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EXPERIMENTS IN SPRAY
HYDRAULICS

THESIS FOR THE DEGREE OF M. S.

Glenn R. Starcher
1930

Spraying
Till Spray hydraulics

Horticulture

Praying

EXPERIMENTS IN SPRAY HYDRAULICS

Thesis

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Glenn R. Starcher

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V.R. Gardner*

THESIS

EXPERIMENTS IN SPRAY HYDRAULICS

Introduction.

One of the most outstanding differences in fruit tree spraying today as compared to a few years ago is the high pressures at which the materials are now being applied. Before the advent of the gasoline engine, practically all the spraying was done by hand power, and it was unusual to maintain pressures much in excess of 100 pounds to the square inch. No doubt the growers might have preferred higher pressures so as to be able easily to reach the tops of the trees, but hand pumping was too laborious an operation, even with the best of equipment.

Now that the gasoline engine is here, spraying pressures have been steadily increasing. Stronger and better hose is being built that will easily accommodate pressures of from 400 to 600 pounds, and even more in some cases. Pumps are being built that deliver larger and larger volumes of solution at these high pressures. It takes careful spraying at high pressures to cover the trees and fruit efficiently. More and more attention is being given to the pressure at which the spray is applied and just how much is applied. Modern spray schedules call for thorough spraying of large orchards in just a few days.

Object of Studies.

This experiment was undertaken in an effort to learn more about the volume of delivery under various conditions, and the pressure losses encountered due to these varying conditions. Hose of $3/8$, $1/2$, and $3/4$ inch diameters and of 50 and 12 $1/2$ foot lengths was used. The volume of delivery and pressures at both the air chamber and the gun were determined, using various sized disc apertures at different pressures with both standard and large hose fittings. From these data the pressure losses in the pipes and hose were determined. Similar but less complete studies were made of the multiple nozzle rods. Also, various combinations of cutoffs, pipes, and whirl-plates were tried with these rods to see how they influenced the rate of delivery and spraying pressure.

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Review of Literature.

Since high pressure spraying is a development of very recent times, there is little literature available on that subject. Some of the oldest work along related lines was done in connection with tests on fire hose.

In 1878 Ellis (3) reported experiments conducted to show the pressure losses, water deliveries, etc., for both leather and rubber fire hose of various diameters, lengths, and pressures. The pressures were all relatively low, none exceeding 130 pounds. However, his explanations and theories of discharge should be similar to those for the much higher pressures and smaller hose used in modern spraying.

Pressure gauges placed along the flow of water show only the pressure at that point not converted into velocity, so this loss plus the gauge reading is the actual pressure. A gauge at the nozzle would register a pressure of zero. Table I gives the velocity of flow in feet per second and the pressure in pounds required to produce that given velocity, which amount must be added to the apparent pressure to give the actual pressure.

Table I.

Velocity	Pressure	Velocity	Pressure	Velocity	Pressure
8.6 feet	.5 lbs.	21.0 ft.	3.0 lbs.	29.9 ft.	6.0 lbs.
11.2 "	1.0	22.8	3.5	32.3	7.0
14.9	1.5	24.4	4.0	34.5	8.0
17.2	2.0	25.9	4.5	36.6	9.0
19.3	2.5	27.2	5.0	38.6	10.0

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From other data supplied by Ellis (3) calculations were made of the velocity in feet per second required through different sized pipes to deliver various amounts of water per minute.

Table II

Diameter of Pipe	1 gal.	5 gal.	10 gal.	15 gal.
1/4 inch	6.67 feet	33.3 feet	66.7 feet	100.0 feet
3/8	2.92	14.6	29.2	43.8
1/2	1.63	8.2	16.3	24.5
5/8	1.05	5.3	10.5	15.8
3/4	.72	3.6	7.2	10.8
7/8	.53	2.7	5.3	8.0
1	.41	2.1	4.1	6.2

From tables I and II it is possible to calculate the actual pressure if the gauge reading, the size of pipe on which the gauge is fixed, and the volume of delivery are known.

The amount of friction in a hose depends directly on the velocity of flow. Doubling the velocity increases the loss in pressure by nearly four times. Doubling the diameter of the pipe decreases by one-half the friction loss at the same velocity. By reducing the velocity so as to have the original delivery, or one-fourth the original velocity, the friction loss is reduced by about thirty-two times. This makes it clear why it is necessary to have adequate waterways in modern spray pumps.

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Hughes and Safford (6) in 1911 collected data to show that for fire hose laid in its ordinary smooth curves but not cramped or kinked, the friction loss would be about 6% greater than for perfectly straight hose. It seems likely that there would be a similar friction loss in spray hose.

The effects of couplings and other constrictions in the hose in relation to pressure loss are also quite fully discussed by Hughes and Safford (6). They say, "If water is caused to flow through a constriction, the increased velocity through the "throat" will produce a corresponding pressure drop. A diverging stream is always less stable than a converging stream; that is, it is more readily broken up into whirlpools and eddies, and hence more loss of energy takes place beyond a constriction than back of it or in it." Daugherty (2) found that the loss of pressure due to a reduction of the area of the stream at couplings was about equal to the sum of the loss in sudden contraction on entering the bushing, and the loss in sudden enlargement on leaving the bushing. There was relatively little loss in the constricted area itself. Gradual constrictions caused very much less loss of pressure. Any features which disturb or change the velocity of flow induce some additional friction losses. These observations should make it clear as to why the large hose fittings used in parts of the present experiment gave the results they did. Mason (7) brought out the interesting point that each tee or elbow in a pipe line causes friction equal to about forty feet of the straight pipe, so it is

little wonder that angles are to be avoided as much as reasonably possible in spraying equipment.

Mason (7) also reports experiments with different types of nozzles. He found that the thinner the disc, the wider the ring of spray; but the thin discs wore out quickly and required frequent replacements to maintain a constant delivery. Inner discs or whirl-plates have from two to six slanting entrances arranged around the outer edge, through which the spray material enters the eddy chamber. The more holes there are, the narrower the cone of spray and the more drive it has. The present experiment shows that pressure and volume of delivery are also affected.

Anderson and Roth (1) observe that disc apertures of $3/32$ and $7/64$ inch should be the ones most frequently used in orchard work; and efficient operation of a spray gun requires not less than 250 pounds of pressure. Hough (5) says that a nozzle with six holes in the whirl-plate produces a desirable type of cone which carries three times farther than the fan-like cone produced by the same nozzle when there are only two holes in the whirl-plate. He recommends that apples be sprayed with a pressure not exceeding 400 pounds, with pressures of from 300 to 325 pounds to be preferred. He also says that disc openings of $1/16$ and $1/12$ inch diameters have proved to be the most useful in multiple nozzle rods. Discs of these sizes wore to $1/12$ and $1/10$ inch holes, respectively, in about forty-five hours of continuous spraying when three pounds of lead arsenate to the hundred gallons of water was sprayed out at 300 pounds pressure.

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As summarized by Hughes and Safford (6) the factors causing accumulation of pressure losses because of friction are : (a) Increased area of rubbing surface, as with smaller pipe, (b) Increased roughness of the lining of the channel, (c) Increase with the square of the velocity, (d) Abrupt changes in the cross-sectional area of the channel, (e) Bends or junctions with other channels, (f) Increase of suspended matter in the water, and (g) Decrease in temperature.

Method of Procedure.

All of the following experiments were run with a three cylinder Bean pump with a rated capacity of sixteen gallons per minute. Power was furnished by a five horsepower electric motor bolted to the frame where the gasoline engine had been removed. Electric energy supplied a more convenient and more uniform source of power than could be expected from a gasoline engine. All the tests were run inside a building where the outfit stayed all the time. Tap water was used in all the tests. Water alone will not wear the pump and nozzle parts as rapidly as most spray mixtures, so its use here led to a greater degree of accuracy between tests than could be expected with actual spray mixtures.

In all the tests of water delivery with the different hose and discs a Hardie model D spray gun was used (Fig.I). The gun was always opened to its fullest extent. The pressure gauges used were of the type such as are standard equipment on practically all spray rigs, and were calibrated from zero to 600 pounds in intervals of ten pounds. It was found that after being used for some time the various gauges did not quite read consistently, so a new one was set aside as a standard and used only occasionally in checking and adjusting the others on the pump. Because of the slight variation in the gauges and the oscillation of the indicator hand when under pressure and the large interval between calibrations, it was impossible to make readings closer than five pounds, and there are occasional indications of more error than that.

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In order to make it more convenient to read the pump pressures, the air chamber gauge was set on the back of the spray rig and connected to the air chamber with a $3/8$ inch piece of spray hose. This connection reduced the vibration of the gauge hand but had no other effects.

Timing of spray delivery was done with a stop-watch. Each run was for two minutes so as to reduce as much as possible any error there might be in timing. The water was sprayed into a sixty gallon tank setting on an accurate platform scales. For practically all the tests two readings were made and unless they checked within a quarter of a pound, three and possibly four readings were made. In converting the deliveries to gallons, 8.35 pounds was taken as the weight of a gallon of water.

Throughout this paper disc aperture diameters are referred to as whole numbers, one sixty-fourth of an inch being the standard. For instance, the disc having a $4/64$ or $1/16$ inch opening is called a number four, and the disc having an $8/64$ or $1/8$ inch opening is called a number eight.

The pressure gauge at the end of the hose next to the spray gun was fitted into a tee of three-quarter inch galvanized iron pipe (Fig. II). In order to connect this tee with the male coupling at the end of the hose, it was necessary to weld a piece of female coupling to one end of the tee.

Some of the data are incomplete at the high pressures and for large disc apertures because the expected delivery would be in excess of the capacity of the pump, or because the air chamber pressure would have to be higher than the 450 pounds which was the maximum pressure used.

Presentation of Data.

One set of tests was made to determine the volume of delivery and the loss in pressure between the pump and the gun. In these tests the pressure at the pump was maintained at 200, 250, 300, 350, 400 and 450 pounds. Determinations were made at each of these pressures with $3/8$, $1/2$, and $3/4$ inch hose. The hose length was 50 feet in each instance. Disc apertures of 4, 6, 7, 8, 9, 10, 12, 14, and 16 sixty-fourths of an inch were used with each hose at every pressure indicated. One run was made when the hose fittings were of the common or standard type and a second run was made when fittings with larger openings were used. The specifications of these fittings are given in Table VI, and Figure IV shows photographs of them. Tables III, IV, and V present the results of these determinations.

Another similar set of tests was made to determine how much pressure at the pump is necessary with the various hose and discs to maintain 150, 200, 250, 300, 350, and 400 pounds at the gun. The results of these determinations are presented in Tables VII, VIII, and IX. Only the standard fittings were used in these tests. There is some inconsistency in a comparison of the gun and air chamber pressures for the $3/8$ inch hose in Tables III and VII. After the first set of records was made one fitting was broken, and the substitution of another increased the pressure losses slightly.

In order to determine if the loss of pressure was due more to friction in the hose or at the fittings, tests were made with 12 $1/2$ feet of $3/8$ inch hose. Standard and large fittings were used. The results are presented in Table X. Volumes of delivery were not determined but they could be

calculated from Graph XI.

Multiple nozzle rods having from three to eight nozzles were substituted for the spray gun in certain tests. Pressures of 250, 350, and 450 pounds were maintained at the pump. Three-eighths inch hose 50 feet in length equipped with large fittings was used in these tests. A hose of larger diameter would have been better for this purpose but accurate comparisons can be made by using the pressures at the rod rather than at the pump. Figures V, VI and VII show the heads of the various rods used, and Table XI records the results.

The relation of the diameter of pipe, or tubing used between the cutoff and the nozzle head, to delivery was studied and the results are presented in Table XII. A third pressure gauge was attached to the outer end of the pipe so as to observe the pressure loss in the pipe. Fifty feet of 3/8 inch hose with large fittings was used. Pump pressures were maintained at 350 and 450 pounds, with numbers 4 and 6 discs. A Bean head of four nozzles and a Hardie cutoff was used in all the comparisons. One section of tubing was three feet long and of 5/8 inch diameter and the other was four feet long and of 5/16 inch diameter.

Table XIII shows another comparison of various parts of different rods. The whirl-plates in Hardie rods have four openings, while those in the Bean have six, all of which vary between 9/64 and 10/64 inch in diameter. In these tests both types of whirl-plates were used in both Hardie and Bean rods. The air chamber pressures were 250, 350, and 450 pounds, using 50 feet of 3/8 inch hose with large fittings.

Four different types of cutoffs were tested at 350 and 450 pound pump pressures, as shown in Tables XIV and XV. Two were from Bean rods, one was a Hardie, and the other a Friend. These are shown in Figures IX, X, XI, and XII. Numbers 4 and 6 discs were used with 50 feet of 3.8 inch hose with large fittings. In these tests the pressure gauge was fitted between the cutoff and the entrance to the tube of the rod. Three and six nozzle rods were used in all the tests. The Friend cutoff could not be used with the six nozzle rod when it had number 6 discs in it. Its small capacity caused the rapid flow of water to shut it off automatically.

The amount of hose expansion at different pressures is shown in Table XVI. These figures are an average of four measurements taken at eighteen and twenty-four inches from one end of the hose, and are for high grade $3/8$, $1/2$, and $3/4$ inch hose.

The data in Table XVII are similar to some of those in Table XI except that they are more complete. These tests were run with an eight nozzle rod to determine the pressure loss in the rod up to the nozzle fittings. Pressure readings were taken at the pump, at the entrance to the rod, and between the second tee and the nozzles. The air chamber pressures were 200, 250, 300, 350, 400, and 450 pounds, using 50 feet of $3/8$ inch hose with large fittings.

In another set of tests pressure readings were taken at five different points on the rod, as shown in Figure XIII. The pressure at the cutoff was maintained at 300 pounds. In one test the fitting between the end of the tube and the first tee in the head was entirely eliminated.

Discussion of Results

Disc Aperture

Uniformly increasing the diameter of the disc aperture gave an almost equally uniform increase in the volume of delivery at each pressure. The increase, however, was less than the proportional increase in the area of the aperture. Doubling the diameter slightly more than doubled the quantity of delivery. As the aperture was gradually increased in size, there was a slightly more rapid increase in the volume of delivery at the same pressure at the gun. At 200 pounds pressure with disc size increases of 6 to 7, 7 to 8, 8 to 9, and 9 to 10, the increase in delivery was 0.83, 0.93, 1.15, and 1.53 gallons per minute respectively. (See Tables III, IV, V, VII, VIII, IX, etc., and Graph XI, for data on deliveries through different disc apertures.)

Pressure

Uniform changes in pressure gave equally uniform changes in delivery. The amount of change was relatively small, however. Increasing the gun pressure from 200 to 400 pounds with disc sizes 4, 6, 7, 8, 9, 10, and 12 increased the deliveries 43%, 42%, 43%, 45%, 45%, 43%, and 44%, respectively. The differences shown are probably due to experimental error. (Refer to Tables VII, VIII, and IX, and Graph XI, which show the effects on delivery of increased pressure). When compared with the pump pressures the percentage of difference would be less, and would be much more variable because of the variable pressure losses in the hose.

The rate of delivery is only indirectly dependent upon the pump pressure. It is the pressure of the solution after it gets to the gun that is important. If the pressure at the gun is known it is possible to calculate the gallons per minute delivery, from Graph XI. It doesn't make any difference what type, length, or size of hose is used, nor what the air chamber pressure is. The volume of delivery depends directly on what the pressure is after it gets to the gun, and the size of the disc aperture.

Diameter of Hose

There is much less spray delivery with hose of small diameters than with those of larger size. In comparing the capacity of the $3/8$ and $1/2$ inch hose this difference became noticeable with deliveries around four gallons a minute. The difference between the $1/2$ and $3/4$ inch hose is much less marked, and did not become excessive until deliveries of about ten gallons a minute were encountered. These differences in delivery might well be expected when a comparison of the pressure losses with different discs at various pressures is made, as in Graph IV. For instance, with a pump pressure of 400 pounds and using a number 10 disc there was a decrease in pressure at the gun of 130 pounds with a $3/8$ inch hose, 50 pounds with a $1/2$ inch hose, and 20 pounds with a $3/4$ inch hose.

Type of Hose Fittings

When the large hose fittings (See Fig.IV and Table VI) were substituted for the standard ones, there was a marked increase in the volumes of delivery, with a corresponding decrease in the pressure loss in the hose. With the 3/4 inch hose there was practically no change, presumably because the standard fittings were already sufficiently large to accommodate the flow of water without excessive friction. With the 3/8 and 1/2 inch hose the improved results were so great as to be worthy of notice. The 3/8 inch hose increased its output up to approximately that of the 1/2 inch hose with standard fittings. This means that if under given deliveries the 1/2 inch hose is ordinarily recommended, it would be equally satisfactory to use lighter and cheaper 3/8 inch hose with large fittings. Similarly, the 1/2 inch hose with large fittings is practically the equal of a 3/4 inch hose for the deliveries in the range of this experiment, up to sixteen gallons a minute. Comparisons of the pressure losses between hose equipped with standard and those with large fittings are shown in Tables III, IV, and V, and Graphs VIII, IX, and X. The expected differences in volume of delivery are also shown for the 3/8 and 1/2 inch hose, and there are almost no differences with the 3/4 inch hose. At a 350 pound air chamber pressure with a number 10 disc the deliveries with standard and then large fittings were 7.28 and 8.26 gallons for a 3/8 inch hose, 8.28 and 8.64 gallons for a 1/2 inch hose, and 8.69 and 8.65 gallons for a 3/4 inch hose.

Hose Expansion

It is a well known fact that spray hose expands and shortens up when under pressure. From the figures given in Table XVI it can be readily seen that the amount of increase is so little as to have almost no effect on increasing the carrying capacity of the hose. When the pressure was increased from 150 to 450 pounds the increase in outside diameter for the 3/8 inch hose was 0.024 inches, for the 1/2 inch hose 0.027 inches, and for the 3/4 inch hose 0.047 inches.

Length of Hose

In tests with both 50 feet and 12 1/2 feet of 3/8 inch hose under similar conditions it was shown that most of the pressure loss in hose of those lengths was due to friction at the couplings and not to friction in the hose itself. A comparison of Graphs VIII and XII brings out this point. There are almost the same number of pounds of pressure lost between the two tests of standard and large fittings with 50 feet of hose as with 12 1/2 feet. Decreasing the length of the hose 75% decreased the pressure loss only about 25% to 30% with both standard and large fittings. For instance with a pump pressure of 350 pounds there was a pressure loss of 170 pounds with 50 feet of 3/8 inch hose and 130 pounds with 12 1/2 feet of similar hose.

Number of Nozzles

Multiple nozzle rods are now being used in order to get a fine spray of good drive that will at the same time cover large areas quickly. A rod with four nozzles having number 6 discs will not deliver quite four times as much solution as

a gun having one number 6 disc. There will be more friction loss in the rod due to the necessarily much ~~more~~ rapid flow through it. A rod delivering the same volume of spray as a gun will require a greater pressure because there is more friction in it, especially around the nozzles. However, if the gun is partly closed so as to produce a more desirable type of spray, the additional friction around the disc aperture will tend to make the gun and rod more nearly equal. Table XI and Graph XIII show the differences in delivery for various rods at the same air chamber pressures. These results, though, are hardly a fair test for the larger deliveries because as mentioned before, the 3/8 inch hose was too small. Pressures taken at the rod rather than at the pump offer a fairer basis of comparison in this instance. For a delivery of 12 1/2 gallons a minute through an eight nozzle rod with number 5 discs, a pressure at the rod of 220 pounds was required, while for a similar delivery through a gun with a number 14 disc only 200 pounds was needed.

Size of Waterways in Rods

Since some multiple nozzle rods are made of larger tubing than others, two sizes were tested for the pressure losses in them, and the resulting deliveries. It was found that with number 4 discs there were almost no noticeable variations, but when the volume was increased by using number 6 discs there was a marked difference in delivery and in pressure loss through the tubes (Graph XIV shows the deliveries for the different rods and Table XII gives the pressure losses in the tubes, as well as the delivery figures). Using four

number 6 discs at a pressure of 350 pounds at the rod there was a loss of 20 pounds at the outer end of a 5/8 inch tube, and a loss of 90 pounds with a 5/16 inch tube.

A similar test to show the amount of pressure loss in eight nozzle rods from the entrance of the rod to the nozzle section revealed rather high losses. (See Table XVII). Using number 6 discs at a rod pressure of 215 pounds, 75 pounds was lost in the rod. The narrow waterways and the several angles in the pipes are responsible for the excessive pressure loss. By eliminating one fitting through the use of a different type of tee, a pressure loss of 25 pounds at that point was avoided, with a pressure of 300 pounds at the cutoff. (See Figure XIII).

Nozzle Whirl-Plates

It makes quite a noticeable difference in multiple nozzle rods as to whether the whirl-plates have six or only four openings. (See Figure XIV). Naturally, there is more friction when the water has to flow through fewer holes. If the desire is to have a spray of the more spreading type with less drive, produced by having only four holes in the whirl-plate, it has its useful place. Otherwise the six hole type is better because of its saving in pressure and increased delivery. (Table XIII and Graph XV show the results of these tests). The best spray rod used was a combination of nozzles and whirl-plates made by one manufacturer, and pipe and cutoff made by another.

Cutoffs

There is a wide difference between the varied cutoffs used on spraying equipment. The waterways in some are narrow and crooked, while in others they are large and straight. A comparison of the deliveries through four types (See Figures IX to XII) is shown in Tables XIV and XV and in Graphs XVI and XVII. For small deliveries, as with the three nozzle rods there were but slight differences. When the volume of delivery was increased by using six nozzles, the factor of friction in the cutoff became more noticeable. For instance, at a pump pressure of 450 pounds, using number 4 discs the pressures just beyond the cutoff for the four types was 400 pounds, 400 pounds, 390 pounds, and 370 pounds.

Conclusion

All these tests serve to emphasize the fact that there are exceptionally wide ranges of pressures and rates of applications from which to choose in carrying out a spraying program. The variety of fixtures and appliances is almost as great, so it takes careful study and consideration to make use of the most desirable conditions for any particular purpose. Some types of equipment are much better than others in conserving the pump pressures, and it seems that there is still considerable room for improvement in even the best that is now available.

Summary

1. Spraying pressures and volumes of delivery vary directly with the pump pressures and the size of disc apertures used.

2. The pressure at the nozzle rather than that at the pump is important in effective spraying.

3. For small deliveries $3/8$ inch hose is just as good as the larger sizes, but for greater deliveries, larger hose should be used.

4. There is more pressure lost at the hose fittings than in the hose itself for lengths of around 50 feet or less.

5. The larger the hose fittings, the less is the loss of pressure from friction there.

6. Expansion of the hose when under pressure has little part in increasing the volume of delivery.

7. Increasing the number of nozzles on a rod increases the volume of delivery and at the same time reduces the spraying pressure.

8. Multiple nozzle rods require slightly more pressure for a given delivery than spray guns do.

9. Constrictions and angles in rods and guns cause heavy pressure losses when operating at high capacities.

10. The proportion of the original pressure that is lost between the pump and the nozzles depends upon the size of hose and hose fittings, type of cutoff, size of tubing in the rod, angles and constrictions in the tubing, size and number of holes in the whirl-plates, and size of disc apertures.

Acknowledgments

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Fig. 1 Hardie Spray Gun

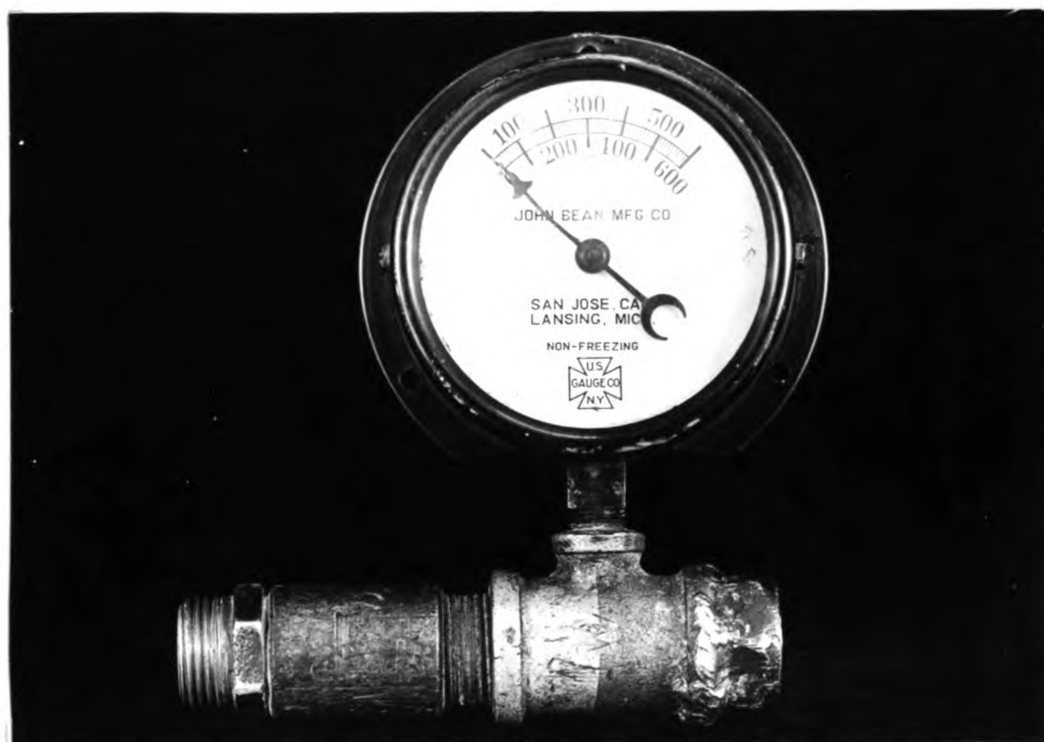


Fig. 2 Pressure Gauge and Fittings



Fig. 3 Ready for Use



Fig. 4 Standard and Large Hose Fittings

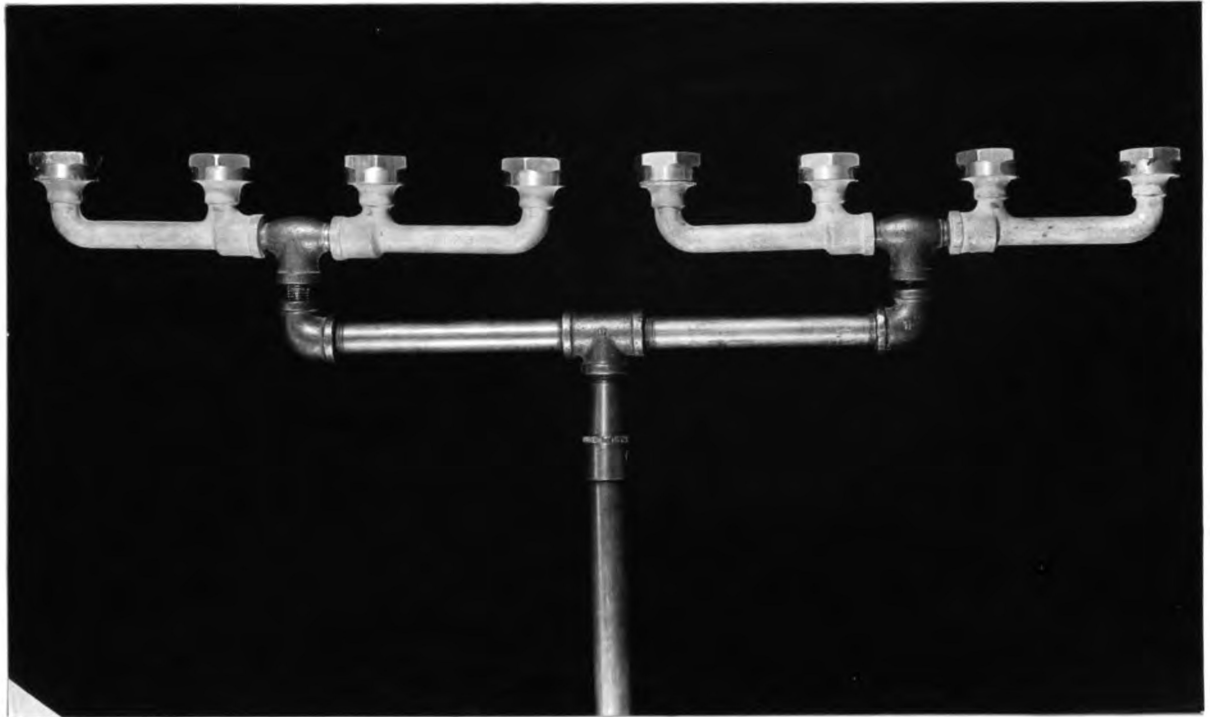


Fig. 5 Head of Bean Eight-Nozzle Rod

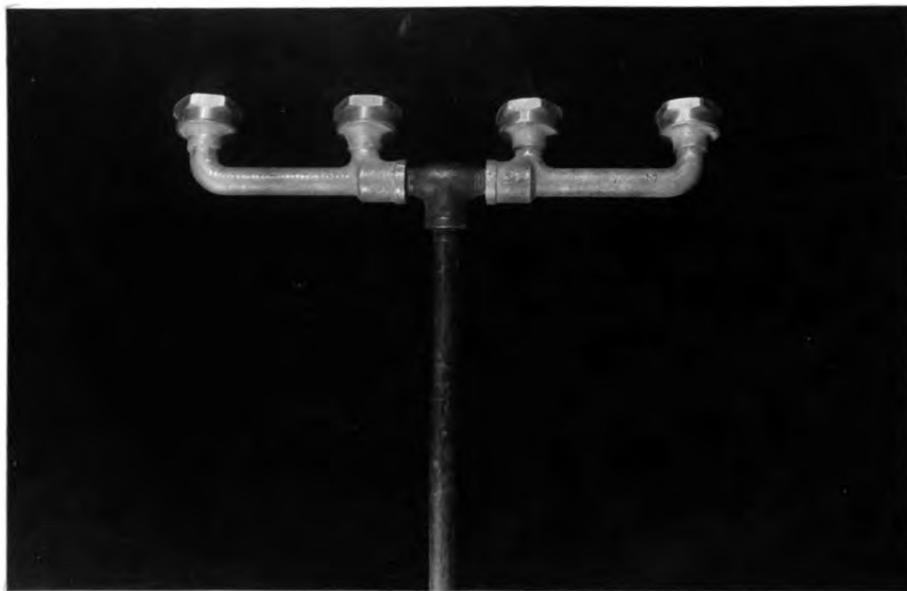


Fig. 6 Head of Bean Four-Nozzle Rod

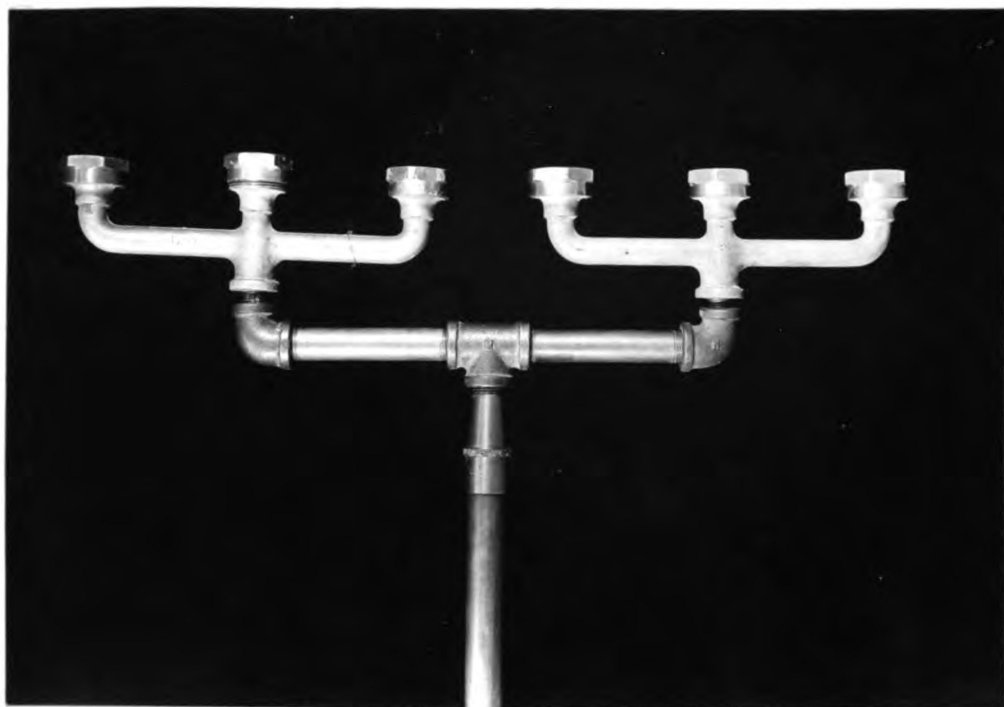


Fig. 7 Head of Bean Six-Nozzle Rod

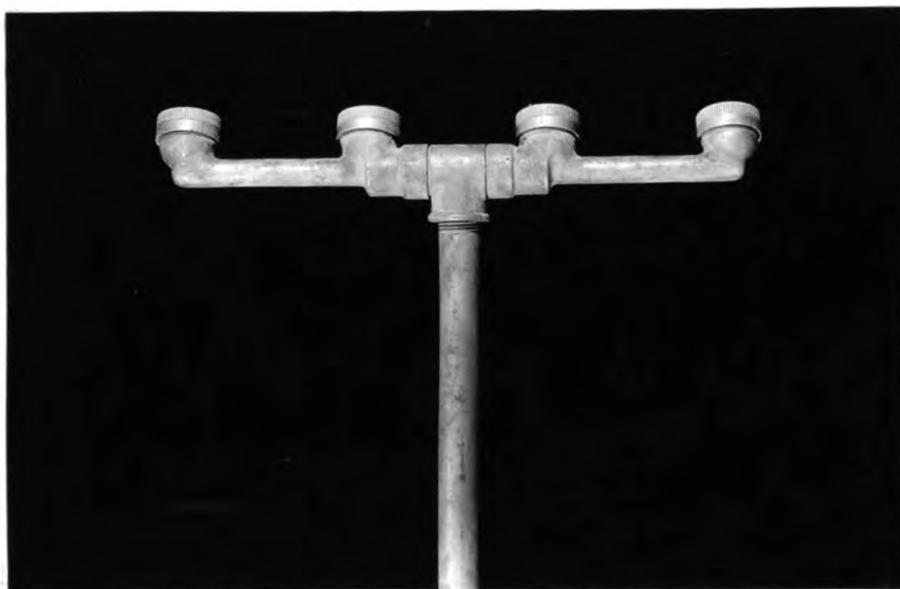


Fig. 8 Head of Hardie Four-Nozzle Rod

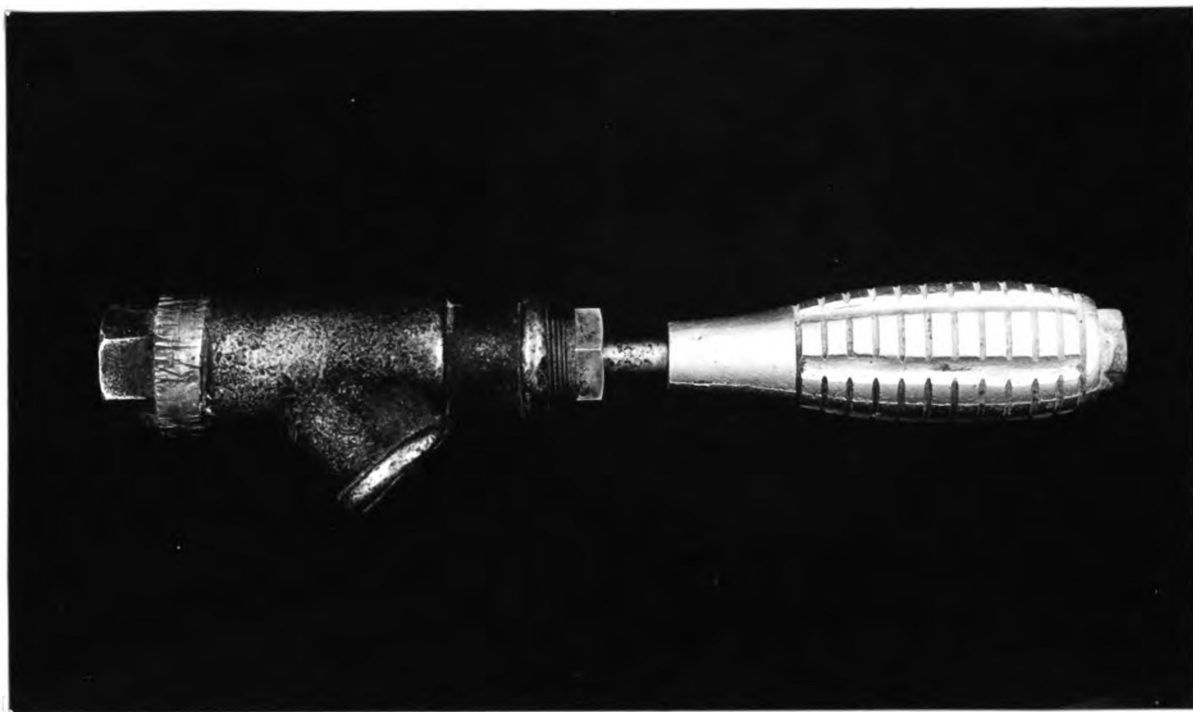


Fig. 9 Hardie Rod Cutoff



Fig. 10 Bean Three and Four-Nozzle Rod Cutoff

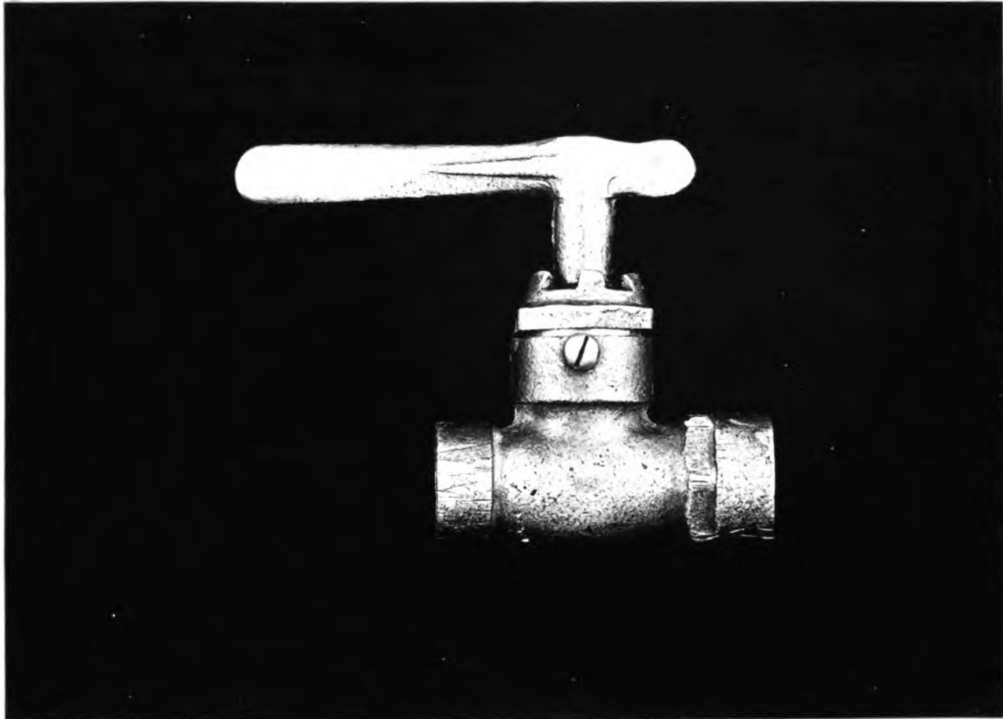


Fig. 11 Bean Six and Eight-Nozzle Rod Cutoff



Fig. 12 Friend Cutoff

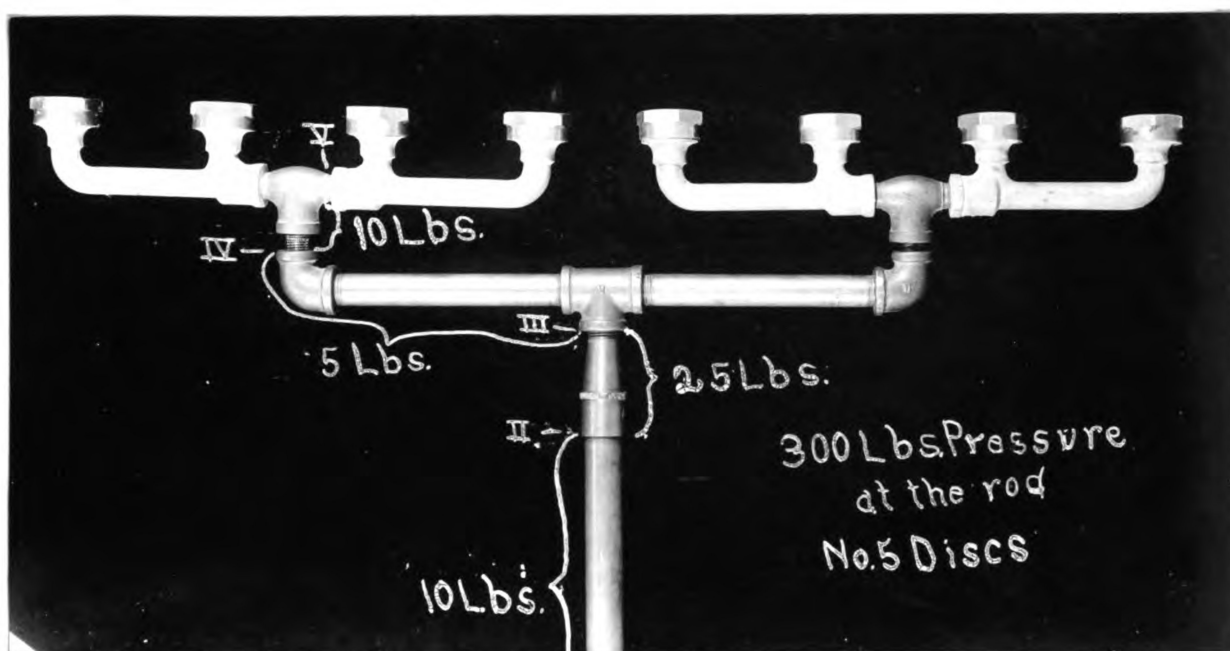


Fig. 13 Pressure Losses for Various Parts of Bean Rod

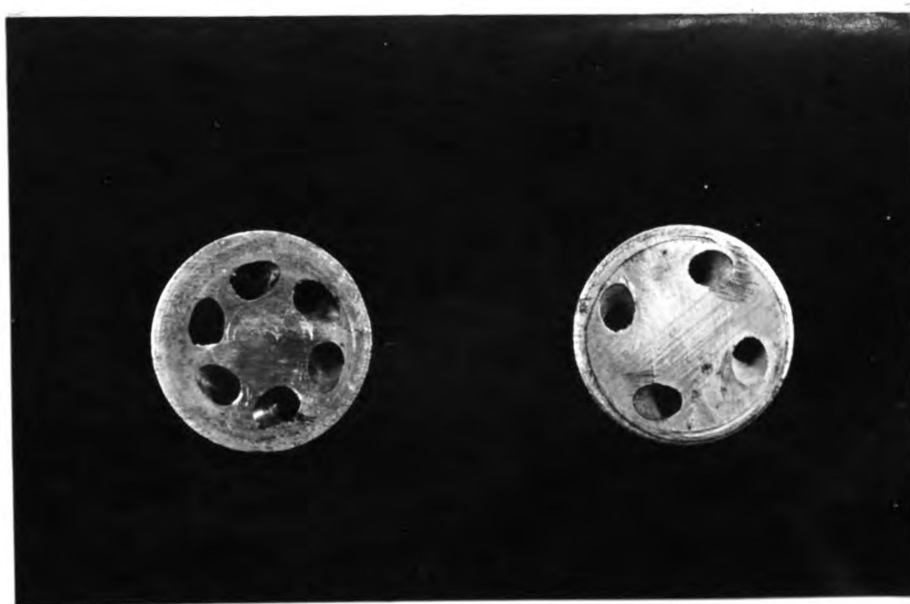
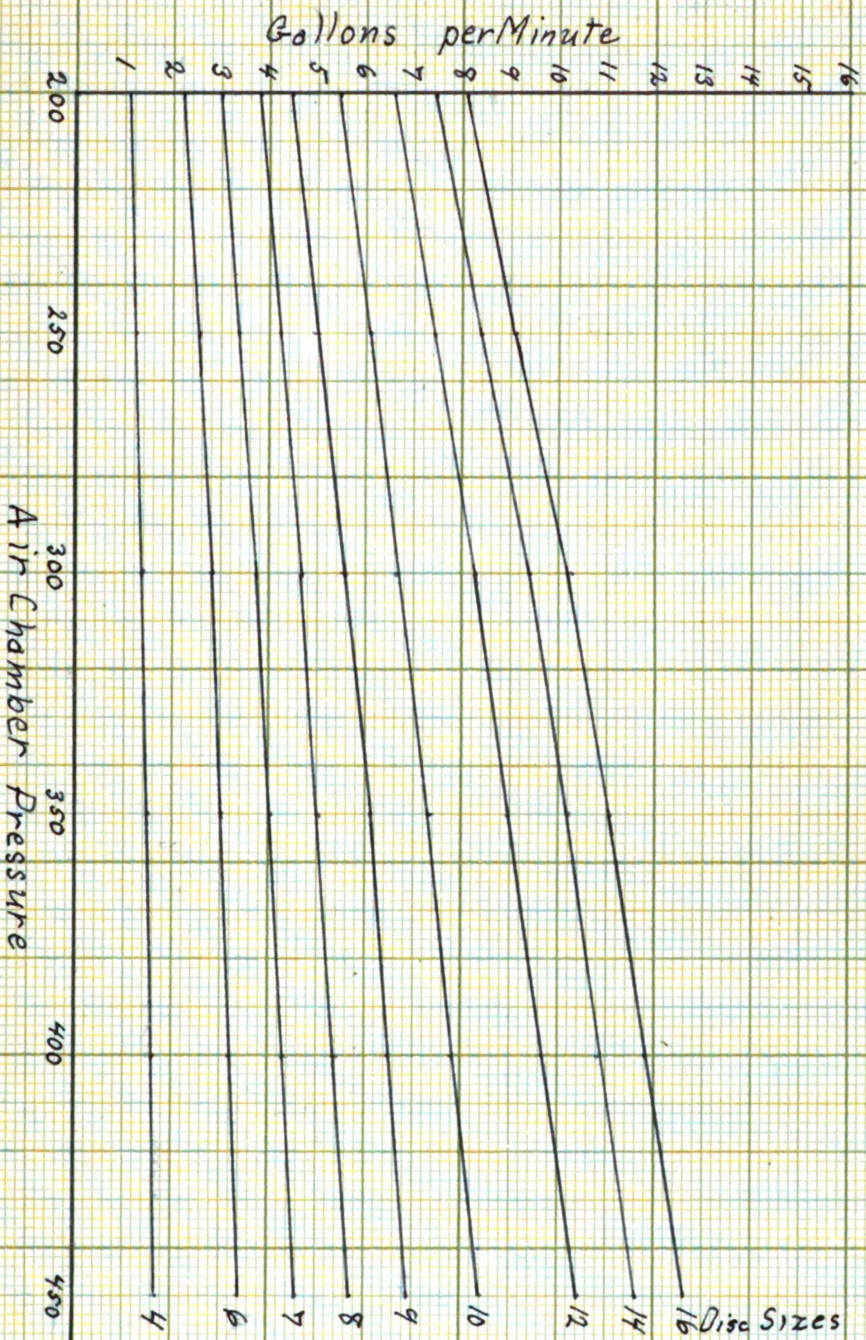


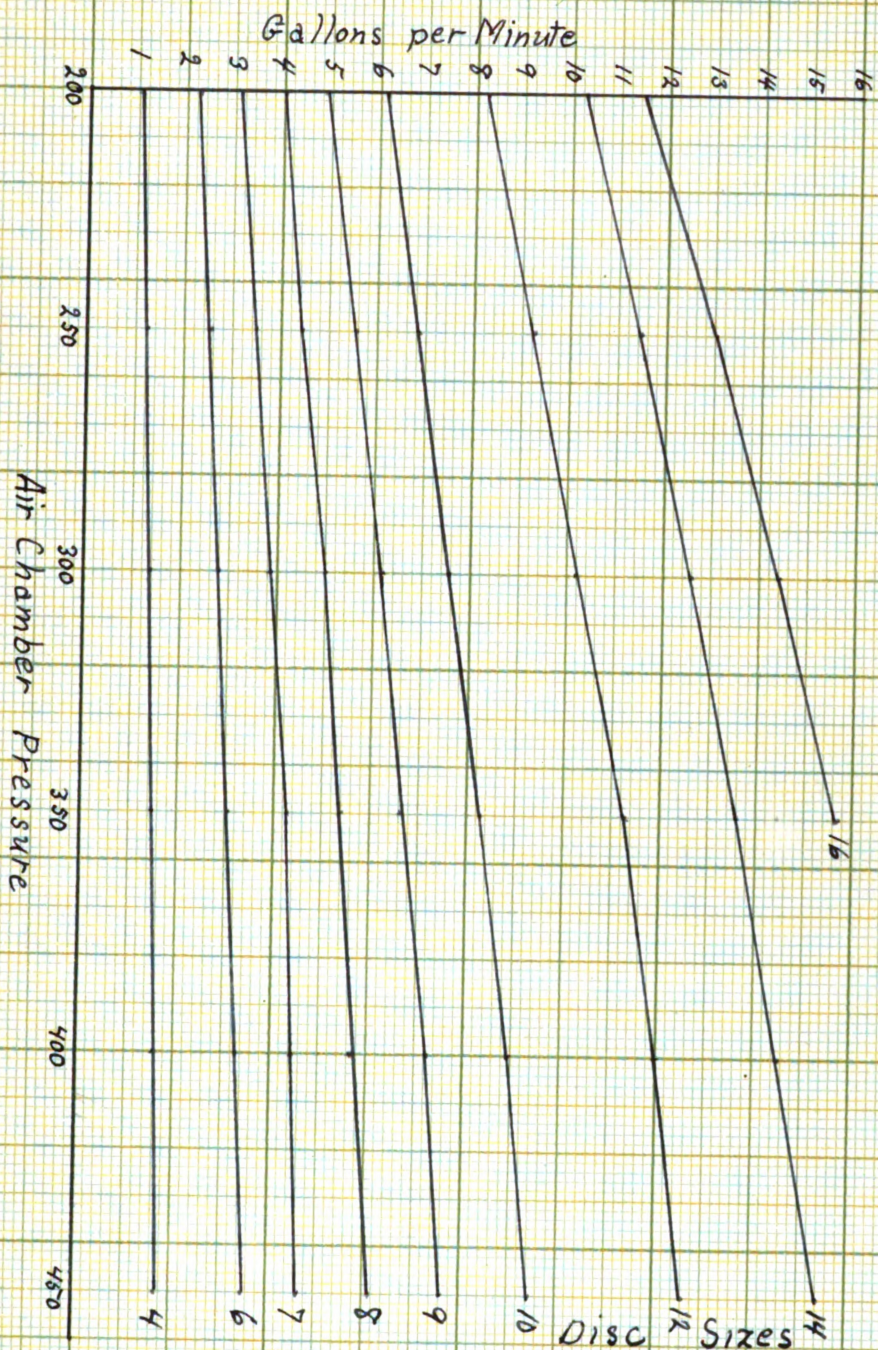
Fig. 14 Bean and Hardie Whirl-Plates

Graph I



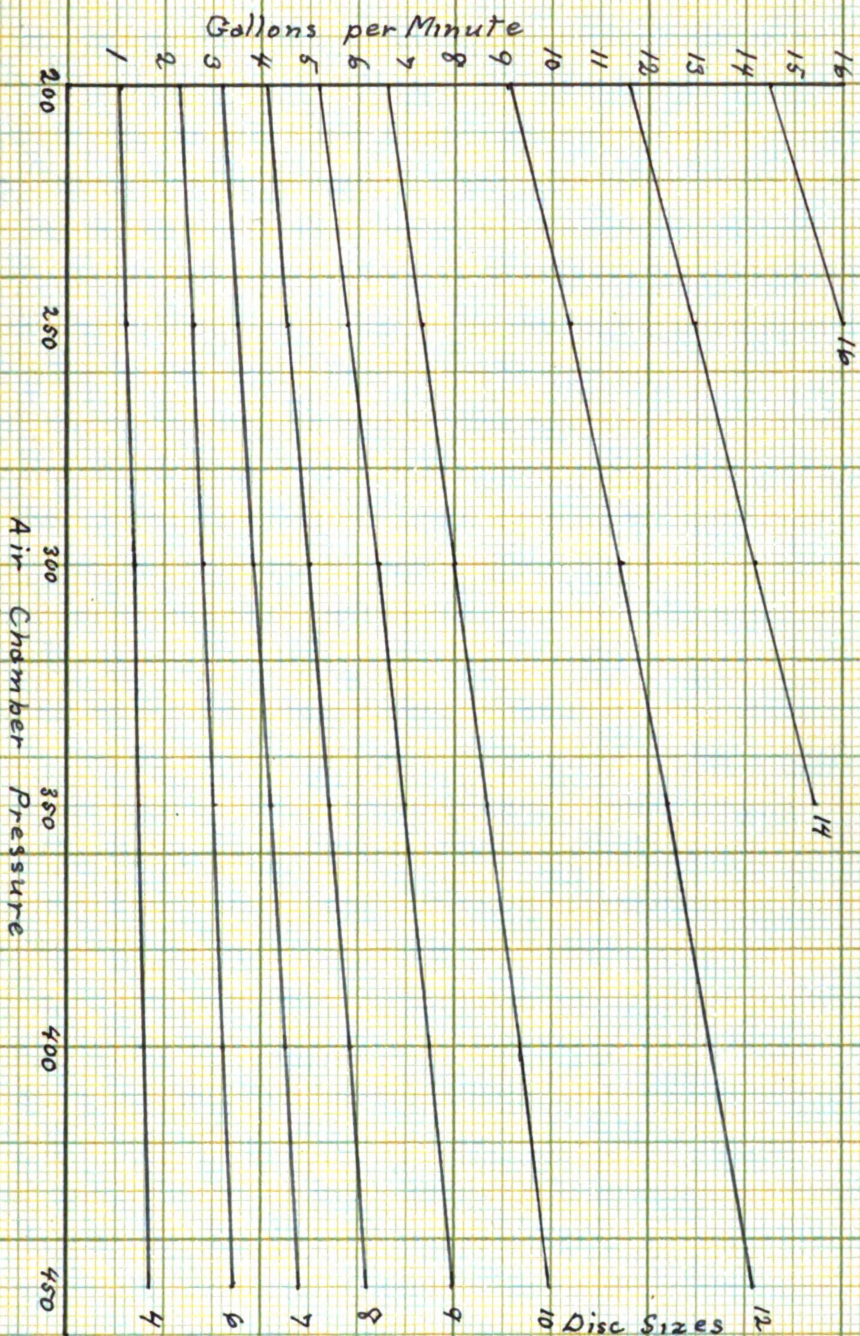
Water Delivery at Various Air Chamber Pressures, With Different Sized Discs, for 50 Feet of $\frac{3}{8}$ inch Hose, Using Standard Hose Fittings.

Graph II



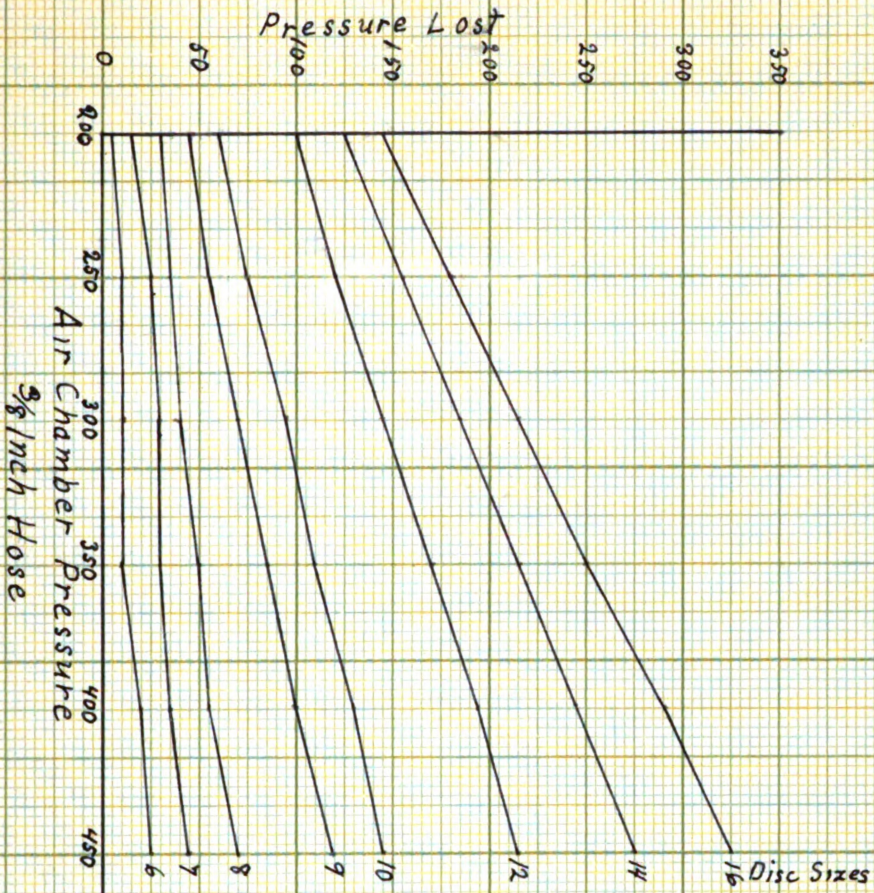
Water Delivery at Various Air Chamber Pressures, With Different
Sized Discs, for 50 Feet of $\frac{1}{2}$ inch Hose, Using Standard
Hose Fittings

Graph III

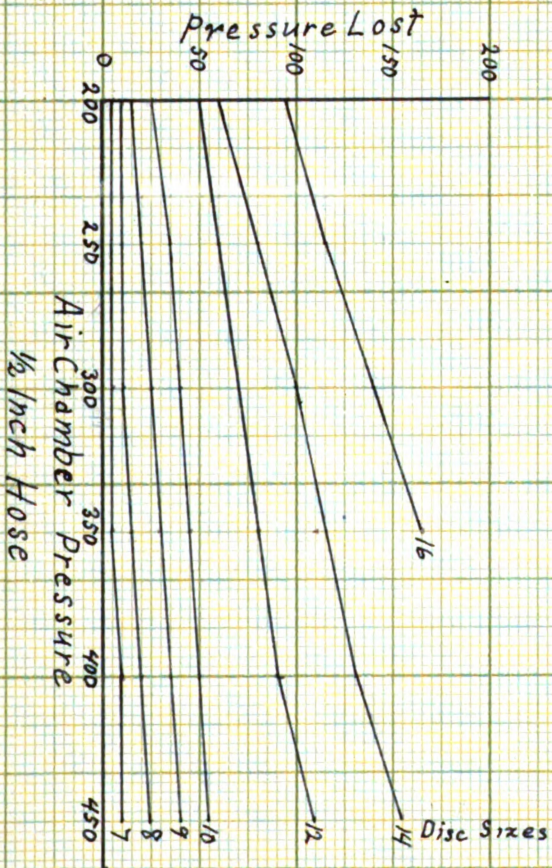
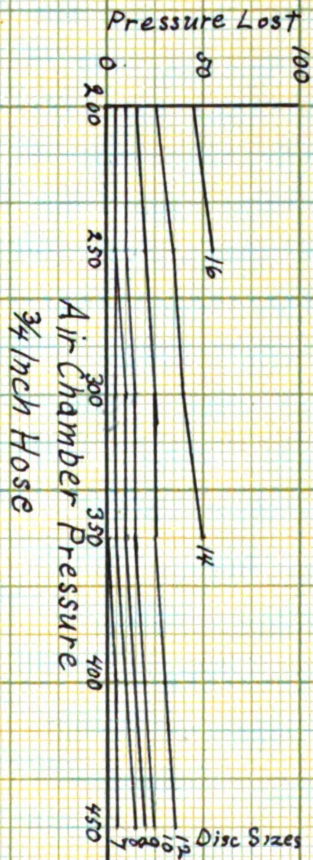


Water Delivery at Various Air Chamber Pressures, With Different Sized Discs, for 50 Feet of 3/4 inch Hose, Using Standard Hose Fittings

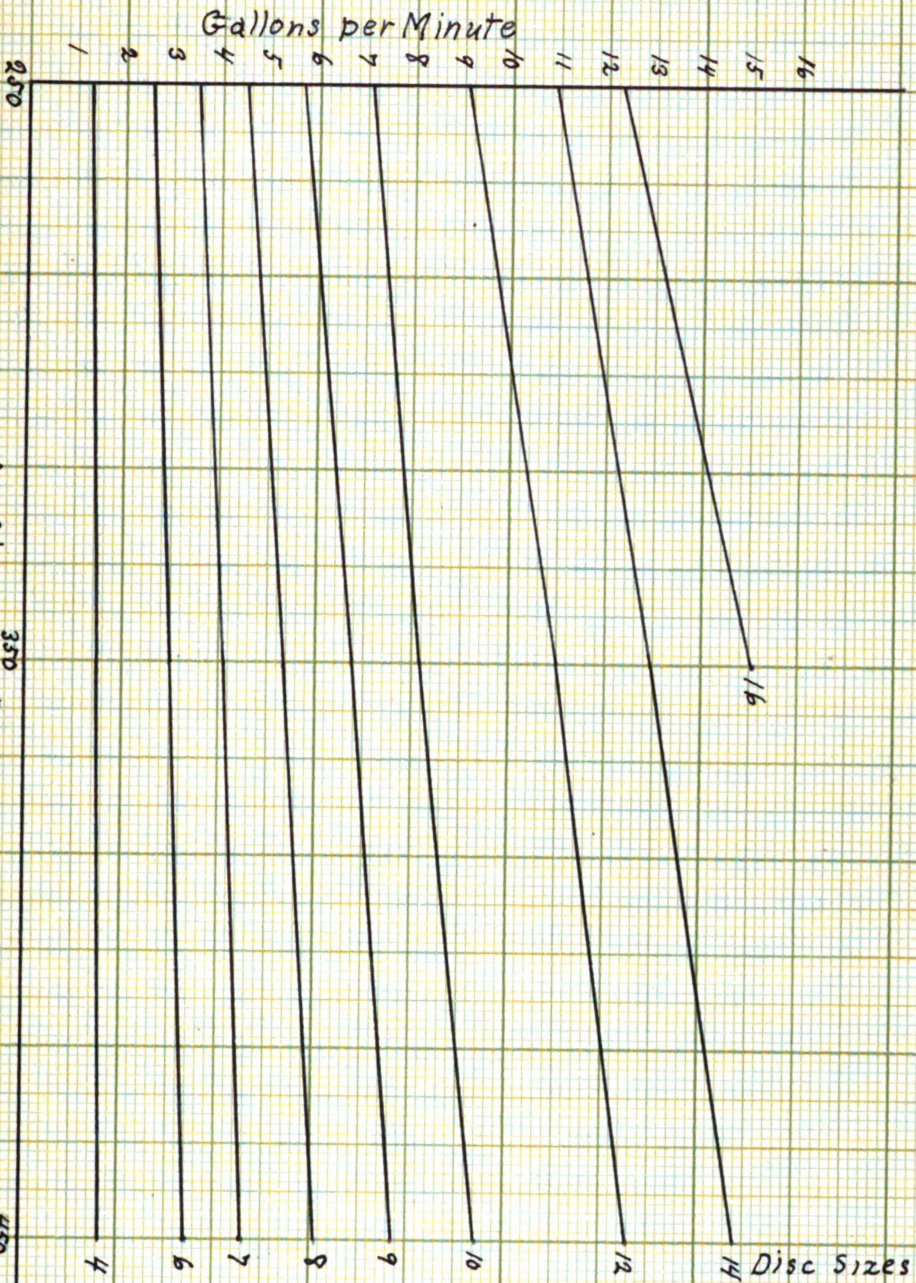
Graph IV



Comparison of the Losses of Pressure With 50 Feet of $\frac{3}{8}$, $\frac{1}{2}$, and $\frac{3}{4}$ inch Hose, With Different Disc Sizes, and Various Air Chamber Pressures.

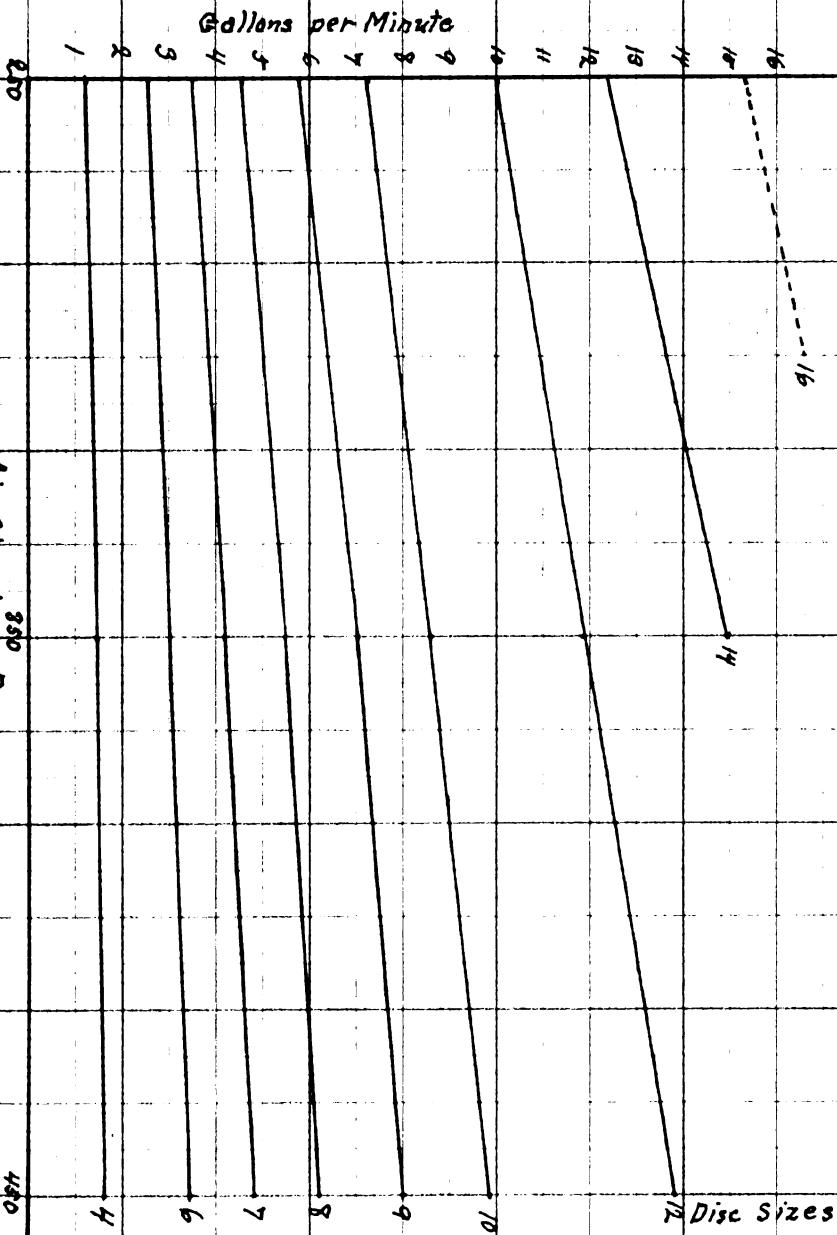


Graph IV



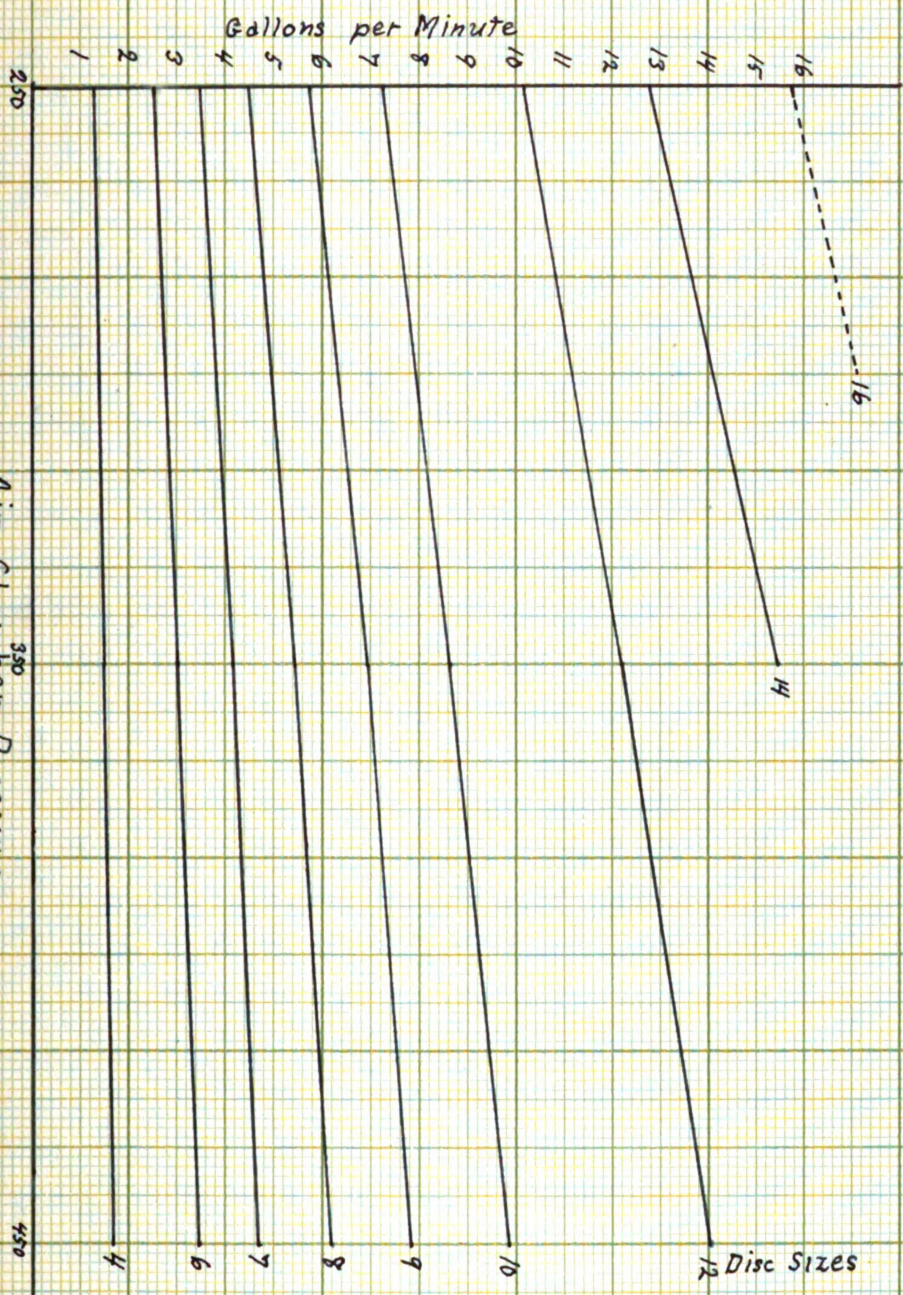
Water Delivered at Various Air Chamber Pressures With Different Disc Sizes, for 50 Feet of 3/4 inch Hose, Using Large Hose Fittings.

Graph VI



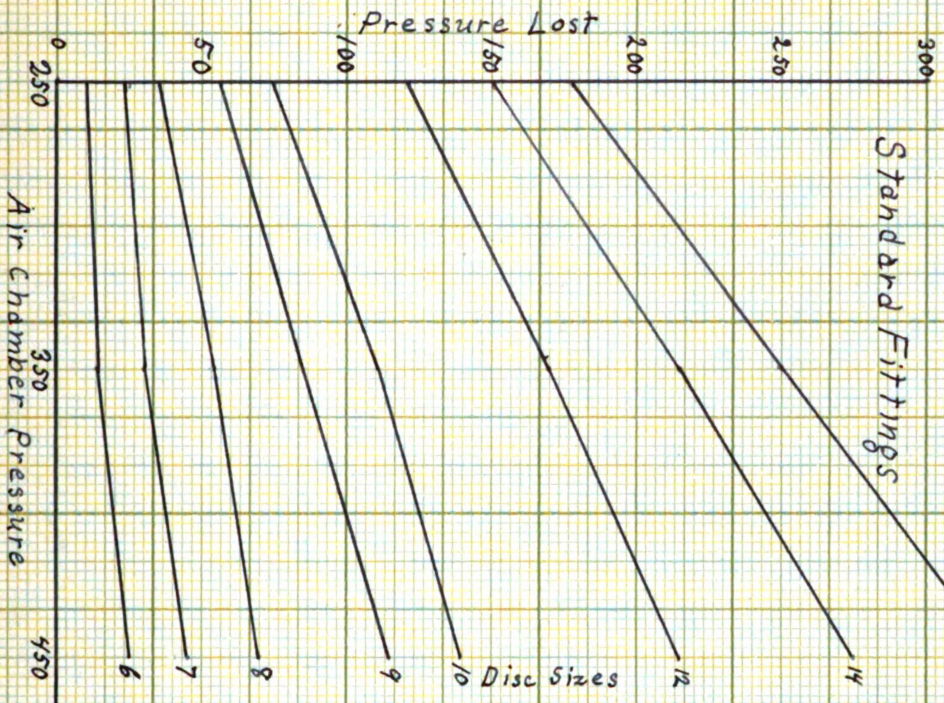
Water Delivery at Various Air Chamber Pressures With Different Disc Sizes, for 50 Feet of $\frac{1}{2}$ Inch Hose, Using Large Hose Fittings

Graph III

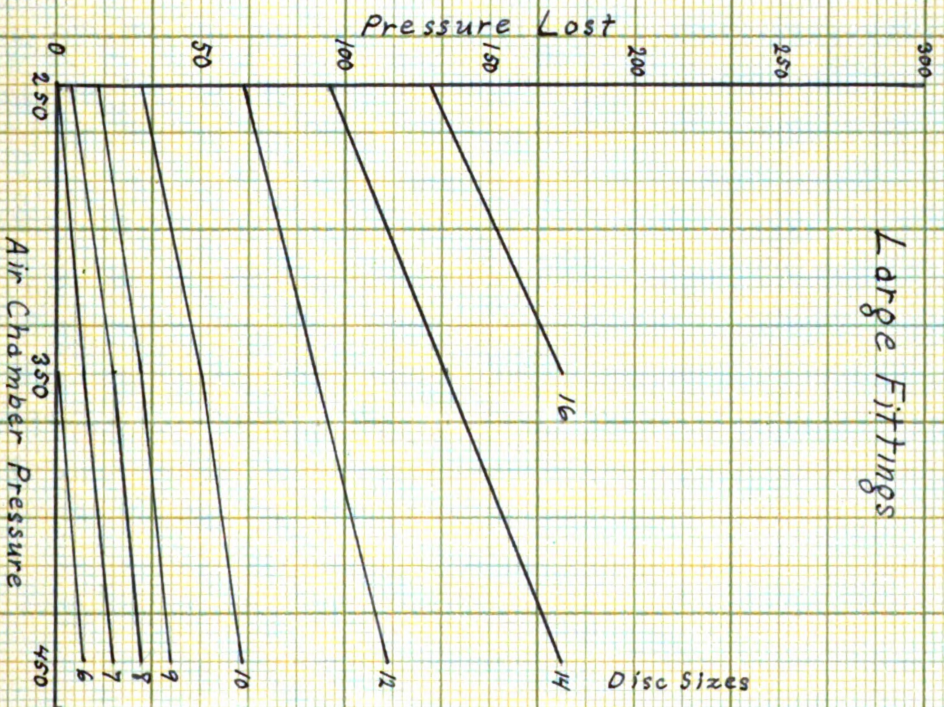


Water Delivery of Various Air Chamber Pressures With Different Disc Sizes
For 50 Feet of 3/4 inch Hose, Using Large Hose Fittings.

Graph VIII



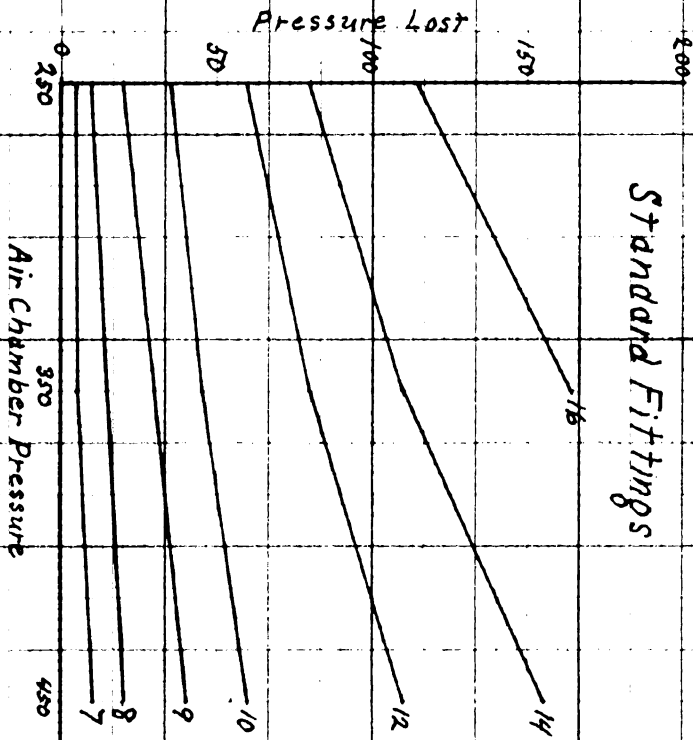
Large Fittings



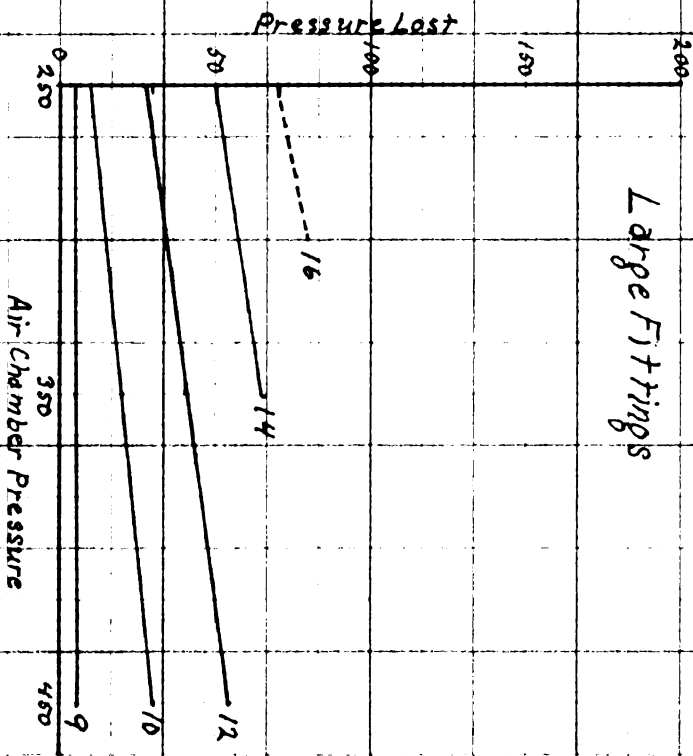
Comparison of Standard and Large Hose Fittings Showing the Loss in Pressure Between the Air Chamber and the Spray Gun for Various Sized Discs, at Different Air Chamber Pressures, Using 50 Feet of 3/8 Inch Hose

Graph IX

Standard Fittings

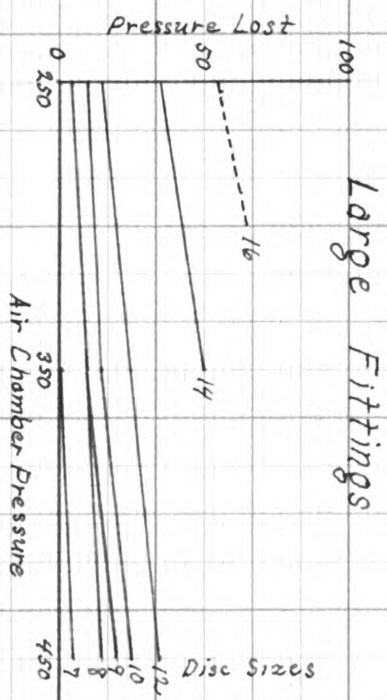
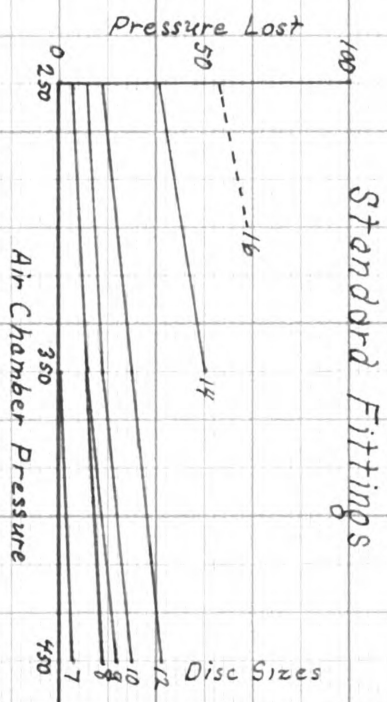


Large Fittings



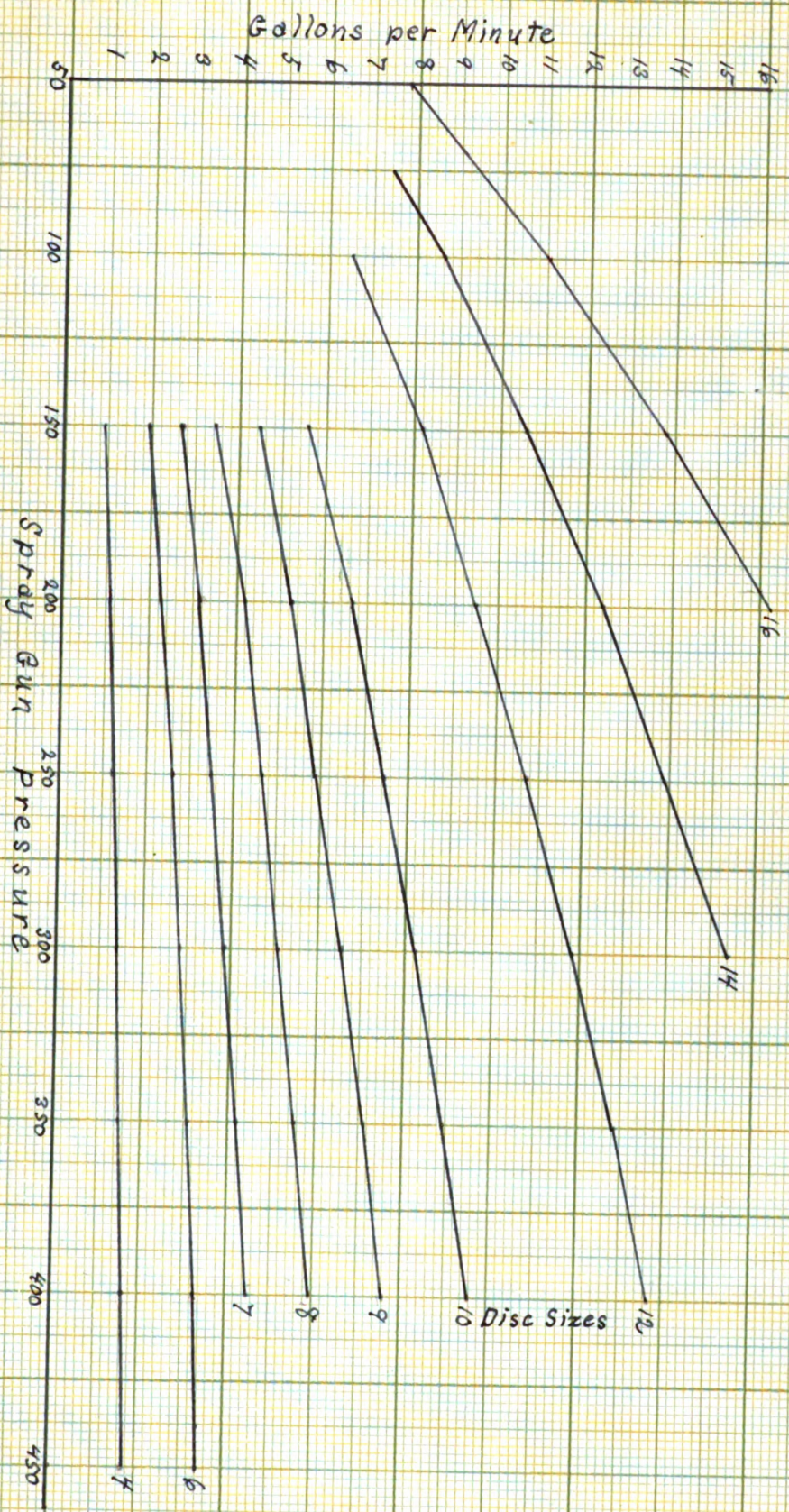
Comparison of Standard and Large Hose Fittings Showing the Loss in Pressure Between the Air Chamber and the Spray Gun for Various Disc Sizes, at Different Air Chamber Pressures, Using 50 Feet of $\frac{1}{2}$ Inch Hose

Graph X



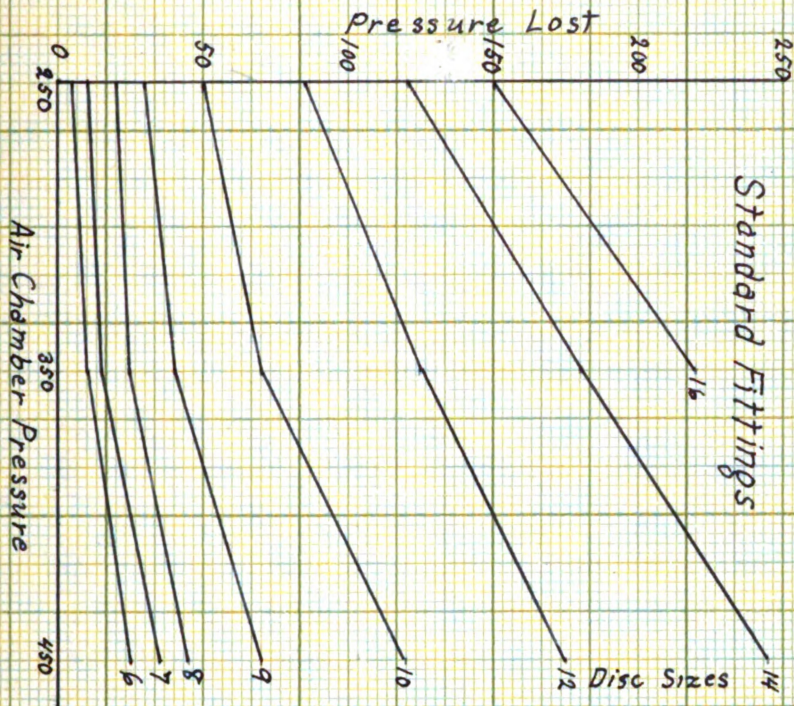
Comparison of Standard and Large Hose Fittings Showing the Loss in Pressure Between the Air Chamber and the Spray Gun for Various Disc Sizes, at Different Air Chamber Pressures, Using 50 Feet of $\frac{3}{4}$ Inch Hose.

Graph XI

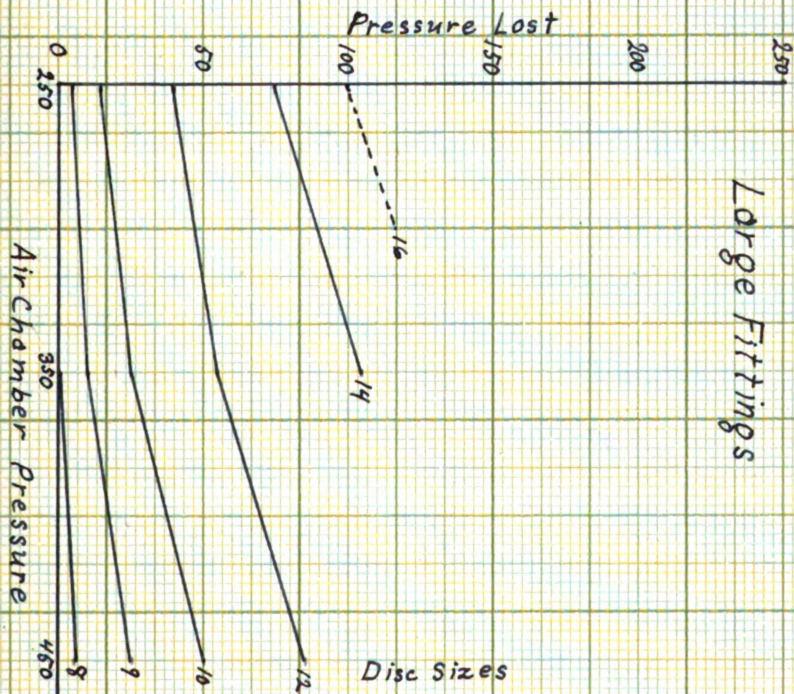


Water Delivery at Various Spray Gun Pressures With Different Disc Sizes, for Any Hose.

Graph XII

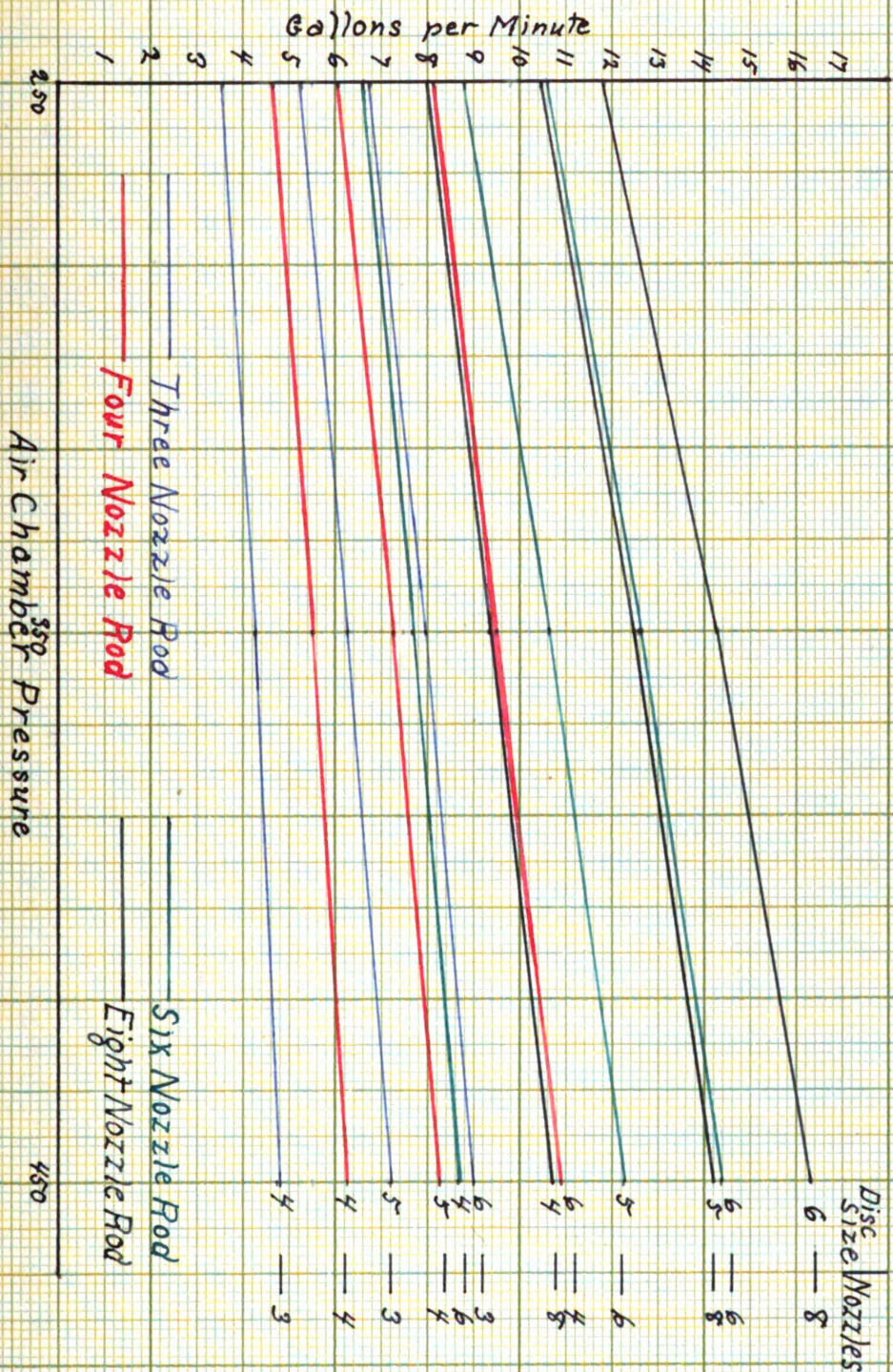


Large Fittings



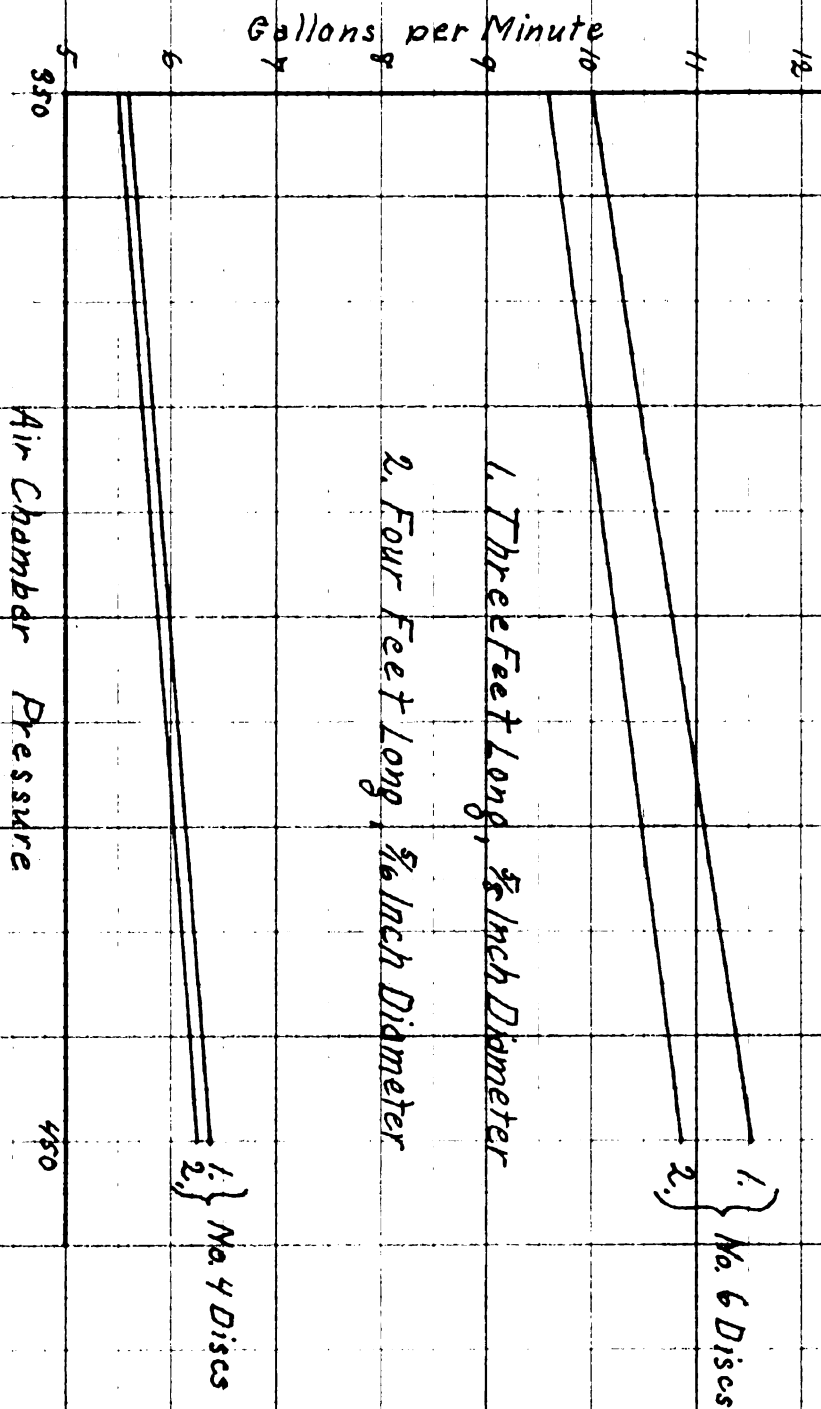
Comparison of Pressure Losses Between the Air Chamber and the Spray Gun
With Various Sized Discs at Different Air Chamber Pressures, Using
Standard and Large Hose Fittings on 12 1/2 Feet of 3/8 Inch Hose.

Graph XIII



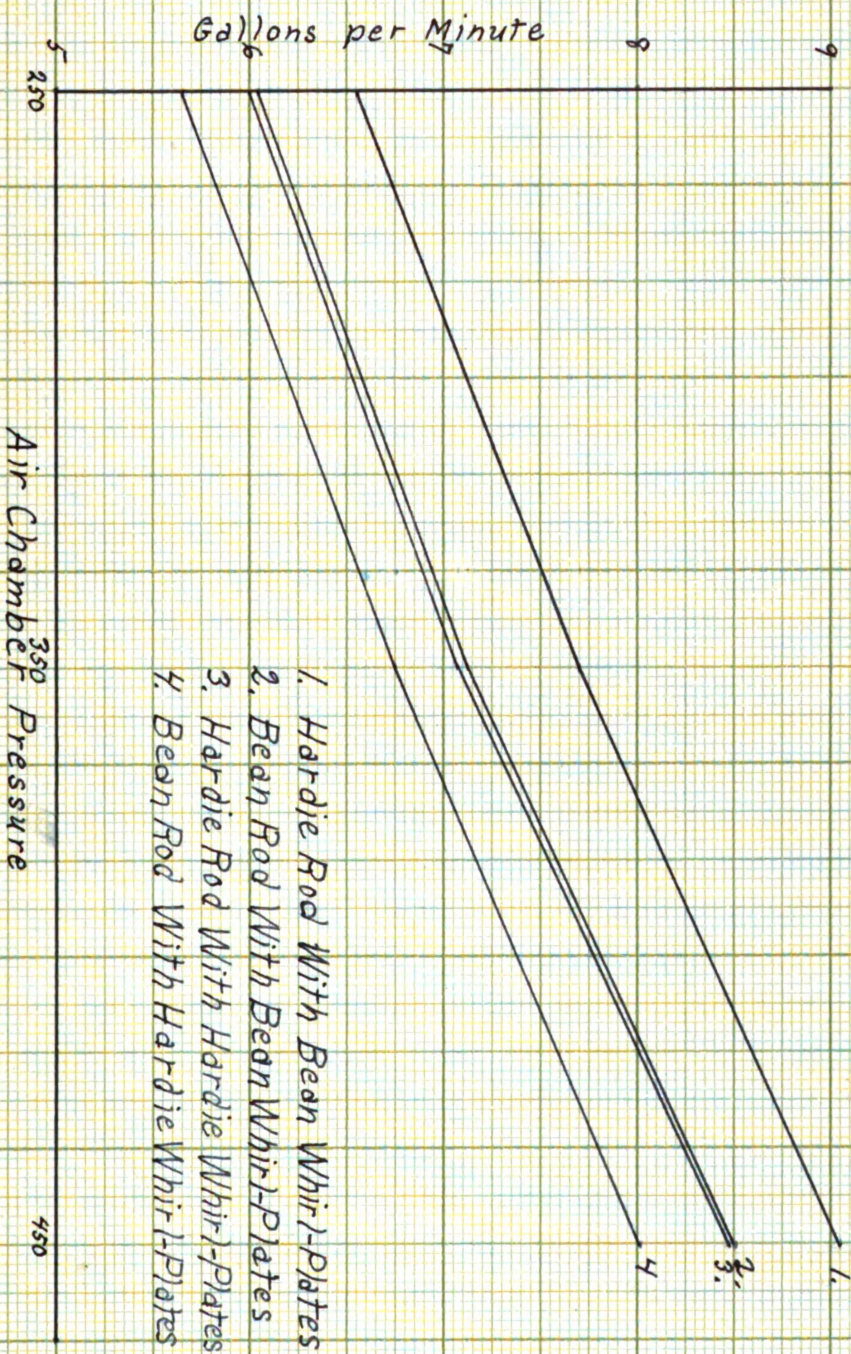
Water Delivery Through Rods at Various Air Chamber Pressures, as Influenced by the Number of Nozzles and the Disc Size, Using 50 Feet of 3/8 Inch Hose With Large Fittings

Graph XIV



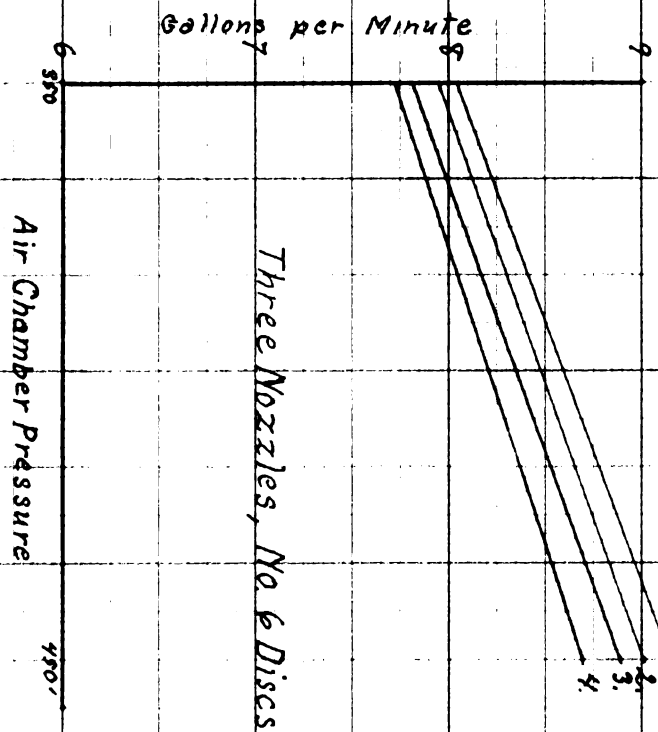
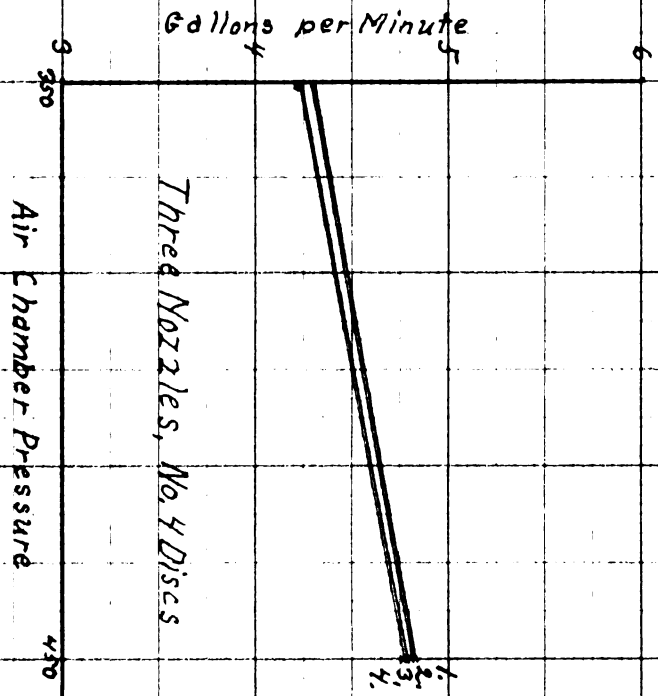
Relation of Type of Rod Tube to Water Delivery at Different Air Chamber Pressures, Using a Four Nozzle Head,

Graph XV



Effect of Different Rod and Whirl Plate Combinations on
Water Delivery at Various Air Chamber Pressures,
Using Four Nozzle Rods With No. 5 Discs.

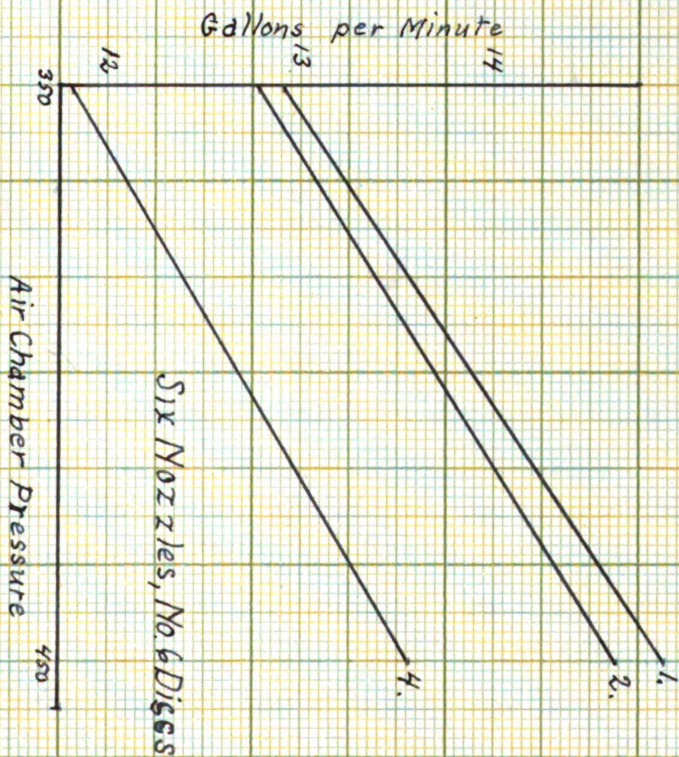
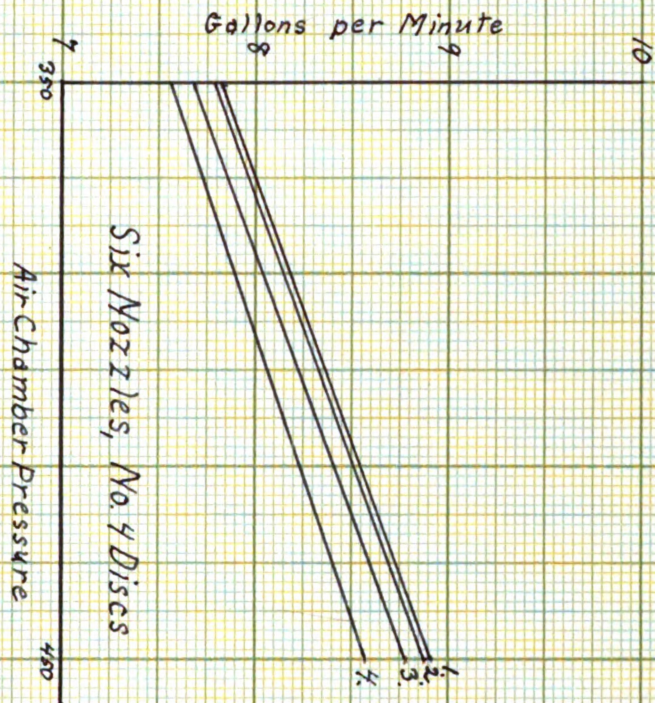
Graph XVI



Relation of Type of Rod Cutoff to Water Delivery at Various Air Chamber Pressures

- Cutoffs
- 1 Hardie
 - 2 Bean
 - 3 Friend
 - 4 Bean

Graph XIII



Relation of Type of Rod Cutoff to Water Delivery at Various Air Chamber Pressures

Cutoffs

1. Hardie
2. Bean
3. Friend
4. Bean

TABLE III.

Spray Gun Deliveries at Constant Air Chamber Pressures.

Hose Size	Disc Size	Pressure at Air Chamber	Pressure at the Gun		Pressure Lost		Delivery in Gal. per Min.	
			Standard Fittings	Large Fittings	Standard Fittings	Large Fit.	Standard Fittings	Large Fittings
50 Feet of 3/8 inch	4	200	200		0		1.11	
		250	250	250	0	0	1.26	1.26
		300	300		0		1.39	
		350	350	350	0	0	1.47	1.47
		400	400		0		1.59	
		450	450	450	0	0	1.68	1.68
	6	200	195		5		2.29	
		250	240	250	10	0	2.54	2.58
		300	290		10		2.78	
		350	340	350	10	0	3.02	3.04
		400	380		20		3.21	
		450	425	440	25	10	3.40	3.44
	7	200	185		15		3.02	
		250	225	250	25	0	3.41	3.53
		300	290					
		350	340					
		400	380					
		450	425					

TABLE III.

Spray Gun Deliveries at Constant Air Chamber Pressures.

Hose Size	Disc Size	Pressure at Air Chamber	Pressure at the Gun		Pressure Lost		Delivery in Gal. per Min.	
			Standard Fittings	Large Fit- tings	Standard Fittings	Large Fit.	Standard Fittings	Large Fittings
50 Feet of 3/8 inch	4	200	200		0		1.11	
		250	250	250	0	0	1.26	1.26
		300	300		0		1.39	
		350	350	350	0	0	1.47	1.47
		400	400		0		1.59	
		450	450	450	0	0	1.68	1.68
	6	200	195		5		2.29	
		250	240	250	10	0	2.54	2.58
		300	290		10		2.78	
		350	340	350	10	0	3.02	3.04
		400	380		20		3.21	
		450	425	440	25	10	3.40	3.44
	7	200	185		15		3.02	
		250	225	250	25	0	3.41	3.53
		300	270		30		3.74	
		350	320	340	30	10	4.06	4.10
		400	365		35		4.33	
		450	405	430	45	20	4.55	4.66
	8	200	170		30		3.83	
		250	215	245	35	5	4.27	4.58
		300	260		40		4.69	
		350	295	330	55	20	5.07	5.36
		400	345		55		5.43	
		450	380	420	70	30	5.73	6.11
	9	200	150		50		4.48	
		250	185	235	65	15	4.94	5.73
		300	220		80		5.54	
		350	265	320	85	30	6.11	6.83
		400	300		100		6.53	
		450	330	410	120	40	6.89	7.69
	10	200	140		60		5.45	
		250	175	220	75	30	6.13	7.08
		300	205		95		6.72	
		350	240	300	110	50	7.28	8.26
		400	270		130		7.81	
		450	310	385	140	65	8.35	9.46
	12	200	100		100		6.53	
		250	130	185	120	65	7.45	9.15
		300	155		145		8.28	
		350	180	260	170	90	8.89	11.03
		400	205		195		9.71	
		450	235	335	215	115	10.36	12.57
	14	200	75		125		7.45	
		250	95	155	155	95	8.29	10.93
		300	115		185		9.30	
		350	135	215	215	135	10.14	12.96
		400	155		245		10.87	
		450	175	275	275	175	11.65	14.87
	16	200	55		145		8.06	
		250	70	120	180	130	9.10	12.37
		300	85		215		10.21	
		350	100	175	250	175	11.05	15.10
		400	110		290		11.85	
		450	125		325		12.58	

TABLE IV.

Spray Gun Deliveries at Constant Air Chamber Pressures.

Hose Size	Disc Size	Pressure at Air Chamber	Pressure at the Gun Standard Fittings	Large Fittings	Pressure Lost Standard Fittings	Large Fit.	Delivery in Gal. per Min. Standard Fittings	Large Fittings
50 Feet of 1/2 inch	4	200	200		0		1.11	
		250	250	250	0	0	1.26	1.26
		300	300		0		1.38	
		350	350	250	0	0	1.47	1.47
		400	400		0		1.59	
		450	450	250	0	0	1.68	1.68
	6	200	200		0		2.31	
		250	250	250	0	0	2.58	2.58
		300	300		0		2.84	
		350	350	350	0	0	3.06	3.06
		400	400		0		3.29	
		450	450	450	0	0	3.48	3.48
	7	200	195		5		3.14	
		250	245	250	5	0	3.49	3.56
		300	295		5		3.85	
		350	345	350	5	0	4.18	4.22
		400	390		10		4.48	
		450	440	450	10	0	4.70	4.79
	8	200	190		10		4.00	
		250	240	250	10	0	4.46	4.64
		300	290		10		5.00	
		350	335	350	15	0	5.33	5.52
		400	380		20		5.69	
		450	430	450	20	0	6.12	6.24
	9	200	185		15		4.94	
		250	230	245	20	5	5.60	5.87
		300	275		25		6.23	
		350	320	345	30	5	6.75	7.04
		400	365		35		7.25	
		450	410	445	40	5	7.68	8.01
	10	200	175		25		6.15	
		250	215	240	35	10	6.89	7.32
		300	260		40		7.66	
		350	305	330	45	20	8.28	8.64
		400	350		50		8.90	
		450	395	420	55	30	9.45	9.91
	12	200	150		50		8.23	
		250	190	220	60	30	9.27	10.0
		300	230		70		10.19	
		350	270	305	80	45	11.24	11.89
		400	310		90		12.04	
		450	340	400	110	50	12.69	13.83
	14	200	140		60		10.25	
		250	170	200	80	50	11.50	12.39
		300	200		100		12.59	
		350	240	285	110	65	13.59	14.95
		400	270		130		14.49	
		450	295		155	--	15.33	-----
	16	200	105		95		11.50	
		250	135	180	115	70	13.07	15.27
		300	160		140		14.40	
		350	185	----	165	--	15.73	-----
		400	Exceeds pump Capacity	----	----	----	-----	-----
		450		----	----	----	-----	-----

TABLE V.

Spray Gun Deliveries at Constant Air Chamber Pressures.

Hose Size	Disc Size	Pressure at Air Chamber	Pressure at the Gun		Pressure Lost		Delivery in Gal. per Min.	
			Standard Fittings	Large Fittings	Standard Fittings	Large Fit.	Standard Fittings	Large Fittings
50 Feet of 3/4 Inch	4	200	200		0		1.11	
		250	250	250	0	0	1.26	1.26
		300	300		0		1.38	
		350	350	350	0	0	1.48	1.48
		400	400		0		1.59	
		450	450	450	0	0	1.68	1.68
	6	200	200		0		1.92	
		250	250	250	0	0	2.31	2.31
		300	300		0		2.59	
		350	350	350	0	0	2.83	2.83
		400	400		0		3.07	
		450	450	450	0	0	3.29	3.29
	7	200	200		0		3.15	
		250	250	250	0		3.51	3.50
		300	300		0		3.86	
		350	350	350	0	0	4.19	4.18
		400	395		5		4.48	
		450	445	445	5	5	4.76	4.78
	8	200	195		5		4.03	
		250	245	245	5	5	4.56	4.52
		300	295		5		4.99	
		350	340	340	10	10	5.43	5.42
		400	385		15		5.80	
		450	435	435	15	15	6.20	6.20
	9	200	195		5		5.18	
		250	245	245	5	5	5.84	5.82
		300	290		10		6.44	
		350	340	340	10	10	6.96	6.96
		400	385		15		7.47	
		450	430	430	20	20	7.90	7.89
	10	200	190		10		6.54	
		250	240	240	10	10	7.33	7.28
		300	285		15		8.02	
		350	335	335	15	15	8.69	8.65
		400	380		20		9.33	
		450	430	425	20	25	9.98	9.85
	12	200	185		15		9.13	
		250	235	235	15	15	10.38	10.18
		300	275		25		11.47	
		350	325	325	25	25	12.40	12.32
		400	370		30		13.23	
		450	415	415	35	35	14.11	14.04
	14	200	175		25		11.65	
		250	215	215	35	35	12.93	12.92
		300	260		40		14.23	
		350	300	300	50	50	15.48	15.46
		400	Exceeds pump Capacity	---	---	---	---	---
		450	---	---	---	---	---	---
	16	200	155		45		14.50	
		250	195	195	55	55	16.02	15.91
		300	Exceeds pump Capacity	---	---	---	---	---
		350	---	---	---	---	---	---
		400	---	---	---	---	---	---
		450	---	---	---	---	---	---

TABLE VI.

Diameters of Hose Fittings.

Standard Fittings

Hose Size	Female		Male	
	Pipe End	Hose End	Gun End	Hose End
3/8 Inch	.250 Inch	.230 Inch	.226 Inch	.203 Inch
1/2 Inch	.363	.324	.305	.367
3/4 Inch	.438	.391	.375	.398
Large Fittings				
3/8 Inch	.328	.297	.320	.289
1/2 Inch	.406	.406	.406	.406
3/4 Inch	.664	.648	.672	.652

TABLE VII.

Spray Gun Deliveries at Constant Gun Pressures

3/8 Inch Hose 50 Feet Standard Fittings

Disc Size	Gun Pressure	Air Chamber Pressure	Gallons per Minute	Disc Size	Gun Pressure	Air Chamber Pressure	Gallons per Minute
4	150	150	.93	10	150	220	5.70
	200	200	1.11		200	300	6.72
	250	250	1.26		250	370	7.49
	300	300	1.39		300	440	8.28
	350	350	1.47		350	---	---
	400	400	1.59		400	---	---
6	150	160	1.98	12	150	300	8.20
	200	215	2.33		200	400	9.53
	250	265	2.61		250	---	---
	300	315	2.82		300	---	---
	350	370	3.06		350	---	---
	400	420	3.28		400	---	---
7	150	165	2.71	14	150	395	10.63
	200	220	3.19		200	---	---
	250	280	3.57		250	---	---
	300	335	3.91		300	---	---
	350	390	4.22		350	---	---
	400	450	4.51		400	---	---
8	150	175	3.48	16	150	---	---
	200	235	4.06		200	---	---
	250	295	4.59		250	---	---
	300	350	5.04		300	---	---
	350	415	5.46		350	---	---
	400	---	---		400	---	---
9	150	200	4.48				
	200	275	5.24				
	250	335	5.93				
	300	400	6.53				
	350	---	---				
	400	---	---				

TABLE VIII.

Spray Gun Deliveries at Constant Gun Pressures

1/2 Inch Hose 50 Feet Standard Fittings

Disc Size	Gun Pressure	Air Chamber Pressure	Gallons per Minute	Disc Size	Gun Pressure	Air Chamber Pressure	Gallons per Minute
4	150	150	.93	10	150	180	5.69
	200	200	1.11		200	235	6.75
	250	250	1.26		250	290	7.51
	300	300	1.38		300	350	8.29
	350	350	1.47		350	405	8.98
	400	400	1.59		400	---	---
6	150	150	1.92	12	150	200	8.23
	200	200	2.31		200	265	9.52
	250	250	2.58		250	325	10.78
	300	300	2.84		300	385	11.84
	350	350	3.06		350	---	---
	400	400	3.29		400	---	---
7	150	155	2.69	14	150	230	10.63
	200	205	3.14		200	310	12.47
	250	260	3.52		250	380	13.94
	300	310	3.88		300	---	---
	350	360	4.19		350	---	---
	400	410	4.49		400	---	---
8	150	160	3.50	16	150	280	13.77
	200	210	4.07		200	---	---
	250	265	4.63		250	---	---
	300	320	5.08		300	---	---
	350	375	5.49		350	---	---
	400	425	5.88		400	---	---
9	150	165	4.43				
	200	220	5.22				
	250	275	5.90				
	300	330	6.57				
	350	385	7.11				
	400	440	7.68				

TABLE IX.

Spray Gun Deliveries at Constant Gun Pressures

3/4 Inch Hose 50 Feet Standard Fittings

Disc Size	Gun Pressure	Air Chamber Pressure	Gallons per Minute	Disc Size	Gun Pressure	Air Chamber Pressure	Gallons per Minute
4	150	150	.93	10	150	160	5.63
	200	200	1.11		200	210	6.69
	250	250	1.26		250	265	7.45
	300	300	1.38		300	315	8.22
	350	350	1.48		350	370	8.91
	400	400	1.59		400	425	9.56
6	150	150	1.92	12	150	165	8.23
	200	200	2.31		200	215	9.52
	250	250	2.59		250	270	10.78
	300	300	2.83		300	325	11.83
	350	350	3.07		350	380	12.89
	400	400	3.29		400	430	13.74
7	150	150	2.69	14	150	170	10.62
	200	200	3.15		200	225	12.47
	250	250	3.51		250	280	13.92
	300	300	3.86		300	350	15.48
	350	350	4.19		350	---	---
	400	405	4.50		400	---	---
8	150	150	3.47	16	150	190	13.77
	200	205	4.09		200	---	---
	250	255	4.64		250	---	---
	300	305	5.08		300	---	---
	350	360	5.52		350	---	---
	400	410	5.94		400	---	---
9	150	150	4.46				
	200	205	5.24				
	250	255	5.93				
	300	310	6.53				
	350	360	7.10				
	400	420	7.62				

TABLE X.

Pressure Tests With a Short Hose

12 1/2 Feet of 3/8 Inch Hose

Disc Size	Air Chamber Pressure	Gun Pressure		Loss in Pressure	
		Standard Fit.	Large Fit.	Standard Fit.	Large Fit.
4	250	250	250	0	0
	350	350	350	0	0
	450	450	450	0	0
6	250	245	250	5	0
	350	340	350	10	0
	450	425	450	25	0
7	250	240	250	10	0
	350	335	350	15	0
	450	415	450	35	0
8	250	230	250	20	0
	350	325	350	25	0
	450	405	445	45	5
9	250	220	245	30	5
	350	310	340	40	10
	450	380	425	70	25
10	250	200	235	50	15
	350	280	330	70	20
	450	330	400	120	50
12	250	165	210	85	40
	350	220	295	130	55
	450	275	365	175	85
14	250	130	175	120	75
	350	170	245	180	105
	450	205	---	245	---
16	250	100	150	150	100
	350	130	---	220	---
	450	---	---	---	---

TABLE XI.

Spray Delivery With Multiple Nozzle Rods

3/8 Inch Hose, 50 Feet, Large Fittings

Number of Nozzles	Size of Discs	Air Chamber Pressure	Pressure at the Rod	Pressure Loss to the Rod	Gallons per Minute
3	4	250	245	5	3.59
		350	340	10	4.29
		450	430	20	4.79
3	5	250	230	20	5.24
		350	320	30	6.32
		450	410	40	7.25
3	6	250	220	30	6.64
		350	305	45	7.96
		450	380	70	9.01
4	4	250	240	10	4.67
		350	325	25	5.53
		450	415	35	6.27
4	5	250	215	35	6.09
		350	290	60	7.26
		450	380	70	8.29

TABLE XI. Cont.

Number of Nozzles	Size of Discs	Air Chamber Pressure	Pressure at the Rod	Pressure Loss to the Rod	Gallons per Minute
4	6	250	210	40	8.14
		350	270	80	9.58
		450	350	100	10.88
6	4	250	210	40	6.57
		350	295	55	7.73
		450	380	70	8.80
6	5	250	185	65	8.88
		350	255	95	10.66
		450	335	115	12.26
6	6	250	155	95	10.61
		350	215	135	12.69
		450	275	175	14.27
8	4	250	200	50	8.02
		350	280	70	9.48
		450	360	90	10.97
8	5	250	160	90	10.50
		350	220	130	12.49
		450	290	160	14.50
8	6	250	130	120	11.86
		350	185	165	14.26
		450	Exceeds pump capacity		

TABLE XII.

Comparison of Spray Rod Pipes

50 Feet of 3/8 Inch Hose

Large Fittings

Pipe Diameter	Number of Nozzles	Size of Discs	Pressure at Air Chamber	Pressure at Rod	Pressure at lower end of pipe	Gallons per Minute
5/8 In.	4	4	350	325	315	5.60
5/16	4	4	350	325	310	5.53
5/8	4	4	450	420	410	6.37
5/16	4	4	450	420	400	6.26
5/8	4	6	350	275	260	10.02
5/16	4	6	350	275	200	9.58
5/8	4	6	450	350	330	11.51
5/16	4	6	450	350	260	10.85
Hardie pipe			5/8 Inch diameter and 3 feet long.			
Bean pipe			5/16 Inch diameter and 4 feet long.			

TABLE XIII.

Effect of Whirl Plates on Delivery

1. Hardie Rod with Bean Whirl-plates
2. Bean Rod with Bean Whirl-plates
3. Hardie Rod with Hardie Whirl-plates
4. Bean Rod with Hardie Whirl-plates

3/8 Inch Hose, 50 Feet, Large Fittings
No. 5 Discs

Holes in Whirl Plates Vary in
Size from 9/64 to 10/64 Inch

Combination Number	Air Chamber Pressure	Pressure at Rod	Gallons per Minute
1	250	205	6.56
2	250	205	6.04
3	250	210	6.02
4	250	205	5.65
1	350	295	7.70
2	350	300	7.13
3	350	300	7.08
4	350	300	6.74
1	450	380	9.04
2	450	380	8.50
3	450	380	8.47
4	450	380	8.02

TABLE XIV.

Water Delivered Through Different Cutoffs

1. Hardie Cutoff, as used on their Multiple Nozzle Rods
2. Bean Cutoff, as used on their 6 and 8 Nozzle Rods
3. Friend Cutoff
4. Bean Cutoff, as used on their 3 and 4 Nozzle Rods

Make of Cutoff	Number of Nozzles	Size of Discs	Pressure at the Air Chamber	Pressure at the Rod	Gallons per Minute
1	3	4	350	330	4.30
2	3	4	350	330	4.29
3	3	4	350	330	4.24
4	3	4	350	330	4.23
1	3	4	450	420	4.80
2	3	4	450	420	4.79
3	3	4	450	420	4.77
4	3	4	450	420	4.76
1	3	6	350	305	8.05
2	3	6	350	305	7.96
3	3	6	350	295	7.81
4	3	6	350	290	7.73
1	3	6	450	380	9.15
2	3	6	450	380	9.01
3	3	6	450	375	8.88
4	3	6	450	360	8.68

TABLE XV.

Water Delivered Through Different Cutoffs

1. Hardie Cutoff
2. Bean Cutoff
3. Friend Cutoff
4. Bean Cutoff

Make of Cutoff	No. of Nozzles	Size of Discs	Pressure at Air Chamber	Pressure at Rod	Gallons per Minute
1	6	4	350	305	7.82
2	6	4	350	305	7.79
3	6	4	350	295	7.69
4	6	4	350	285	7.57
1	6	4	450	400	8.92
2	6	4	450	400	8.88
3	6	4	450	390	8.78
4	6	4	450	370	8.57
1	6	6	350	215	12.91
2	6	6	350	215	12.79
3	6	6	350		
4	6	6	350	175	11.81
1	6	6	450	275	14.87
2	6	6	450	270	14.63
3	6	6	450		
4	6	6	450	230	13.55

TABLE XVI.

Hose Diameter, Showing Expansion for Various Pressures

Pressure	Average Outside Diameter		
	3/8 Inch	1/2 Inch	3/4 Inch
0	.844 Inch	.965 Inch	1.375 Inch
150	.898	1.020	1.469
200	.906	1.031	1.477
250	.914	1.039	1.488
300	.914	1.043	1.496
350	.914	1.043	1.504
400	.922	1.047	1.508
450	.922	1.047	1.516

TABLE III.

Spray Gun Deliveries at Constant Air Chamber Pressures.

Hose Size	Disc Size	Pressure at Air Chamber	Pressure at the Gun		Pressure Lost		Delivery in Gal. per Min.	
			Standard Fittings	Large Fit- tings	Standard Fittings	Large Fit.	Standard Fittings	Large Fittings
50 Feet of 3/8 inch	4	200	200		0		1.11	
		250	250	250	0	0	1.26	1.26
		300	300		0		1.39	
		350	350	350	0	0	1.47	1.47
		400	400		0		1.59	
		450	450	450	0	0	1.68	1.68
	6	200	195		5		2.29	
		250	240	250	10	0	2.54	2.58
		300	290		10		2.78	
		350	340	350	10	0	3.02	3.04
		400	380		20		3.21	
		450	425	440	25	10	3.40	3.44
	7	200	185		15		3.02	
		250	225	250	25	0	3.41	3.53

TABLE XVII.

Pressure Tests With Eight Nozzle Rod

3/8 Inch Hose Large Fittings

Disc Size	Pressure at Air Chamber	Pressure at Entrance to rod	Pressure Lost in rod	Pressure at The Nozzles	Gallons per Minute
4	200	165	30	135	7.10
4	250	200	30	170	8.02
4	300	235	35	200	8.77
4	350	280	40	240	9.48
4	400	320	35	285	10.21
4	450	360	40	320	10.97
6	200	105	35	70	10.24
6	250	130	45	85	11.86
6	300	155	55	100	13.05
6	350	185	65	120	14.26
6	400	215	75	140	15.25
6	450	Exceeds pump capacity			----

3/4 Inch Hose

Disc Size	Pressure Readings				
	At Entrance To Rod I	At End Of Tube II	At Entrance to First Tee III	At Entrance to Second tee IV	Just beyond second tee V
5	300	Eliminate tip to tube 290 290	265		250
5	300		265	260	275
5	300			285	250*
5	300				275**
5	300				

* For Normal Rod

** With Tube Tip Eliminated

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