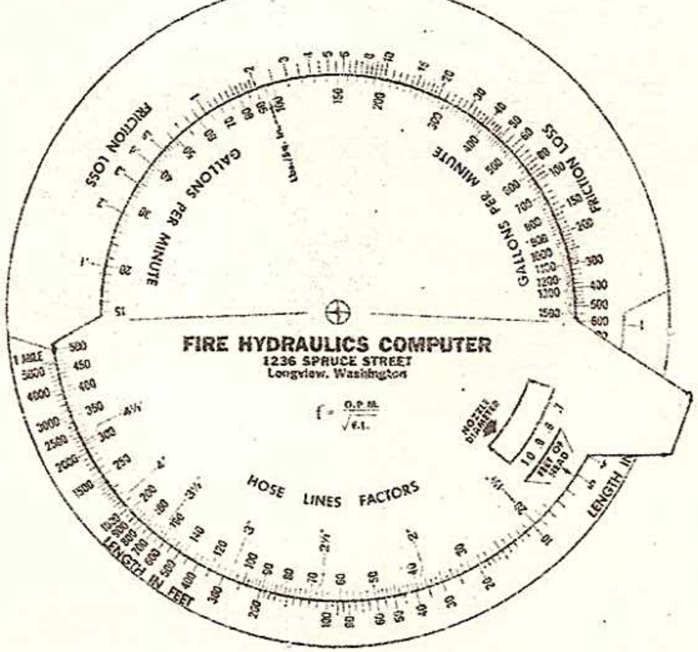
FIRE HYDRAULICS COMPUTER



HOW TO USE YOUR

FIRE HYDRAULICS COMPUTER

THIS COMPUTER HAS TWO MAIN FUNCTIONS.

FIRST OF ALL, IF ANY THREE OF THESE FOUR THINGS ARE KNOWN, THE OTHER UNKNOWN CAN BE DETERMINED SIMPLY BY ALIGNING THE TWO KNOWNS THAT READ IN CONJUNCTION WITH EACH OTHER, THEN READING OPPOSITE THE OTHER KNOWN:

1. FRICTION LOSS IN THE LAY
2. GALLONS PER MINUTE FLOWING
3. LENGTH OF THE HOSE LAY
4. NUMBER AND SIZE OF HOSE LINES

THE FRICTION LOSS SCALE IS ON THE LOWER DISK, AND READS IN CONJUNCTION WITH THE GALLONS PER MINUTE SCALE ON THE UPPER DISK. THE LENGTH IN FEET SCALE IS ON THE LOWER DISK, AND READS IN CONJUNCTION WITH THE HOSE LINES FACTORS SCALE ON THE UPPER DISK. PLEASE READ THE ENCLOSED REPRINT OF THE ARTICLE "A NEW LOOK TO HYDRAULICS" FROM FIRE ENGINEERING MAGAZINE FOR FURTHER DETAILS ABOUT THE FACTOR SYSTEM.

EXAMPLE: WHAT WILL BE THE FRICTION LOSS IN 500' OF 2½" HOSE, WITH 250 G.P.M. FLOWING?

BY ALIGNING THE 500' WITH THE 2½" HOSE LINE, AND THEN READING OPPOSITE 250 G.P.M. ON THE FRICTION LOSS SCALE, WE FIND THAT THE FRICTION LOSS IS 67 POUNDS.

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YOU WILL NOTICE THAT THE FACTORS FOR VARIOUS COMMON HOSE SIZES ARE INDICATED:

HOSE		FACTOR
1½"		20
2½"		68
3"	(2½" COUPLINGS)	108
3½"		166
4"		225
4½"		305

NOTE: ERROR ON COMPUTOR F215 FOR 4" HOSE SHOULD BE F225.

THESE FACTORS ARE BASED ON TABLES IN THE N.F.P.A. HANDBOOK. SOME DEPARTMENTS HAVE FOUND THROUGH TESTING THAT THEIR HOSE DOES NOT HAVE AS MUCH FRICTION LOSS AS THESE TABLES INDICATE. IF THIS IS YOUR CASE, ALIGN THE FRICTION LOSS WITH THE FLOW DURING YOUR TEST, AND THE FACTOR CAN BE READ OPPOSITE THE LENGTH TESTED. BEAR IN MIND, HOWEVER, THAT THERE ARE USUALLY FRICTION LOSSES IN VALVES, WYES, SIAMESES, HOSE BENDS, ETC., THAT A TEST OF HOSE LAID STRAIGHT DOES NOT TAKE INTO ACCOUNT. SOME FEEL THAT IT IS WISE TO ALLOW MORE FRICTION LOSS THAN A TEST INDICATES TO COMPENSATE FOR THESE ADDITIONAL LOSSES.

WHERE PARALLEL LINES OF EQUAL LENGTH ARE USED, JUST ADD THEIR FACTORS. FOR INSTANCE, WHERE TWO $2\frac{1}{2}$" LINES ARE USED, THE FACTOR IS 68 PLUS 68, OR 136. THE FACTOR FOR A 3" AND A $2\frac{1}{2}$" LAID PARALLEL IS 108 PLUS 68, OR 176, AND SO ON.

THE LENGTH IN FEET SCALE AND THE HOSE LINES SCALE CAN BE USED TO CONVERT ONE LAY TO ANOTHER.

EXAMPLE: 500' OF 3" HOSE HAS THE SAME FRICTION LOSS AS 200' OF $2\frac{1}{2}$" HOSE, FOR THE SAME FLOW.

EXAMPLE: 550' OF 4" HOSE HAS THE SAME FRICTION LOSS AS 50' OF $2\frac{1}{2}$" HOSE.

IN FACT, FOR ANY POSITION OF THE TWO SCALES, ALL COMBINATIONS OF HOSE LINES AND LENGTH IN FEET ALIGNING HAVE THE SAME FRICTION LOSS, FOR A GIVEN FLOW.

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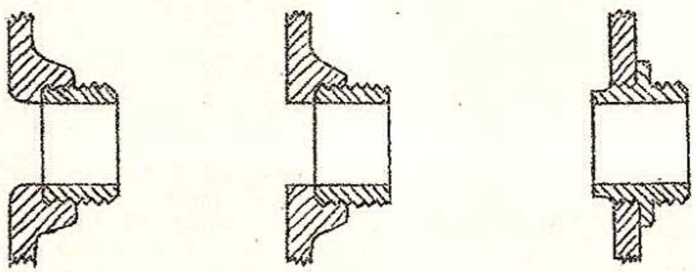
NOW, FOR THE SECOND FUNCTION OF THE COMPUTER.

WHEN A NOZZLE TIP SIZE IS ALIGNED IN THE WINDOW (LABELED NOZZLE DIAMETER) THE G.P.M. DISCHARGE FOR ANY NOZZLE PRESSURE CAN BE READ.

EXAMPLE: A 2" TIP DISCHARGES 1300 G.P.M. AT 120 POUNDS NOZZLE PRESSURE, BUT ONLY DISCHARGES 841 G.P.M. AT 50 POUNDS NOZZLE PRESSURE.

BECAUSE OF TURBULENCE, THE DISCHARGE FROM AN OPEN HOSE BUTT WILL BE LESS THAN WHAT IT WOULD BE THROUGH A SMOOTH NOZZLE OF THE SAME SIZE. SO, TO DETERMINE THE FLOW THROUGH AN OPEN HOSE BUTT, PLACE THE HOSE DIAMETER AT .9 ON THE LOWER EDGE OF THE WINDOW.

HYDRANTS VARY ACCORDING TO THE WAY THEY ARE CONSTRUCTED. IF THE OUTLET IS SMOOTH AND ROUNDED, USE COEFFICIENT OF .9; IF THE OUTLET IS SQUARE AND SHARP, USE COEFFICIENT OF .8; IF THE OUTLET IS SQUARE AND PROJECTS INTO BARREL, USE COEFFICIENT OF .7.



.9 .8 .7

BETWEEN 1-1/8" AND 1-1/4" NOZZLE DIAMETERS, THERE IS A POSITION MARKED TO INDICATE A BRESNAN DISTRIBUTOR. ALTHOUGH THE SUM OF THE OPENINGS ON A TYPICAL BRESNAN DISTRIBUTOR IS EQUAL TO A 1-5/8" NOZZLE, IT'S FLOW CHARACTERISTICS ARE THAT OF A NOZZLE 1-1/5" IN DIAMETER.

THERE IS ALSO PROVISION FOR CONVERTING FROM FEET OF HEAD TO POUNDS PER SQUARE INCH, OR VICE VERSA. THE TWO ARROW POINTERS, ONE BELOW THE NOZZLE DIAMETER WINDOW, THE OTHER BETWEEN 90 AND 100 G.P.M. ON THE GALLONS PER MINUTE SCALE, ARE USED FOR THIS CONVERSION. WHEN USED FOR THIS PURPOSE, THE POUNDS PER SQUARE INCH IS NOT FRICTION LOSS, NECESSARILY, HOWEVER.

EXAMPLE: WATER 150' HIGH WILL CAUSE 65 POUNDS PER SQUARE INCH OF PRESSURE.

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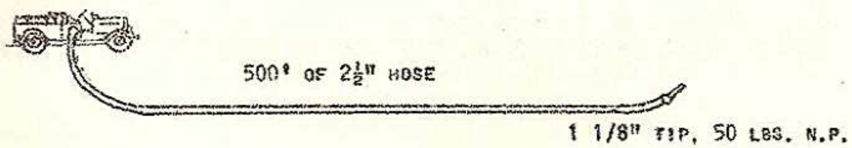
NOW, LET US SOLVE SOME TYPICAL PROBLEMS:



AN ENGINE IS PUMPING INTO 500' OF $2\frac{1}{2}$" HOSE WITH A 1-1/8" TIP HAVING 50 POUNDS NOZZLE PRESSURE. WHAT IS THE ENGINE PRESSURE?

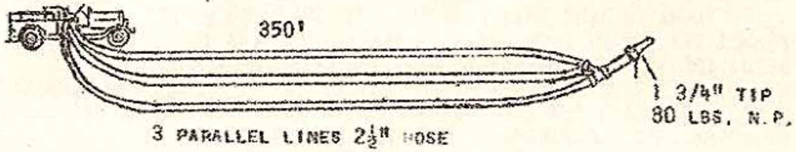
SOLUTION: THE ENGINE PRESSURE IS THE SUM OF THE FRICTION LOSS AND THE NOZZLE PRESSURE, PLUS ANY OTHER LOSSES SUCH AS BACK PRESSURE WHEN LINE IS LAID UPHILL, LOSSES IN SIAMESE CONNECTIONS, MASTER STREAM APPLIANCES, ETC.

BEFORE SOLVING THE PROBLEM, THE G.P.M. MUST BE DETERMINED. BY PLACING 1-1/8" TIP IN THE NOZZLE DIAMETER WINDOW, WE FIND THAT A NOZZLE PRESSURE OF 50 POUNDS WILL RESULT IN A FLOW OF 265 G.P.M. NOW WE CAN ALIGN THE 500' WITH THE $2\frac{1}{2}$" HOSE LINE, THEN READ THE FRICTION LOSS FOR THE LAY OPPOSITE 265 G.P.M., WHICH IS 75 POUNDS. THIS FRICTION LOSS ADDED TO THE 50 POUNDS NOZZLE PRESSURE WILL GIVE AN ENGINE PRESSURE OF 125 POUNDS.

HOW LONG COULD THE ABOVE LAY BE, SUPPLYING THE 1-1/8" TIP AT 50 POUNDS NOZZLE PRESSURE, IF YOU WERE PUMPING AT 250 POUNDS ENGINE PRESSURE INTO THE $2\frac{1}{2}$" HOSE?

SOLUTION: BY SUBTRACTING 50 POUNDS NOZZLE PRESSURE FROM THE 250 POUNDS ENGINE PRESSURE, WE FIND THAT 200 POUNDS CAN BE USED IN FRICTION LOSS. ALIGNING 200 POUNDS FRICTION LOSS WITH 265 G.P.M., THE DISTANCE OF 1350' IS READ OPPOSITE $2\frac{1}{2}$" HOSE.

HERE'S ANOTHER PROBLEM:



AN ENGINE IS PUMPING INTO 350' OF THREE PARALLEL LINES OF 2½" HOSE, WHICH ARE CONNECTED TO A DELUGE GUN HAVING A 1-3/4" TIP. 80 POUNDS IS WANTED AS A NOZZLE PRESSURE. WHAT IS THE ENGINE PRESSURE?

SOLUTION: FIRST DETERMINE THE FLOW. A 1-3/4" TIP AT 80 POUNDS IS 815 G.P.M.; WITH 350' ALIGNED WITH A FACTOR OF 204 (3 TIMES 68), 815 G.P.M. ALIGNS WITH 57 POUNDS FRICTION LOSS. 57 POUNDS FRICTION LOSS, PLUS 80 POUNDS NOZZLE PRESSURE, PLUS ABOUT 10 POUNDS FRICTION LOSS IN THE DELUGE GUN, EQUALS <u>147</u> POUNDS ENGINE PRESSURE.

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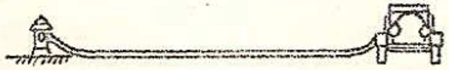
PROBLEM: YOU ARE OPERATING A 1,000 G.P.M. PUMPER WITH THREE HOSE BEDS; ONE CONTAINING 600' OF 2½" HOSE, THE SECOND CONTAINING 600' OF 3", AND THE THIRD CONTAINING 600' OF 3½" HOSE.



YOU WISH TO KNOW HOW FAR AWAY YOU CAN PLACE YOUR PUMPER FROM THE HYDRANT AND STILL PUMP 1,000 G.P.M. THE HYDRANT WILL DELIVER 1,000 G.P.M. AT 80 POUNDS.

SOLUTION: LEAVING ABOUT 10 POUNDS PRESSURE COMING INTO THE PUMPER, YOU CAN THEN USE UP THE REMAINING 70 POUNDS FROM THE HYDRANT IN FRICTION LOSS. PLACING THE 1,000 G.P.M. OPPOSITE THE 70 POUNDS FRICTION LOSS ON THE COMPUTER, THE MAXIMUM DISTANCES CAN BE READ FROM 2½" HOSE (33') THROUGH 3" (84'). 3½" (192'), OR COMBINATIONS OF THESE: A 3½" AND A 3" LAID PARALLEL (FACTOR OF 274) COULD BE 500' LONG, AND STILL DELIVER THE 1,000 G.P.M. TO THE PUMPER.

SUGGESTION: A LIST OF THE DISCHARGES AT VARIOUS RISIDUAL PRESSURES THAT CAN BE EXPECTED FROM THE HYDRANTS IN YOUR HIGH VALUE DISTRICT, TAPED TO THE BACK OF THE COMPUTER, WILL BE VERY USEFUL IN SOLVING PROBLEMS SUCH AS THIS.

EXAMPLE:

G.P.M.	-	PRESSURE
0	@	102 POUNDS
725	@	90 POUNDS
1000	@	80 POUNDS
1225	@	70 POUNDS
1425	@	60 POUNDS
1600	@	50 POUNDS
1775	@	40 POUNDS
1900	@	30 POUNDS
2050	@	20 POUNDS
2175	@	10 POUNDS
2300	@	0 POUNDS

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THE PURPOSE OF THIS INSTRUCTION BOOKLET IS NOT TO TEACH HYDRAULICS, BUT TO GIVE YOU AN IDEA OF SOME OF THE USES OF THE FIRE HYDRAULICS COMPUTER. IF YOU CONTINUE TO PRACTICE WITH IT, YOU WILL FIND IT VERY USEFUL IN YOUR HOSE LAYOUTS, TESTING OF PUMPERS AND HYDRANTS, ETC.

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$$f = \frac{G.P.M.}{\sqrt{F.L.}}$$

The "f" system for standardizing friction loss in hose and making friction loss calculations gives . . .

A New Look to Hydraulics

By DAN PIERCEY

Friction loss is much more than a resistance to overcome in maintaining good nozzle pressures. In fact, it is the underlying cause of the greatest handicap facing most fire departments—the shortage of men and money.

If that seems like a far-fetched statement, take a moment to think about why it is that such large, cumbersome hoses are needed.

There is only one reason and that is to get away from friction loss.

The manpower time factor, usually blamed on the nature of fire—its propagation rate, etc.—is therefore partially the fault of friction loss. And ultimately, a portion of every major, fire department expenditure such as men, apparatus, hose, gasoline, etc., is chargeable to the effects of friction loss. To know, in dollars and cents, how great this portion is would require a costly study. But it is reasonable to assume that it is enormous.

It seems strange then, that the fire service as a whole, should treat the problem with such indifference. Just because there is no foreseeable way to completely eliminate friction loss does not mean that we shouldn't try to deal with it as efficiently as possible, and lessen it in some way.

We are not dealing with it as efficiently as possible because our mathematical perspective is one from a bygone era, when it was thought friction loss for each hose diameter, was relatively stable, and that 2½-inch hose was an ideal conversion standard for all other hose. But it has long since been discovered that, in any hose, friction loss varies with quality, and quality with time. So much so, in fact, that fixed calculating methods, such as the old "Q" formulas, can not be relied on for perpetual accuracy.

Naturally it wouldn't be right for me to carry on like this without having in mind a proposal for making a systematic assault on the problem. However, I would not be so vain as to say my proposition is the final answer. I can promise only that it is better than what we have now. It is called the *"f" System* for rating hose and making friction loss calculations.

The *"f" System* sprung out of the fact that in any hose carrying water at a rate suitable for fire fighting purposes, the flow and the square root of friction loss, vary in such a way that their ratios remain approximately constant. This constant, represented by the small letter *"f"* is the key to the system.

• Example I: Here is an approximation of the way flow and friction loss might vary in a 100 foot section of 2½-inch hose.

$G.P.M._1 = 210 \qquad F.L._1 = 9$ p.s.i.
$G.P.M._2 = 420 \qquad F.L._2 = 36$ p.s.i.

Notice that the ratios are proportional, the values constant.

$$\frac{G.P.M._1}{\sqrt{F.L._1}} :: \frac{G.P.M._2}{\sqrt{F.L._2}} = 70 :: 70$$

This particular 2½-inch hose has a constant or *"f"* value of *70*. In other words, as far as friction loss is concerned, this hose is of *f70* quality. An inferior make of 2½-inch hose might have an *f65* rating.

From the foregoing it is evident that an equation can be written for finding the *"f"* quality of any hose:

$$\frac{G.P.M.}{\sqrt{F.L.}} = f \qquad \text{Equation (1)}$$

When using Equation 1 in the actual rating process, friction loss should be 25 p.s.i., approximately the mean tolerable friction loss in fire hose, and a perfect square, simplifying computation. Nozzle pressure should be at least 100 p.s.i. to guarantee an adverse friction loss condition in the hose. Thus, with an equation, and similar conditions for its use having been established, all that remains to be done is to test a number of market samples. The average *"f"* numbers obtained can then be used as standards.

Friction loss calculations

With Equation 1 the results of any friction loss test may be written with a single "f" number instead of a table. Likewise, any friction loss table will yield an *"f"* number that can be used in Equation 2 to find friction loss at any flow.

$$F.L. = \left(\frac{G.P.M.}{f}\right)^2 \qquad \text{Equation (2)}$$

• Example II: At 350 G.P.M. what would be the friction loss in the 100 feet of *f70* hose from Example I?

$$F.L. = \left(\frac{350}{f70}\right)^2$$

$$F.L. = 5^2$$

$$F.L. = 25 \text{ pounds}$$

With the addition of a length factor, Equation 2 becomes a friction loss formula for general use. The length factor: L = number of 100 foot sections making up the total line.

$$F.L. = \left(\frac{G.P.M.}{f}\right)^2 (L) \qquad \text{Equation (3)}$$

The *Fire Protection Handbook*, twelfth edition, contains friction loss tables for all diameters and types of fire hose. The following *"f"* numbers were derived from this source.

Hose	"f" number
1½ inch	f20
2½ inch	f68
3 inch	f108
3½ inch	f166

Although this seems to be the most

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current of such data and is probably suitable for general use, it is, by no means, of recent origin. For greatest accuracy, a department can find "*f*" for the hose it is now using with the following formula:

$$f = \frac{G.P.M.}{\sqrt{F.L. \div L}} \qquad \text{Equation (4)}$$

This can be done along with the next periodic pressure test, without added inconvenience. Friction loss should be about 25 pounds per hundred feet. Using the formula is simplified by testing 400 feet at a time.

The formula may also be applied to friction loss tables to find "*f*" for any diameter or type of hose. Here also, F.L. should be about 25 pounds.

With the friction loss formula, Equation 3, it is quite easy to find the total friction loss in any hose layout. Keep in mind that conversion factors are not required at any time.

Single lines

• Example III: With 150 feet of 1½-inch hose, you are satisfying an 80 G.P.M. nozzle. What then is the friction loss?

$$F.L. = \left(\frac{80}{f20}\right)^2 (1\tfrac{1}{2})$$

$$F.L. = 4^2\ (1\tfrac{1}{2})$$

$$F.L. = 24 \text{ pounds}$$

• Example IV: 500 G.P.M. is flowing through 200 feet of 3-inch hose. What then is the friction loss?

$$F.L. = \left(\frac{500}{f108}\right)^2 (2)$$

$$F.L. = 4.6^2\ (2)$$

$$F.L. = 42.3 \text{ pounds}$$

Compound lines

A compound line consists of two or more parallel lines of equal length, but not necessarily of equal diameter. The "*f*" number for such a layout is the "*f*" sum of the lines involved.

• Example V: Three 300-foot 2½-inch lines are supplying 1000 G.P.M. to a deluge set. What then is the friction loss?

$$F.L. = \left(\frac{1000}{3f68}\right)^2 (3)$$

$$F.L. = \left(\frac{1000}{204}\right)^2 (3)$$

$$F.L. - 4.9^2\ (3)$$

$$F.L. = 71.4 \text{ pounds}$$

• Example VI: Using the same layout as in Example V, except that one of the lines is 3 inches—what is the friction loss?

$$F.L. = \left(\frac{1000}{2f68 + f108}\right)^2 (3)$$

$$F.L. = \left(\frac{1000}{244}\right)^2 (3)$$

$$F.L. = 4.1^2\ (3)$$

$$F.L. = 50.4 \text{ pounds}$$

Complex lines

A complex line consists of any combination of compound (c) and single (*s*) lines. $F.L. = F.L._c + F.L._s$

• Example VII: Two 200-foot 2½-inch lines are siamesed into a single 50-foot 3-inch line. At 600 G.P.M., what is the friction loss?

$$F.L._c = \left(\frac{600}{2f68}\right)^2 (2) = 38.8$$

$$F.L._s = \left(\frac{600}{f108}\right)^2 (\tfrac{1}{2}) = 15.4$$

$$F.L. = 54.2 \text{ pounds}$$

Planning hose layouts

In planning it is usually desirable to compare the friction loss in different layouts. This is easily done by comparing "*f*" numbers. For a given length, the higher the "*f*" number, the better the water carrying ability, the lower the pressure needed.

• Example VIII: It is necessary to move 1000 G.P.M. from one point to another by one of the three following lays. Which would be lowest in friction loss?

Two 2½-inch lines	= 2f68 =	f136
One 3-inch line	=	f108
One 3½-inch line	=	f166

It can be seen at a glance that the 3½ inch is superior, and the 3 inch is least desirable.

Comparing hose lays

To find the maximum amount of line "a" than can replace line "b" without increasing friction loss, use this equation:

L = total length of line

$$L_a = \left(\frac{f\text{ line a}}{f\text{ line b}}\right)^2 (1_b) \qquad \text{Equation (5)}$$

• Example IX: From Example VIII we know that two 2½-inch lines are superior to one 3-inch line. If we wish to replace 100 feet of 3-inch line with two 2½-inch lines, how long may they be without increasing friction loss?

$$L_a = \left(\frac{2f68}{f108}\right)^2 (100)$$

$$L_a = 1.58\ (100)$$

$$L_a = 158 \text{ feet}$$

Therefore, 158 feet of double 2½-inch, *f68* line has the same friction loss as 100 feet of single 3-inch, *f108* line.

Finding flow

For some nozzles, such as fog nozzles, water curtains, distributors, etc., the flow cannot be accurately determined with the same method used for ordinary straight stream nozzles, even though you know the nozzle pressure and orifice area. One alternative is to catch the flow in some type of basin or tank and measure it; the other is to find the friction loss by subtracting from the engine pressure, the pressure at the base of the nozzle, and the application of this formula:

$$G.P.M. = f\,\frac{\sqrt{F.L.}}{L} \qquad \text{Equation (6)}$$

Friction loss in appliances

For siameses, standpipes, monitors, suction hose, etc., "*f*" numbers can be established with Equation 1, and friction loss at various flows found with Equation 2.

Summary

Friction loss is a serious handicap to fire department organization and fire fighting operations. If it is to be dealt with appropriately, we must abandon our complacency and establish a starting point from which progress can be made.

In the meantime, our friction loss mathematics, no longer commensurate with what we know to be the truth, must be up-dated.

Since G.P.M. is the only prime, fire fighting consideration with which friction loss is closely related, it seems only reasonable that this relationship should serve as the fundamental principle, upon which to formulate any rating or calculating system. Of several basic ways to view this relationship, one seems to be definitely best for our purpose, mainly because of its simplicity. It is,

$$G.P.M./\sqrt{F.L.} = \text{a constant } (f).$$

From here it is only a matter of applying, transposing and enlarging this basic equation to fit our needs. The extent to which this has been done is called the "*f*" *System.*

Conclusion

1. The "*f*" *System* offers a basis for standardizing and improving friction loss quality in hose and appliances.

2. This basis, also the backbone of a working system for making friction loss calculations, is a constant reminder that quality is one of the conditions of friction loss.

3. The working system is a simple, complete system, with all components containing a common element, based on a common fact, and is therefore easily taught, quickly learned and easily used. Its accuracy, the maximum possible for simple formulas, will not be lost with future improvements in hose quality, nor will its form have to be altered to accommodate these changes. □□