both ends, the fire supply at each end would be 40 cubic feet, or 300 gallons, per minute, or a total for both ends of 80 cubic feet, or 600 gallons, per minute, with the water flowing at a velocity of 3 ½ feet per second and a loss of frictional head of 9 feet, or 4 lbs., per thousand feet of length. In case the water is to be taken from one end of the pipe only, it would be better to have the pipe 8 inches in diameter. This would secure about the same discharge, 640 gallons per minute, at the same velocity, and with no greater loss of frictional head, viz., 9 feet, or 4 lbs., per square inch. (See Tables, pages 8, 9.)

Fire Boats. Where a city has a water front and Fire-Boats their powerful pumps may be made available for protecting the compact portion at small expense by running 8-inch pipes (10-inch would be better still) with hydrant connections from the water front to the mercantile centre, thus bringing into the heart of conflagration districts a pressure exceeding that of many steam engines and capable of forcing water to the very tops of high, modern fireproof structures—which, by the way, ought always to be provided with external standpipes and Siamese connections at the street, for the use of Fire Departments, even where fire-boats are not available, so as to save the loss of time of carrying hose for the upper stories, especially if the elevator should happen not to be running, as at night. Where pipes with connections at the water front for the use of fire-boats are thus extended into the city an intelligent system of rating should allow 5 % deduction in rate to all buildings on the line of the pipes or within 500 feet of hydrant connections, see items Nos. 186 and 221 of the Universal Mercantile Schedule.

Where the water of the harbor is salt, it may be well to flush the main after a fire by attaching an engine at the land end and blowing fresh hydrant water through the pipe, although with a well tarred cast-iron pipe this would probably be an unnecessary precaution.

Milwaukee is provided with two fire-boats, and has nearly six miles of fire-boat pipe lines, which vary in length from 800 to 3,500 feet. These lines are tapped at each corner as well as in the middle of the block by large hydrants. Six-inch pipe was found to be too small, and at present all fire-boat pipe lines being laid are 8 and 10 inch—10 inches for a half or two-thirds of the distance, the remainder being 8-inch. Chief Foley states that in a test with a 3,250 ft. line, using 2 ½ inch nozzle, the jet of solid water was 120 feet, or the height of an ordinary elevator. In another test, with a 2,250 ft. line two leads of 50 feet each, 3 ½ inch hose and 2 inch nozzle, solid water was thrown from both to a height of 180 feet; after which, Siamesing both streams and using a 3-inch nozzle, water in a solid stream was thrown 198 feet. The connections at the water front are for six 3 ½ inch leads for all the long lines. In warm weather the lines are kept full to save time in starting, but emptied with freezing weather.

The experience of Milwaukee, proves the great advantage of having 10-inch pipe, and nothing less than 8-inch, although the 6-inch does admirable work. The difference in the cost as compared with 8 and 10-inch is so slight in view of the great superiority of the larger pipe as to make the false economy of small pipe extremely shortsighted.

Detroit has a most extensive system, its pipe lines having been laid in nine streets and varying in length from 700 to 4,000 feet. The long line of 4,000 feet has delivered from one hydrant four 1 ¾ and one 2-inch magnificent fire steams. The superiority of the streams delivered from the pipe lines as compared with those of the engine is readily apparent to the most casual observer. The water comes with greater force, in a more solid body, and does the most effective work.

The Detroit lines are provided with a cut-off valve opposite each hydrant, so that in the event of walls falling on the hydrant the water may be shut off without shutting off the entire main, and the pipes are inclined toward the river, enabling the fire boat to fill them when necessary, while in cold weather they are immediately emptied by means of a valve at the foot of the street. In the warmer months they are allowed to remain filled.

I quote from a valuable paper written by Mr. James E. Tryon, Secretary of the Fire Commission, Detroit, on the subject "What a Water Supply Engineer Can Do in the Fire Department," and read by him at the Convention of the New England Water-Works Association, in June, 1894:

"The Detroit pipe lines, laid for the purpose of making the fire boat available for fires at least one-half mile distant from the river, were planned by and laid under the supervision of the compiler of this paper, and a brief description of them may not be out of place. These lines consist of three long lines, two thousand feet each, and three short lines of one thousand feet each, or nine thousand feet in all. For these lines the 8-inch steel pipe, such as the Standard Oil Company uses for piping crude oil from the oil fields to tide water, was selected. The pipe had been subjected to a test of one thousand pounds hydraulic pressure. Connection at the river is made with a three or a five way Siamese with three and one-half inch openings, with a clack valve over each, to enable the boat to start its pumps as soon as the first connection is made. Hydrants having two 3-inch and one 4-inch openings are set at intervals along the line with a manhole opposite each. At the end of the pipe is an air valve loaded to remain open until the water comes, and a relief valve set at 250 pounds, which will open when the pipe is filled and the recoil renders it necessary for something to give way.

We have worked through 1,000 feet of 3-inch hose stretched from a hydrant 2,000 feet from the river, with a pressure of 165 pounds at the hydrant. These results were obtained with a pressure of 176 pounds at the boat. The friction loss in a line 2,000 feet long working through two lines, 100 feet each, of 3-inch hose is as follows:

TWO $1\frac{3}{4}$-INCH STREAMS.

Pressure at Boat.	Pressure at Hydrant	Loss per Foot.
120	80	.0002
140	90	.0025
160	105	.0275
180	120	.0300

These lines were fully completed during the summer of 1893, and were filled repeatedly during the past winter. We have had but two incidents to mar the sucessful working of this branch, one being the failure of the air valve to work, owing to the insufficient load, which made it impossible to fill the pipe, and the other was due to the failure of a relief valve to work, having been set at four hundred pounds. The damage in this case was the blowing off of the Siamese. The pipes are laid as nearly on a level as possible, the lift being about $8\frac{1}{2}$ feet in a thousand. The grade is toward the river, and to prevent the freezing of dead water the pipes are emptied after each filling. When the boat responds to an alarm of fire, connection is made with the most available pipe line and the pumps started just as a land engine fills its line of hose. When the pipe is filled the pumps are stopped to await orders. A single wire laid in a pipe in the same trench with the pipe line is run into the engine room, and a signal code is used, by means of a push button, which can be operated at any hydrant on the line. The boat is signalled by the use of the following code:

1 Bell—Start pnmps.
1 " —Stop pumps.
3 " —Twenty pounds less pressure.
4 " —Twenty pounds more pressure.
6 " —Pick up.

In this way the pipe line enables the boat to play its part in the work of extinguishing the fires that may occur in the City of Detroit."

It would be possible in such cities as Chicago and New York to make use of their powerful fire-boats not merely for supplying water but for furnishing pressure and throwing so many powerful streams as to be equal to twenty or thirty steamers. It seems strange that such precautions are not taken. It is due to Chiefs Swenie and Bonner that I should say here that they are not to blame for so serious an omission. It is estimated that in the territory lying between Chambers Street and Fourteenth Street, New York City, the aggregate value of merchandise and buildings exceeds five hundred millions of dollars. The entire loss-paying ability (i. e., capital and net surplus) of all the Companies doing business in the State, domestic and foreign, does not exceed one-fifth of this sum. It is safe to say that the vacuum in community wealth resulting from the destruction of even one-fifth of this territory would be likely to result in commercial disaster which would be felt from the Atlantic to the Pacific. The simple laying of mains with hydrant outlets, for the fire-boats which are already provided, would go far to prevent the possibility of such a disaster.

On March 12, 1888, in consequence of the blizzard, engines would have been powerless to get to a fire. Not so with the hydrants of the fire-boat pipe lines, however; they could have supplied the needed pressure, and it would have only been necessary to attach hose to the hydrants. Such simple precautions should not be neglected in any of the great cities with a water front.

Water Supply at Harbor Level. At very many places, especially seaboard towns, not having fire-boats with pipe-lines, it might be well to use the neighboring water at its natural level, by means of pipes, or systems of pipes, having both ends immersed to secure a constant circulation, the fire engines connecting their suctions therewith through manholes. Cases in point are the tidal drains at Charleston and the canal and basins system at New Orleans, and at both places much use could be made of the level flow if pipes of proper size were laid and kept fairly clean, as they could be. Much of New York below Canal Street could be protected by the use of a level system such as suggested. At Boston and Norfolk, also, probably it could be made of great service.

Stop-Valves or Gates. Safety cut-off gates should be provided at each corner and on each hydrant branch of the mains, for cutting out any broken pipes, which would otherwise waste the water and diminish the head. By means of these the water may be cut off on each side of a break and a supply secured for a fire in the district or block from neighboring sub-mains, of which there would probably be at least two available on a "gridiron" system. Inasmuch as accidents are liable to happen to pipes, hydrants or gates from opening streets, etc., such provisions are very important. The breaking of a 3-inch or 4-inch service pipe entering a building will often interfere seriously with the supply. In consequence of the fall of a building, a hydrant in full play may be covered with the debris and make it necessary to cut off the section of pipe to which it is attached. The breakage of a 6-inch main and discharge of its contents into the open air would pull down the pressure twenty to thirty pounds and waste enough water to supply a dozen streams. The "stop-valves" or "gates" should be located by some system at a uniform distance from the curb to insure finding them readily in case of necessity, especially when streets are covered with snow. If they are not in the centre of the streets they should be uniformly upon the same geographical side, as upon the northerly and westerly side, and at some fixed distance from the centre of the street and at the same time, exactly on the side line of the cross street. The location of them can also be indicated by a sign on the nearest building or fence showing the direction and number of feet from the curb line.

Careless workmen frequently break gates while making repairs, and neglect to report the fact, with the result that when the broken gate is left closed the result is felt at a fire. In Detroit it was found that out of 2,600 gates 400 were broken and closed. A systematic inspection of the gates should be made by an employee of the department at stated intervals, and a record kept of his report.

The effect of a broken gate neglected and closed is to make a dead end of the pipe on which it occurs—a fatal fact which may not be discovered until a fire occurs; hence the necessity of regular and recorded inspections.

Number of Fire Streams Based Upon Population. Hydraulic experts differ somewhat as to this point from each other and, especially in the case of smaller towns, from Underwriters. Mr. Freeman presents "as a rough, general guide" the following table:

Total population of community protected:	No. of 250 gallon streams which should be available simultaneously *in addition to maximum domestic draft:*
1,000	2 to 3
5,000	4 " 8
10,000	6 " 12
20,000	8 " 15
40,000	12 " 18
60,000	15 " 22
100,000	20 " 30
200,000	30 " 50

Ten streams may be recommended for a compact group of large, valuable buildings *irrespective of a small population.*

As a general statement the pipes should be large enough and the hydrants numerous enough so that at least two-thirds of the above number of streams could be concentrated upon any one square in the compact, valuable part of the city or upon any one extremely large building or special hazard.

Mr. J. Herbert Shedd presents a formula showing the number of streams needed, from which the following values are taken:

Population.	No. of 200 gallon streams.
5,000	5
10,000	7
20,000	10
40,000	14
60,000	17
100,000	22
180,000	30

From a fire-extinguishing standpoint, it should be borne in mind always that in gauging the size of pipes and mains and determining the location of hydrants no general rule based upon population would be a safe or a wise one. It might be as necessary for a village of 3,000 inhabitants, by reason of the grouping of manufacturing or special hazards or exceptionally high or large area mercantile structures, to have ten 250-gallon streams as in the case of a town of 40,000; indeed, in the case of the smaller town it might be more necessary than in the case of the larger.

Pipes below Frost Line. In New England the rule is that the axis of water pipes should be five feet below the surface, especially in gravelly or stony ground.

The importance of laying pipes below the frost line ought not to need emphasis. In some sections of the Northwest they may be frozen seven feet below the surface.

Where a pipe line is laid in a street which has not been graded it should be borne in mind that the subsequent grading of the street may lower the surface to within a dangerous distance from the pipe. As much as two feet of the cover may under circumstances be taken off.

Electrolysis. A serious menace to the pipe system of the country has been discovered in fugitive currents of electricity which escape from trolley and other wires unprovided with proper returns in the shape of good copper wire. In numerous instances pipes have been ruined by these currents of electricity, and greater vigilance must be exercised to prevent widespread disaster.

Hydrants. Only "2-way" hydrants should be used in the business or mercantile section. They should be "staggered" through a territory on alternate sides of the street, so that at least half of them would be safe from a line of fire, and they should be so arranged as to be protected from freezing. The importance of protecting hydrants from freezing ought not to require argument. There is no excuse for frozen hydrants as there are many patterns which with proper care will not freeze. As I write, the entire business portion of a New York town has been destroyed because its steam fire department was helpless by reason of the intense cold. It may safely be stated that the property destroyed in a single winter month of any one year, as a consequence of frozen hydrants, would more than pay for protecting all the hydrants in the country permanently against the dangers of frost. They should have drains to the sewer to carry off the water after being used, and be protected by boxing, etc. There is no excuse for the almost universal neglect of simple precautions, upon the observance of which the safety of an entire city may depend. Where these precautions are not systematically taken, not more than half the credit for the fire department in rates should be allowed under the Universal Schedule.

The location of hydrants is an important matter. As a rule, they should be on the corners of streets, for obvious reasons, chiefly because they would, at such locations, be most quickly discovered. It may happen, however, that the location of a hydrant in too close proximity to a dangerous risk of large area or height might be injudicious.

Two "2-way" hydrants are preferable to one "4-way" hydrant, on account of frost and the probability that at least one may not be frozen.

Hydrants should be liberally distributed; it is a mistaken economy to have them too far apart, not alone because of the loss of frictional head in great lengths of hose—a serious matter—but by reason of the simple fact that 6-inch cast-iron pipe can be laid for about the cost of the best 2 ½ inch hose, with the further important difference, as Mr. Freeman suggests, that the life of the hose will not average more than five to ten years, while the pipe will last half a century. The greater length of hose, moreover, is liable to accident at a critical moment.* In the compact mercantile portion hydrants should not be over 250 feet apart.

The post hydrant, having a 5 ¼ inch or 6-inch riser, with rounded corners, is preferable to the flush hydrant, even where the latter has an extra "4-way" outlet, especially in

*Mr. Freeman says: "More than half the static hydrant pressure is wasted in overcoming the friction through too long a line of hose or too small a street main. Good jacketed fire hose now costs about 75 cents per foot. A 6-inch, tar-coated, heavy cast-iron main can be laid for about 75 cents per foot, cost of pipe, trench, lead and laying all included. A city can buy a good two-way hydrant for less than the price of 50 feet of good fire department hose and its water department can buy and put down 100 feet of the best six inch cast iron water pipe for just about the same price that its fire department pays for an equal length of hose."

Northern States, where a covering of snow might interfere with finding the hydrant; on very narrow streets, however, the flush hydrant may be better. In Boston, the location of flush hydrants is indicated by signs on buildings opposite the hydrants, stating the number of feet and the direction from the curb line. An eight-inch feed pipe, a six-inch riser and round corners leading to the hose nipple will be true economy even for a 2-way hydrant, especially where the pressure exceeds 75 lbs. per square inch.

False economy is practised in selecting hydrants having the main gate and riser only four inches in diameter; the 4-inch stand-pipe sacrifices too much valuable water pressure to be longer tolerated in new work and should be discontinued together with the 4-inch water main. For ordinary purposes of fire protection a standard hydrant should have a main gate and riser at least five inches in diameter and be provided with two outlets for hose. It is not necessary to have independent hose gates on these outlets, as if one does not happen to be used it may be covered by a cap or closed by a portable hose gate carried on the hose wagon and already connected into the rear end of the hose line, while a second gate is at hand for attachment of the spare nozzle during the time the hose is being run and before the hydrant gate is open. The standard hydrant should have a bell for connecting with the water pipe at least six inches in diameter.

It would seem unnecessary to suggest that when hydrants are being located they should be attached to the larger of two available mains, were it not for the fact that in so many instances as almost to amount to a rule they are placed upon the smaller of two mains, simply because the connection costs less money for the pipe laying contractor. This fault is so common, and the consequences are so serious, that it should be the rule of any city that no hydrant connection should be covered up until the Fire Department has had an opportunity to examine and pronounce it satisfactory. With the use of modern appliances in the shape of tapping machines it is possible to connect with the large mains without shutting off water.

The Fire Department should have charge of the location of hydrants as in Detroit, the only city I believe, where this is the case. They can be trusted, in all cases, to put a hydrant on the largest available main.

A notable instance of indifference on the part of a Water-Works Company to avail itself of large mains was discovered in Detroit. I quote from Chief Tryon's report of it:

"In April, 1893, a fire occurred in one of the buildings forming a part of the plant of a large brewing company in Detroit. The fire was quite ugly at the outset and the officer in command promptly sent in a third alarm. Three engineers whose engines were located on Jefferson avenue in which was a 42-inch supply main, with a 6-inch distributing main alongside, complained of poor water and proved it by recording a vacuum pressure on their combination guages. It did not need the guage, however, to tell the story, as by standing next the hydrant I could hear the suction. I could only think of a broken gate somewhere on the line, but when the Engineer of the Water Works, set about investigating, he developed one of the most serious minor defects in our system. It appears to have been the practice heretofore to lay large and small supply mains through districts they were intended to supply *without connecting them to cross lines.* In this case the *engines actually pumped dry a section covering many acres, and the investigation revealed that while the 42-inch and 6-inch mains were laid parallel they were only connected at points 5,100 feet (nearly a mile) apart, and that the district north was supplied entirely from this 6-inch main and all hydrants were connected with it" !*

Another fire in March, 1894, developed the fact that while an 8-inch main had been provided, *the hydrant was on a 4-inch main,* from which an engine could not get sufficient water. I quote from Mr. Tryon's report:

"The supply in this case was an 8-inch main, *the hydrants being on 4-inch mains,* one just north and the other just south of the 8-inch. An investigation showed that the following conditions existed: The gate on the north side of Michigan avenue was closed so that the engine *was pumping out of a 4-inch pipe,* having a feed from but one way and *that from a 3-inch pipe.* This was in a section which has been built up a great many years and the pipeage is as old as the locality. Even had not the gate been closed the pipeage was not sufficient to feed the large engines as was shown in the case of No. 8. With one 1¼-inch stream they were all right, but when they came to add a 1⅜-inch stream they were lost."

It may be assumed as a fact that underwriters have no more important business on hand than that of making proper rates for such unprotected territory, for it may safely be said that millions of dollars worth of property located on inadequate street mains is insured below cost under suppositions of adequate mains which, while provided, at great expense, in the street, are absolutely useless for fire purposes owing to the fact that the hydrants are on small pipes.

Hydrants should be painted a bright red, so that the Fire Department can find them easily. Street sprinklers, sewer diggers and other inexperienced persons ought not to be permitted to use them, as they are liable to get out of order.

Two and one-half inch openings should be avoided; 4-inch should be the rule, especially where 3-inch hose can be handled by the Department.

Hydrants should be regularly flushed, to secure reliability of action and remove the sediment which accumulates in the short arm leading to each post.

Hose. The best quality of jacketed fire-hose, rubber lined and perfectly smooth should be used, of 2 ½ inches internal diameter. Attempts have been made to use 3-inch hose and abandoned, in some cases, because it has been thought unwieldy. The 3-inch hose, however, is necessary in compact mercantile districts. Chief Bonner of New York has 19 companies equipped with 3-inch hose and expects to equip 20 more soon.

A modern steam engine, using 3-inch hose, with capacity of 1,200 gallons per minute, can throw one 1 ½ inch and one 1 ¼ inch stream, or, with two short lines of hose, two 1 ½ inch streams can be thrown. Such streams as these do effectual work. As Mr. Tryon laconically expresses it, they are "solid streams, that do not break until they reach the fire, and leave a black mark where they strike."

Uniform Size and Thread. It is remarkable and inexcusable that a uniform size and pitch of thread for couplings have not been established for the entire country so that the apparatus of neighboring towns can be availed of in case of conflagrations.

The dimensions recommended by the National Association of Fire engineers at the 1891 meeting are as follows:

Couplings for 2½ inch hose, 7½ threads to the inch, 3 1-16 inch diameter to top of threads on male coupling.

Couplings for 2⅝ inch hose, 8 threads to the inch, 3 5-16 inches diameter to top of threads on male coupling.

Couplings for 2¾ inch hose, 8 threads to the inch, 3½ inches diameter to top of threads on male coupling.

Couplings for 3-inch hose, 8 threads to the inch, 3⅝ inches diameter to the top of threads on male coupling.

Couplings for 3½ inch hose, 8 threads to the inch, 4 1-16 inches diameter to top of threads on male coupling.

Couplings for 4-inch hose, 8 threads to the inch, 4⅝ inches diameter to top of threads on male coupling.

Couplings for 4½ inch hose, 8 threads to the inch, 5¾ inches diameter to top of threads on male coupling.

Couplings for 5-inch hose, 8 threads to the inch, 6⅛ inches diameter to top of threads on male coupling.

Couplings for 6-inch hose, 8 threads to the inch, 7 1-16 inches diameter to top of threads on male coupling.

Mr. Charles A. Landy, in an instructive paper on this subject recommends, with much reason, it seems to me, the adoption of a uniform thread of 7½ threads to the inch for the reason that the 7½ swivel part of couplings will connect with 7 or 8 thread male couplings and, therefore, meet the majority of existing conditions throughout the country.

The same dimensions should be followed by all mills and manufactories relying upon the co-operation of the nearest city or village department in case of fire. It has frequently happened that such auxiliary aid has been valueless, simply because hose and hydrant threads would not fit those of the department, and reducing or expanding couplings had not been provided to remedy the fault.

This subject of uniform thread and coupling is deserving of a special convention of Engineers for its consideration.

At present numerous cities capable of helping each other are powerless to do so.

As early as 1830, Mr. Braidwood, the celebrated English Fire Engineer, suggested that if uniformity in the structure and design of apparatus could extend to the most minute particulars, "a screw or nut of any one engine would fit every other engine in the kingdom."

Steam Fire Engines. This suggestion of Mr. Braidwood as to uniformity in the size of nuts and parts of machinery is a far reaching one. At present, the situation in this country is grave from the standpoint that steam fire engines, probably without exception, are of such delicate construction that they resemble the machinery of a watch. They are liable to breakage, and when broken it is discovered that they must be sent to a distance, to the shop of the manufacturer, to be repaired, involving the risk of a conflagration during their absence and outlay for expense because of the exclusive privilege of repairing. Money is needlessly spent on nickel-plate, brass finish and gewgaws, which should be either saved altogether or expended in improving the working parts, all of which should be of such simple, strong construction as to be easily repaired by a mechanic of average ability, to be found in any town. A blacksmith, for example, should be capable of repairing almost any portion of a steam fire engine, and the nuts and bolts should be interchangeable. It is safe to say that the reliability of steam fire departments is materially impaired by reason of the faults mentioned, and that the steam fire engine of the future, when underwriters decide to act upon their present convictions, will be one whose working parts are not only so strong as to reduce the breakage risk to the minimum but of such simple character that they can be easily and quickly repaired, in most cases by the substitution of duplicate parts carried by the engineer himself.

Hose Nozzle. $1\frac{1}{8}$ inch is regarded as better for many reasons than $1\frac{1}{4}$, although the latter, especially with Siamese connection, is decidedly preferable where it can be used. The chances of extinguishing a fire are directly proportional to the amount of water thrown. Small streams are less efficient, as a large portion of the stream is evaporated before it reaches the point of conflagration, and unless water is brought to the burning surface it has little effect.

I quote from Mr. Freeman—"The efficiency of a waterworks or fire department, is measured by its ability to control a bad fire before it becomes a sweeping conflagration, and the design should be based upon streams suitable for this purpose.

Experience shows that large streams are much more effective on a fierce fire than small streams. A small stream may be so completely evaporated into steam as it passes through the flames as to never reach the seat of the fire.

A fire cannot be extinguished by *wetting the flames*.

In every fire which makes a flame, there are two processes taking place—the *first process is the roasting out of gas*; the *second is the burning of this gas*.

Water extinguishes mainly by *chilling the ignited surface* so no more gas is given off—the flames then die.

With a large stream, even though half the water be evaporated as it passes through the flames, there may be enough left to *quench the glowing coals which form the heart of the fire.*

Thus we see the reason for the opinion to which many practical firemen have been led by experience that given, say, 1,200 gallons of water per minute under good pressure—this will do more good on a fierce fire if concentrated into four $1\frac{1}{4}$ in. streams of 300 gallons each, than if used in six 1 in. streams of 200 gallons each, or ten $\frac{3}{4}$ in. streams of 120 gallons each.

A $1\frac{1}{4}$ in. stream is used in many departments and is often better than the $1\frac{1}{8}$ inch, if water is plenty and length of hose short. If hose is long, the friction due to pushing so much water through so small a pipe leaves the nozzle pressure so small that the stream is too feeble.

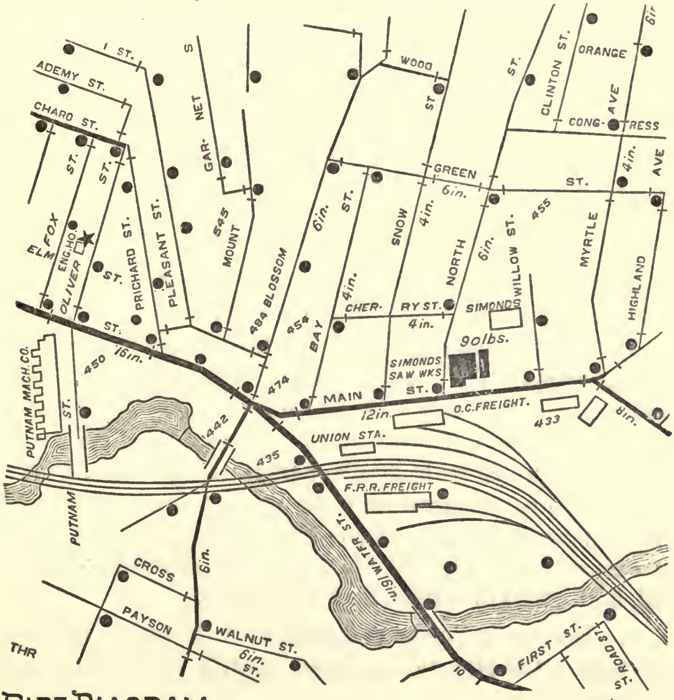
Thus from the hydraulic principles involved, we find that with hydrant pressures of 80 to 100 lbs., and lengths of hose from 200 to 400 feet, the $1\frac{1}{8}$ in. nozzle is the size best adapted for all-round use with $2\frac{1}{2}$ in. hose.

On the other hand, from the teachings of practice and without any discussion of scientific principles, the $1\frac{1}{8}$ in. smooth nozzle has come to be the size most common in the best American fire departments."

In the great Boston fire of 1889, it was safely estimated that enough water was thrown to flood the district of $3\frac{1}{2}$ acres involved $12\frac{1}{2}$ feet deep.

A smooth nozzle and rigid pipe are necessary.

Pipe Diagram. An accurate diagram of the pipe system of the city, showing the size and location of mains and hydrants, with stop-valves and gates, should be in the hands of the Fire Department Chief and the Local Board of Fire Underwriters. In most cities and towns throughout the country, to-day, the only diagram of this kind is in the office of the Water-Works or, worse still, in the possession of some private individual, whose selfish pride in the exclusive possession of it is such that the important secret is likely to die with him. The writer has found this latter condition to exist, strange as it may seem, in more towns than



PIPE DIAGRAM of SECTION of FITCHBURG MASS.

HYDRANTS,– ●
STEAM FIRE ENGINES.–★
DOTTED LINES SHOW CEMENT LINED PIPES

one. In an important western city, not even the water-works company knew the location or sizes of the street mains, and the individual who alone possessed the information was trading upon it in order to enjoy a life monopoly in making repairs.

In making a pipe diagram of the city, it is well to omit the street lines and show only the pipe lines with the names of the streets. This system insures greater clearness, and is the method pursued by Mr. Freeman. The foregoing diagram shows a section of his pipe diagram of the city of Fitchburg, Mass. The heavier arteries or feeders are shown by corresponding heavier lines. The size of the pipe in inches is clearly legible, and where there is both high and low service both systems may be shown by tracing the pipes of the low service in red ink and of the high service in blue ink. The heights of various levels above mean sea level are shown in figures, 474, 454 &c.

Expert Management. The system of a city should be under expert management and the person in charge should understand hydraulic engineering; something more than a knowledge of mechanics is necessary.

Water Works in the Universal Schedule.

It will be observed that the schedule recognizes efficiency and reliability of water-works in the following order:

1. Gravity, with an "effective head" and "volume" at the hydrants. For recognition in schedule rating the reservoir should contain at least five days' supply for domestic and fire service which should be maintained and is more reliable if supplied by hydraulic pumps, in duplicate, from a river or other inexhaustible supply, not liable to drought. If the pumps, whether steam or hydraulic, are arranged to secure also direct pressure in emergency, as already explained, both kinds of service may be secured.

2. Hydraulic Pumps in duplicate, with storage reservoir or tank stand-pipe of ten hours' supply for domestic and fire service.

3. Steam pumps, in duplicate, with a tank stand-pipe or storage reservoir of ten hours supply for domestic and fire service.

4. Direct pressure from Hydraulic Pumps, in duplicate, without tank stand-pipe or storage reservoir.

5. Direct pressure from steam Pumps, in duplicate, without tank stand-pipe or reservoir.

A reservoir system is preferable to all others, and insures uniform pressure in pipes, involving less danger of breakage. While a large reservoir is desirable for storage purposes, however, it is not indispensable for fire purposes. A reservoir sufficient to hold a supply for both domestic and fire service of ten hours would probably be ample for extinguishing any fire. As already stated, one million gallons storage will supply eleven, standard, 250 gallon, fire streams for six hours, and for the ordinary city up to 15,000 inhabitants, a million gallons could be considered an ample reserve of storage for fire purposes.

Fire-proof Pumping Station. It would seem unnecessary to state that the building on whose existence the safety of a city depends should be safe from fire and separated from dangerous manufacturing or other hazards and especially from Electric Lighting Stations. It will be observed that charge is made (item No. 8) for an electric-light station or other special hazard in the pump-house or exposing it. It is a grave question if this charge ought not to be higher, even to the extent of making the "key-rate" of a city having a direct pressure system, so jeopardized, higher than that of a town without any waterworks at all, in view first, of the fact that such a town afterwards gets credit for individual risks in proximity to hydrants to the extent possibly of 15 % (see Nos. 155, 156) and, second, of the fact that a company's conflagration line in the direct pressure town would have been increased by reason of the pressure, but all benefit of the system lost if a fire destroying the pump-house should happen to be coincident with the raging of a conflagration in the city.

Cisterns. In Detroit, small cisterns or reservoirs, holding 7,000 gallons or more, are distributed throughout the city, notwithstanding the pipe system, and would admirably supplement a broken street main. In some cases they are of oblong or sewer shape, of cemented brick.

As stated elsewhere, in all cases where dead ends are necessary in the outskirts of the city, a cistern or reservoir is provided at the end, so that in blowing off the dead end the waste water is husbanded for fire purposes.

CAPACITY OF CISTERNS OR STAND-PIPES IN U. S. GALLONS.

For each 12 inches of depth.

The following table will enable any one to estimate the capacity of tank stand-pipes or cisterns of cylindrical form in U. S. gallons for each 12 inches of depth:

4 feet diameter,	94	11 feet diameter	711
5 " "	147	12 " "	846
6 " "	211½	13 " "	993
7 " "	288	14 " "	1115½
8 " "	376	15 " "	1322
9 " "	476	20 " "	2350
10 " "	587½	25 " "	3672

For example, a cistern 25 feet in diameter would contain 3672 gallons for every foot of depth; and if 10 feet deep, 36720 gallons, or 918 bbls.

A simple rule may be stated as follows: To find the contents in U. S. standard gallons *for each foot of depth* of a cylindrical cistern with a circular base, *multiply the square of the diameter* (*in feet*) *by* $5\frac{7}{8}$*; the product will be the contents in gallons.**

For example, a cistern 20 feet in diameter and 10 feet deep would contain $20 \times 20 \times 5\frac{7}{8} \times 10 = 23500$ gallons (see table above).

*The cubic contents in feet of a cylinder like a cistern are obtained by multiplying the area of the circle by the depth in feet. Inasmuch as the area of a circle is obtained by multiplying the square of the diameter by 7854, and inasmuch as a cubic foot of water contains 7.48 gallons, it is only necessary to multiply the square of the diameter by the product of 7.48 X .7854,—5⅞, to obtain the result in gallons, without the longer computation.

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(COPY.)

INSURANCE DEPARTMENT
State of New York.

11 Broadway, New York, Feb'y 7, 1901.

Hon. Francis Hendricks,
Superintendent of Insurance,
Albany, N. Y.

Sir:

I beg to report that I have concluded the investigation into the condition of THE CONTINENTAL INSURANCE COMPANY of New York, made for the purpose of verifying the correctness of its Annual Statement for the year 1900, now on file in the Insurance Department, and ordered by your appointment No. 1403. The result of the examination establishes conclusively the accuracy of the figures given in said statement as representing the condition of the Company on December 31st, 1900. In it, the values at which the company inventories its securities consisting of bonds and stocks, are, as will be seen, very considerably less than the current market quotations of these items on December 31st last. The inventoried prices given in the statement are in line with a conservative policy heretofore adopted by the company for the purpose of extending these assets in its annual statements at figures well within the possibility of any probable future depreciation likely to occur therein from any unforeseen cause, thus rendering more certain the prompt payment of obligations to policyholders in the event of any contingency arising necessitating a quick conversion of these assets into cash for the payment of extraordinary losses.

The figure representing the liability for premiums unearned was found to be somewhat in excess of the statutory requirement regulating this charge, due to the fact that the company does not deduct from its liabilities, as it might, the unexpired reserve on the premiums past due and which have been deducted from its assets.

A liberal verification of a portion of the unearned premium fund was made by checking in detail the writings, cancellations and re-insurances, and separately scheduling them from original data, and the items of premiums in course of collection and losses outstanding were similarly investigated and verified.

The result shows that the annual statement of the company for the year 1900, now on file in the Insurance Department of New York, meets all legal requirements, the surplus set forth therein being even greater than that claimed by the company, by reason of the facts above stated.

Respectfully submitted,

ISAAC VANDERPOEL,
Chief Examiner.

Ask the Agent of the Continental to explain to you the importance of

THE SAFETY FUND LAW OF NEW YORK,

under which this Company conducts its business.

It is optional with a Company as to whether or not it will voluntarily place its business under the restrictions of this law, but once having done so, it cannot withdraw and must ever thereafter restrict its dividends in accordance therewith.

It was the first and largest Company to comply with the act. The Safety Fund Law provides a Special Reserve Fund for a new Capital, deposited with the Insurance Department of the State of New York, now amounting in the case of the Continental to $600,000, which together with its reserve for policies in force, amounting to $4,806,903 is set aside for the protection of all policy-holders not involved in the burning of a city. Over one hundred Companies failed by the great fires of Chicago and Boston, thirteen months apart; it is therefore very important to property-owners to be insured in a large Safety Fund Company. If they happen to be involved in a sweeping city fire they will receive more under this law than under any other; and if not so involved, are absolutely secure and will be as fully insured as if no such great fire had happened. In addition to this fact the Continental has so regulated its conflagration lines in cities as to have less than its Net Surplus involved anywhere; so that, in case of the burning of any city, it would have an unimpaired capital for the protection of its unburned policy-holders.

A Safety Fund Policy costs no more than any other.

INSURE WITH AN AMERICAN COMPANY.

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INSURE IN AN AMERICAN COMPANY.

RENT INSURANCE. TORNADO INSURANCE.