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PERFORMANCE OF GORMAN-RUPP BACKPACK PUMP WITH RESPECT TO SUCTION LIFT, LENGTH OF HOSE AND DISCHARGE HEAD

by

D. G. Higgins and G. S. Ramsey

F O R E S T   F I R E   R E S E A R C H   I N S T I T U T E

CANADIAN FORESTRY SERVICE

DEPARTMENT OF THE ENVIRONMENT
Nicol Building
331 Cooper Street
Ottawa, Ontario
K1A OH3

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FOREWORD

This Information Report (FF-X-33) is the first in a series of reports dealing with portable forestry fire pumps. These reports are to provide the fire control officer with useful information on a pumping unit before he assigns it, with a crew, to a particular fire. It answers some critical questions, such as: "How many gallons of water per minute can I hope to deliver to the fireline using a pump under various conditions?".

Naturally, each make and model of fire pump has its own operating characteristics. Also each individual pump of a model series will have its own characteristic output which may vary from the average figures as presented in this report. A simple test procedure is available (Macleod, 1947) which enables the pump owner to determine the basic curve of his own unit or units of this type. This may then be used in conjunction with the figures in this report to provide more precise output.

While the information in this report can be used to train pump operators, the book is not intended for the pump operators' use at the fire site. We hope to produce a companion series of simplified operator's manuals to cover the various aspects of hose-lays and pump operation that may be encountered at a fire.

It is unlikely that the experienced operator will place his pump in a position where it cannot deliver water to the fireline because of the limitations of the unit. Unfortunately, experienced well-trained operators are not plentiful. An inexperienced operator with a centrifugal pump may waste time setting up a pump and hose line under conditions where it cannot produce the required gallonage at the fireline. Because the engine is running well he may not realize that at the nozzle insufficient water is flowing.

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INTRODUCTION

The Forest Fire Research Institute of the Canadian Forestry Service has been conducting tests on various makes and models of portable forestry fire pumps for a number of years. Some tests were conducted following the procedure formulated by the Canadian Government Specifications Board in their document "Standard Methods of Test for Portable Forestry Fire Pumps". This includes performance, endurance, muddy water and many other related tests.

From these experiments a great deal of information has been obtained on portable centrifugal pumps with 2-cycle engines. This data, when analyzed will aid fire control organizations in the selection of pumps for their specific requirements and will also provide the operator with information on the performance he may expect from a pumping unit in good working order, operating under difficult conditions. It was realized that little information on pump performance at various actual suction lifts was available. Therefore, the Institute initiated a series of tests to acquire this useful information.

The Gorman-Rupp Backpack Portable Fire Pump was selected as the first pump to be tested in this series. During the summer of 1968 a test following the "Standard Methods of Test for Portable Forestry Fire Pumps" was performed on this model of pump and the results were published in a special report prepared for the Associate Committee on Forest Fire Protection of the National Research Council (Ramsey et al., 1969).

It was realized that an unfavourable change in performance in the flow of liquid through a centrifugal pump might occur as the inlet head (suction lift height) was increased. Two serious effects which could occur are:

(1) a marked drop in efficiency and,
(2) a damaging erosion or pitting of the metal parts due to "cavitation".

> "The word "cavitation" itself implies a cavity or a void. If, at some point in the liquid flow, the existing fluid pressure equals the vapor pressure at the particular temperature, then the liquid will vaporize -- a cavity or void will form. If the fluid pressure fluctuates slightly above and below the vapor pressure, there will be an alternate formation and collapse of the vapor bubbles. Evidence shows that this alternate collapse and formation of bubbles is responsible for the marked drop in efficiency and the pitting of the metal parts."*

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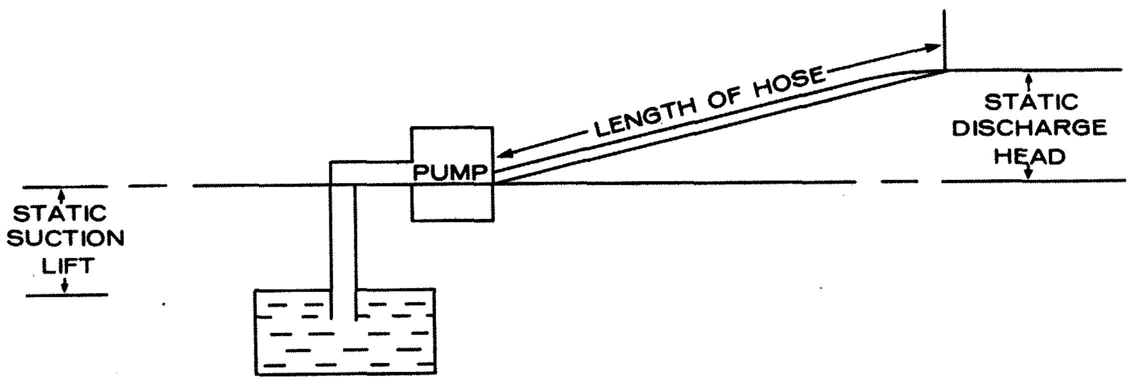
* Fluid Mechanics, R. C. Binder, 1962, p. 325.

One of the prime reasons for performing these tests was to determine at which static suction lift or inlet head pump efficiency took a drastic drop. This is commonly called the "cut-off point". A secondary reason was to find out what changes occur in flowrate and pressure with the addition of hose, at various inlet and outlet heads.

Because of cavitation effects it is recommended that centrifugal pumps be placed as close to the water supply as possible. However, in actual practice the firefighter must often position the pump above a water source, for example on a steep river bank. It was for this reason the Institute was interested in suction lift effects on various makes and models of pumps. This report covers the initial tests of this nature.

GLOSSARY OF TERMS



A. Static Suction Lift

The static suction lift is the vertical distance between the water supply and the pump. If the pump is above the water supply it must lift the water, therefore, it is referred to as a negative static suction lift. If the water supply is above the pump the water is aiding the pump thus it is a positive static suction lift.

Static suction lift is often referred to as static inlet head, static suction head, intake height, intake lift or suction lift.

B. Hose-Lay

"The arrangement of connected lengths of fire hose and accessories on the ground beginning at the first pumping unit and ending at the point of water delivery."*

This is frequently called length of hose line, discharge line, discharge hose or simply hose line.

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* Glossary of Forest Fire Control Terms, Associate Committee on Forest Fire Protection, 1970.

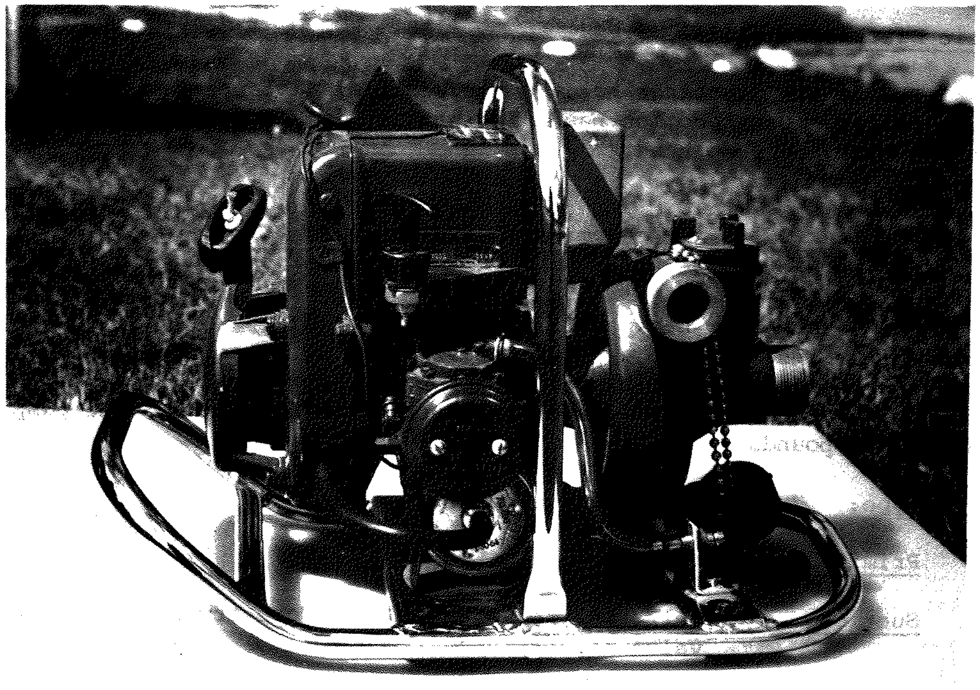

Photo No. 1. Fuel inlet and control side of Gorman-Rupp Backpack Pump.

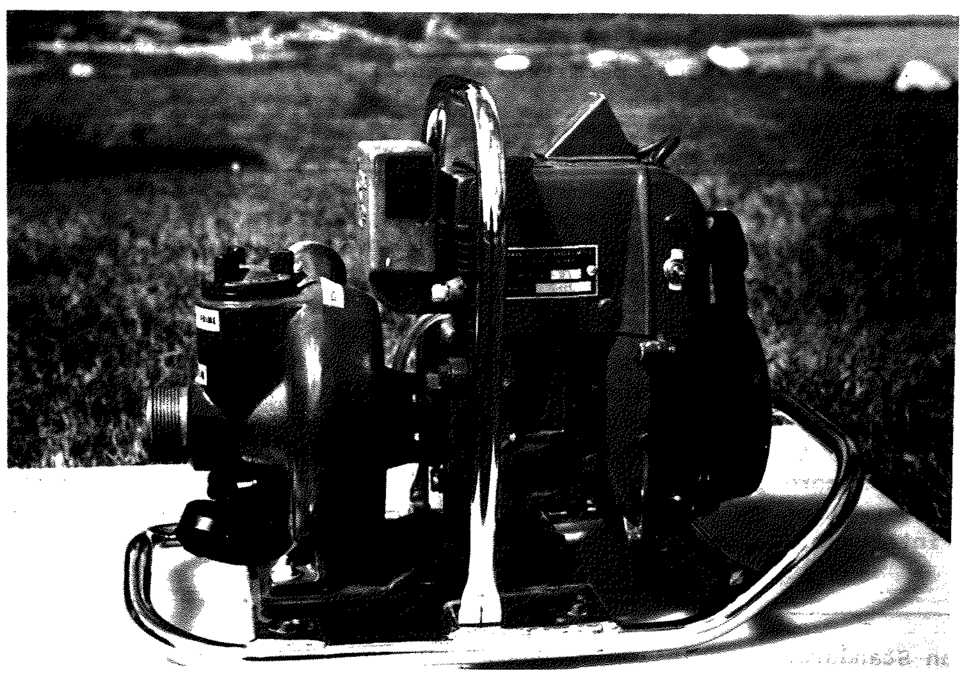

Photo No. 2. Exhaust side of Gorman-Rupp Backpack Pump.

C. Static Discharge Head

The static discharge head is the vertical distance between the pump and the nozzle outlet. Other common names for static discharge head are: static outlet head, static lift and pump head.

DESCRIPTION OF PUMPING UNIT

The Gorman-Rupp Backpack Fire Pump, Model 61-1/2 DP is comprised of an engine-driven pump, secured to a tubular base frame by three rubber vibration mounts. For carrying purposes a padded canvas backpack pump harness is provided. The total weight of the pump unit plus the major accessories is 56 pounds. The pumping unit itself weighs 30 pounds.

PUMP	Type:	single-stage centrifugal
	Priming:	manual
	Suction:	1-1/2 in. for standard CSA Forestry hose couplings* - foot valve necessary
	Discharge:	1-1/2 in. for standard CSA Forestry hose couplings
ENGINE	Type:	West Bend, 2-cycle, 8 h.p., single-cylinder, air cooled engine
	Fuel:	1/2 pint of outboard motor oil to 1 gallon of regular automobile gasoline
	Fuel System:	incorporates the use of an integral fuel pump. Carburetor has a drilled passage which transmits crankcase pressure directly to fuel pump. Diaphragm controls the amount of fuel permitted to enter past the inlet needle.

SET-UP OF APPARATUS AND PROCEDURE FOLLOWED FOR THE TEST

A tower (Photo No. 5) was erected using construction scaffolding to provide levels for actual suction lifts of 5, 10, 15, 20, 25 and 30 feet. At each level a series of calibrated nozzles were used in succession for 5 minute intervals to determine the flow rate developed by the pump at different working pressures. A "bypass box", consisting of 2 ball valves, enabled the operator to divert the flow to an overflow line while changing nozzle tips without interrupting engine operation, after the 5 minute test interval was completed. During each 5 minute interval the unit was adjusted to maximum performance, the discharge pressure and vacuum gauge readings were recorded along with the fuel, air, water and engine head temperatures. The fuel consumption and the revolutions per minute of the engine were also recorded at these intervals (Macleod, 1947).

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* Canadian Standards Association, Standard No. B89-1954.

ACTUAL PERFORMANCE AT VARIED SUCTION LIFTS

The actual performance of the pumping unit was plotted in Figures 1 and 2. The main point to note is that the performance of the pump doesn't change appreciably until the suction lift reaches approximately 13 feet. At this point (referred to as the "cutoff point") the performance of the pump drops drastically.

With the pressure held constant at 60 psi, between 0 and 15 feet, there was a drop in flowrate of approximately 10 per cent, whereas between 15 and 20 feet there was a drop of 25 per cent and between 20 and 25 feet a drop of 37 per cent. The overall loss between 0 and 25 feet was 56 per cent. It was suspected that the impeller would show a considerable amount of pitting from cavitation but upon examination at the conclusion of the tests no damage was noticeable.

Theoretical calculations show that the maximum possible suction lift can vary as much as three feet depending on the atmospheric pressure and the water temperature (see Appendix D). This maximum height ranges between thirty and thirty-three feet. Throughout the month of August several attempts to run the pump with a suction lift of 30 feet were unsuccessful (low atmospheric pressure and high water temperature). However, during the last week in September no problems were found pumping with a suction lift of 30 feet due to the higher atmospheric pressure and lower water temperature at that time. The maximum theoretical suction lift was never reached.

PUMP PERFORMANCE TABLES

When any fire pump is used on a fire, it must be considered as only one component of a complete system to deliver water from a source to a fire line. The other components of the system, intake and discharge hose and nozzle all inter-react with the pump to govern overall system performance. The tables in Appendix B and Appendix C provide the operator with information on the performance he may expect from a Gorman-Rupp Backpack Pump in good working condition, using either the 1/4 in., 5/16 in., 3/8 in. or 1/2 in. nozzle tip and operating at various static suction lifts, with different lengths of 1-1/2 in. unlined linen hose.

Operators often assume that their pumping units are working satisfactorily because the engine sounds well and water is streaming from the nozzle. This assumption often leads to excessive wear and tear to the units. If the operator had a pressure gauge on the hose line at the pump discharge outlet he would be able to compare his actual pump pressure with the pump pressure in Appendix C that pertains to his particular set-up. This would tell him if the performance of the pumping unit is deteriorating. If the performance has dropped drastically he can refer to the trouble chart in the pump manual or if possible replace the unit.

The preceding use of the tables is only one of the many ways, problems may be solved.

These tables can also be used along with the graphs to determine where each pump should be located in a tandem system.

When using the tables to determine what the pump pressure, nozzle pressure and flowrate will be, three things must first be estimated or known:

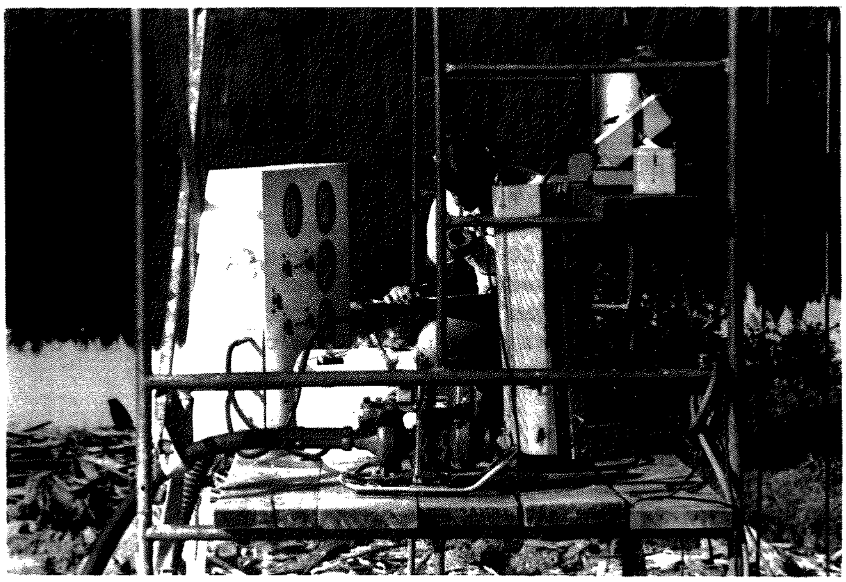


Photo No. 3. Set-up of apparatus on the tower.

Photo No. 4. Tower for suction lift test.

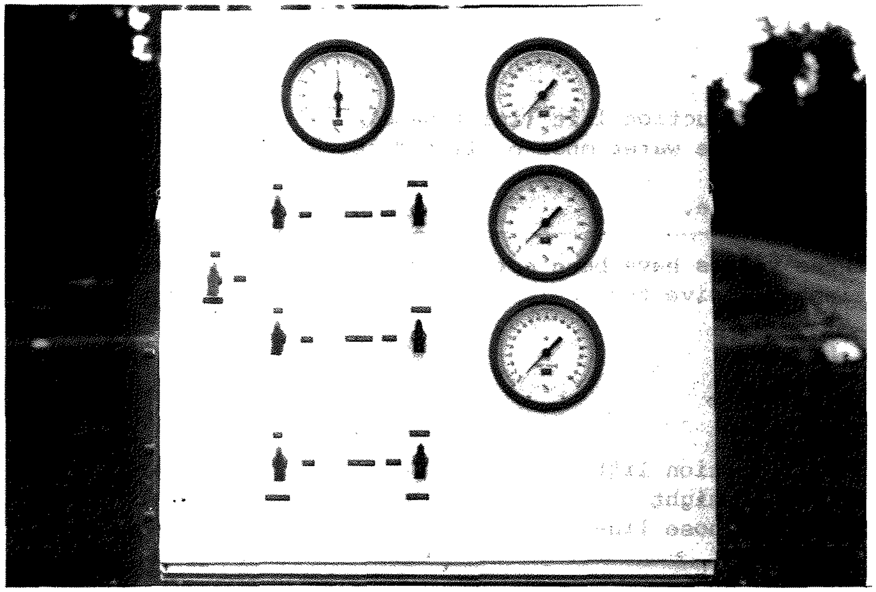


Photo No. 5. Pressure and vacuum gauge panel used on the tower.

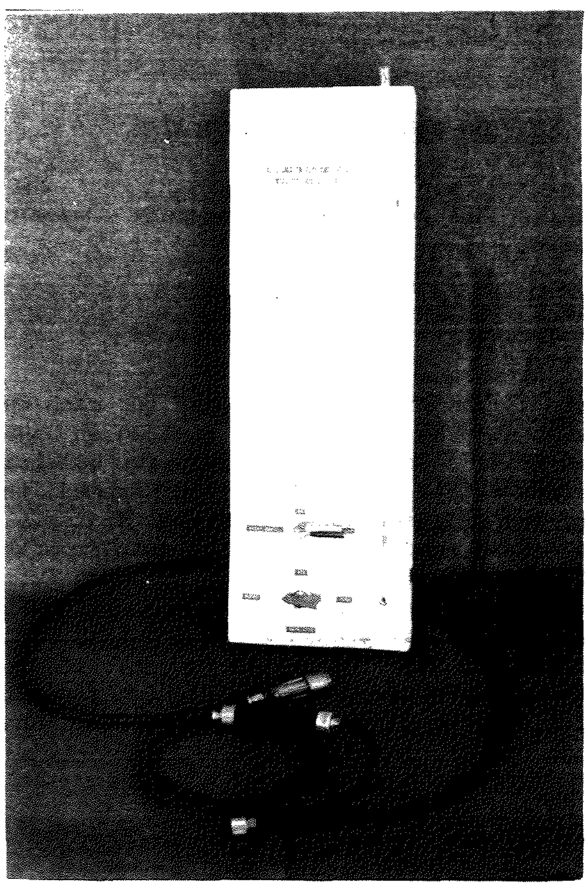


Photo No. 6. Instrument used for measuring fuel consumption.

1. the height of static suction lift (inlet head)
2. the vertical height the water must be lifted above the pump (static discharge head)
3. the length of hose line.

Once the above three values have been estimated, refer to the corresponding table to see what nozzles will give the desired flowrates and pressures.

Example

Estimated

1.	static suction lift	20 feet
2.	vertical height	100 feet
3.	length of hose line	1,000 feet

From Tables No. 3A, 3B, and 7.

Nozzle Tip	Flowrate	Nozzle Pressure	Pump Pressure
1/2"	21.7	13.3	118
3/8"	19.3	47.0	140
5/16"	18.4	54.0	143
1/4"	14.7	97.5	171

HOW THE TABLES WERE CALCULATED

The various tables in Appendix B and Appendix C were developed using the well known pump equation:

Pump Pressure = Nozzle Pressure + Static Discharge Head + Friction Loss

The maximum output from the pump was found for each calibrated nozzle tip at the different suction lift heights and was plotted in Figure 1. These maximum outputs could then be used as starting points for balancing the above equation by a trial and error method. A flowrate was assumed, then the nozzle pressure (from Fig. 3) and the friction loss (from Fig. 4) for a given length of hose could be found. The static head exerted on the pump from the water in the hose was taken as being 0.43 pounds per square inch for each foot of elevation above the pump. The required pump pressure was then determined by adding together the three above pressures. This total pressure was compared with Figure 1 to see if the assumed flowrate coincided with the actual output. If the calculated pressure didn't fall on the performance curve a different flowrate was assumed and the above procedure followed until the pressure did fit. An example follows:

Example

suction lift of 15 feet
static discharge head 100 feet
length of hose-lay 1,000 feet of 1-1/2 inch unlined linen hose (10 one-hundred-foot lengths)
3/8 inch nozzle tip

Assume a flowrate of 23 gpm

static discharge head	=	.43 X 100	=	43 psi
friction loss (Fig. 4)	=	6.9 (per 100 ft. length) X 10	=	69 psi
nozzle pressure (Fig. 3)	=		=	60 psi
pump pressure required	=		=	172 psi

From performance curve (Fig. 1) maximum psi obtainable from pump with a flow of 23 gpm is 152 psi, therefore the equation is not balanced.

Assume a flowrate of 21.5 gpm

static discharge head	=	.43 X 100	=	43 psi
friction loss (Fig. 4)	=	6.1 (per 100 ft. length) X 10	=	61 psi
nozzle pressure (Fig. 3)	=		=	51 psi
pump pressure required	=		=	155 psi

From performance curve (Fig. 1) maximum psi obtainable from pump with a flow of 21.5 gpm is 155 psi, therefore the equation is balanced.

NOTE: Values for the balanced example are indicated by ☐ in the tables.

RULE OF THUMB METHOD FOR SOLVING THE PUMP EQUATION IN THE FIELD

When using the pump equation to estimate if a particular unit will give the required nozzle pressure the following rule of thumb values can be used:

Static Discharge Head

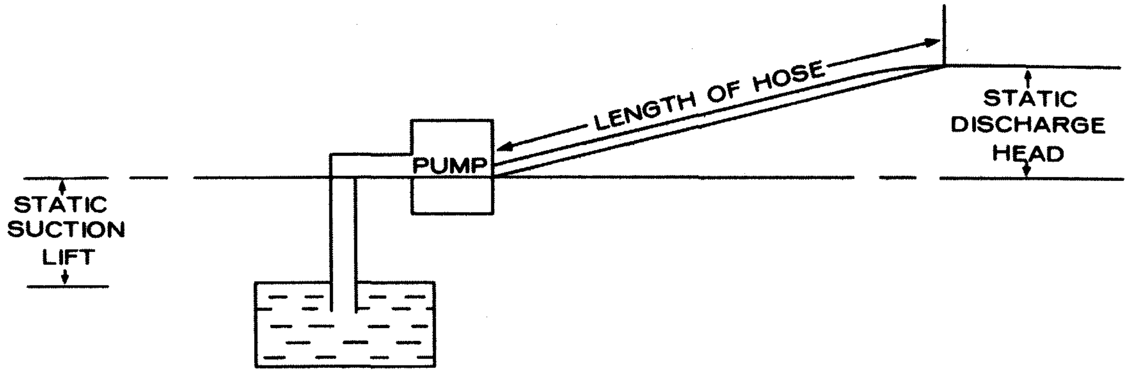
The static discharge head or back pressure exerted at the pump is 0.43 psi for every foot of elevation between the pump and the discharge nozzle. For field calculations this value is usually rounded off to 0.5 psi for each foot of elevation.

Friction Loss

Approximate friction losses per 100-foot length of 1-1/2 inch unlined hose and 1-1/2 inch lined hose, using different nozzle sizes are given in the table below for a pressure of 50 psi. It should be remembered that friction loss increases as the flowrate increases and decreases as the flowrate decreases.

	Nozzle Tip			
Friction Loss Per 100 Feet	1/4 in.	5/16 in.	3/8 in.	1/2 in.
1-1/2 in. unlined hose	2 psi	4 psi	6 psi	20 psi
1-1/2 in. lined hose	1 psi	2 psi	3 psi	10 psi

Set-ups Calculated in the Tables



Static Suction Lift's of 0', 15', 20', and 25'
Static Discharge Heads of 0', 50', 100', and 200'
Hose Lengths of 0', 100', 500', 1,000', 2,000', and 3,000'.

Performance Factors as Seen in the Tables

The following diagrams represent examples calculated from the tables and show the effects static suction lift, length of hose-lay or static discharge head have on the amount of water delivered to a fire by a pump system.

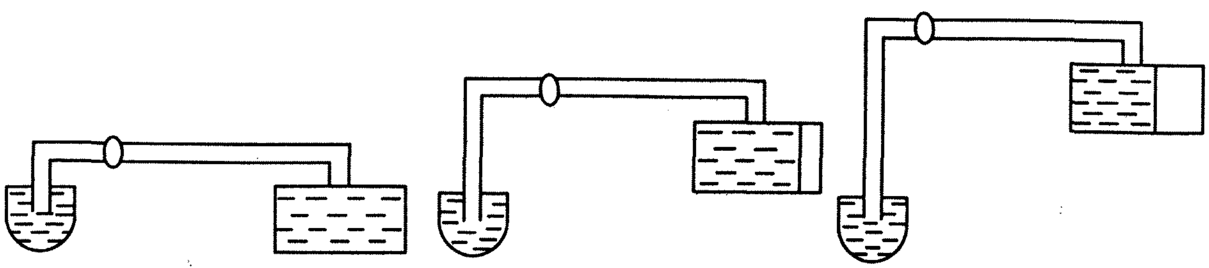
1. Static Suction Lift

length of hose line	1,000 feet
static discharge head	0 feet
nozzle tip	3/8 inch

static suction lift varied from 0 feet to 25 feet.

STATIC SUCTION LIFT

0 ft.	15 ft.	25 ft.
100% flowrate	98% flowrate	68% flowrate

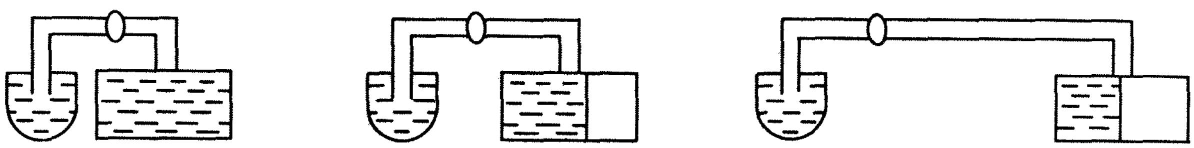


2. Length of Hose

static discharge head 0 feet
static suction lift 0 feet
nozzle tip 3/8 inch
length of hose varied from 0 feet to 3,000 feet.

LENGTH OF HOSE

0 ft.	1,000 ft.	3,000 ft.
100% flowrate	77% flowrate	55% flowrate

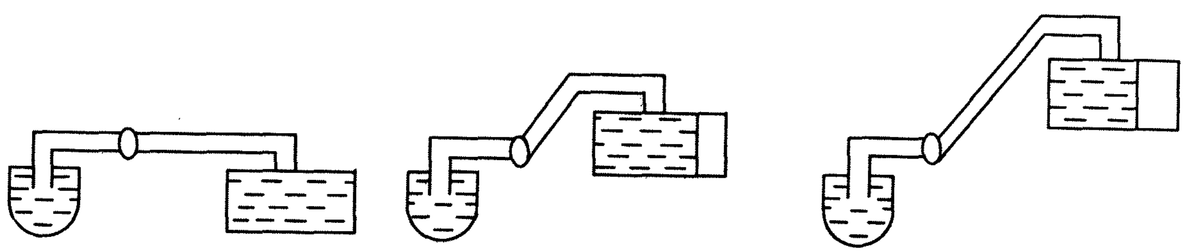


3. Static Discharge Head

length of hose 1,000 feet
static suction lift 0 feet
nozzle tip 3/8 inch
static discharge head varied from 0 feet to 200 feet.

STATIC DISCHARGE HEAD

0 ft.	100 ft.	200 ft.
100%	88%	72%



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APPENDIX A

PERFORMANCE CURVES

FIGURE 1
GORMAN-RUPP PERFORMANCE CURVES

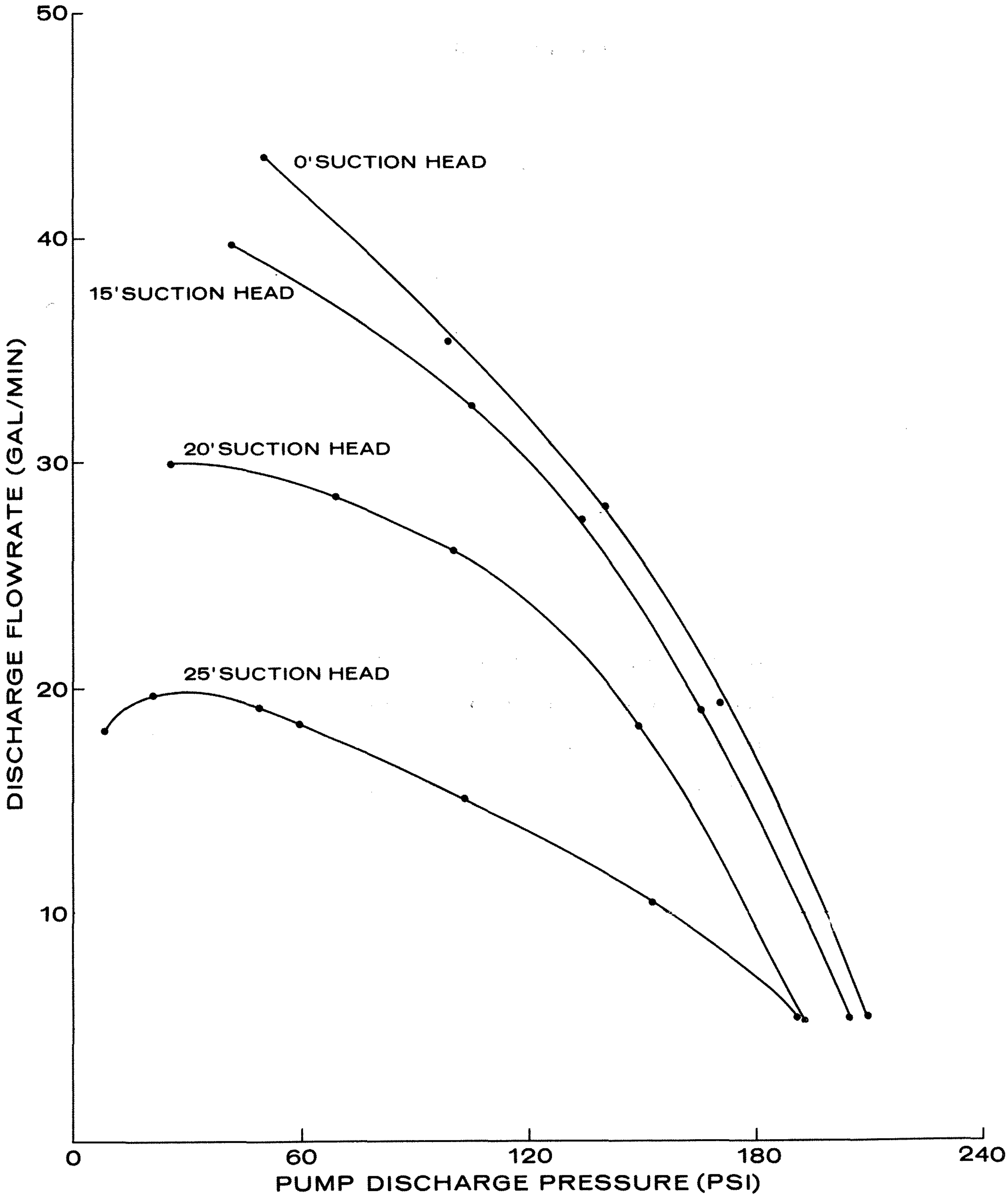


FIGURE 2
PUMP PERFORMANCE AT VARIED SUCTION LIFTS

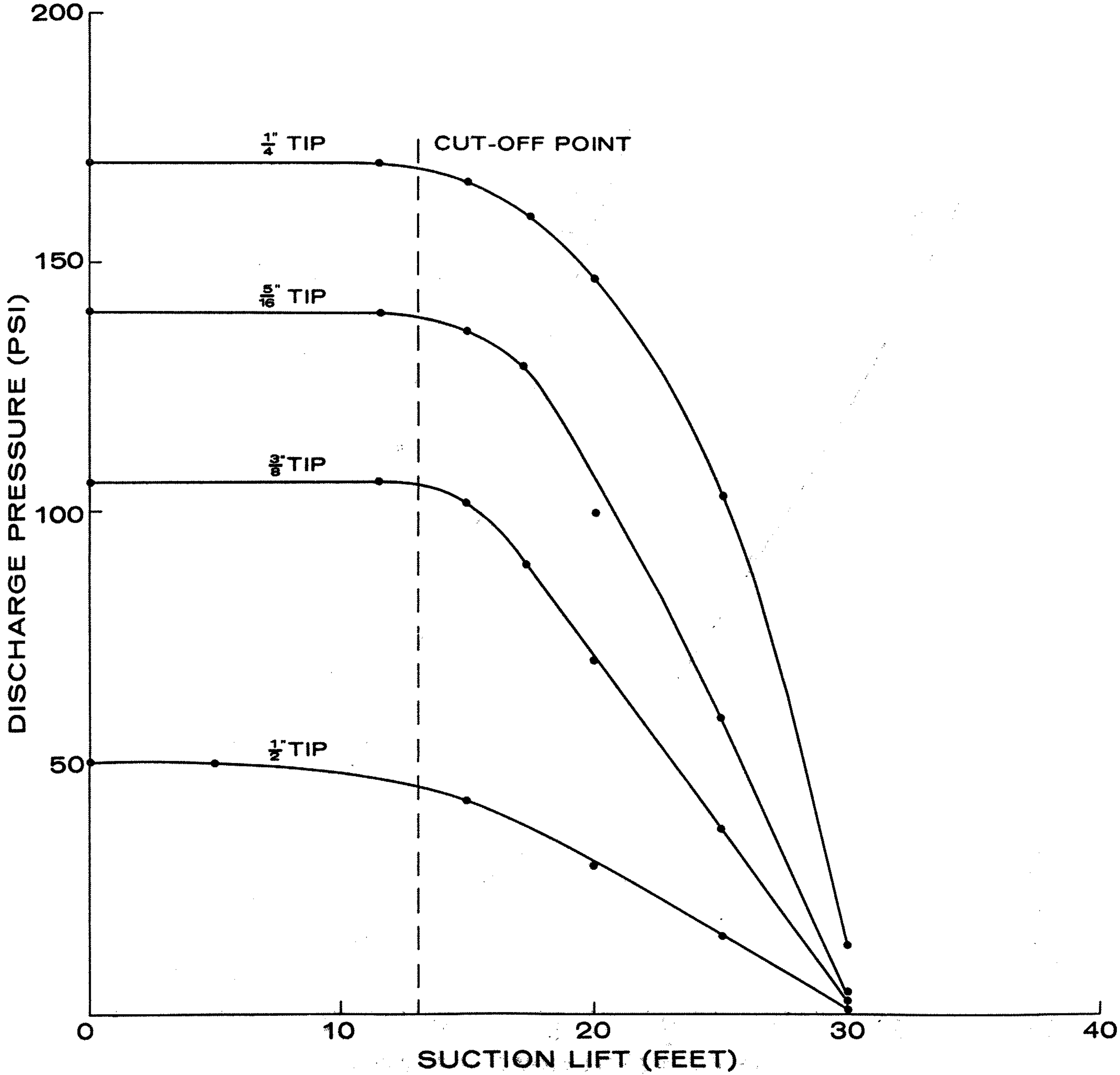


FIGURE 3
NOZZLE DISCHARGE CURVES

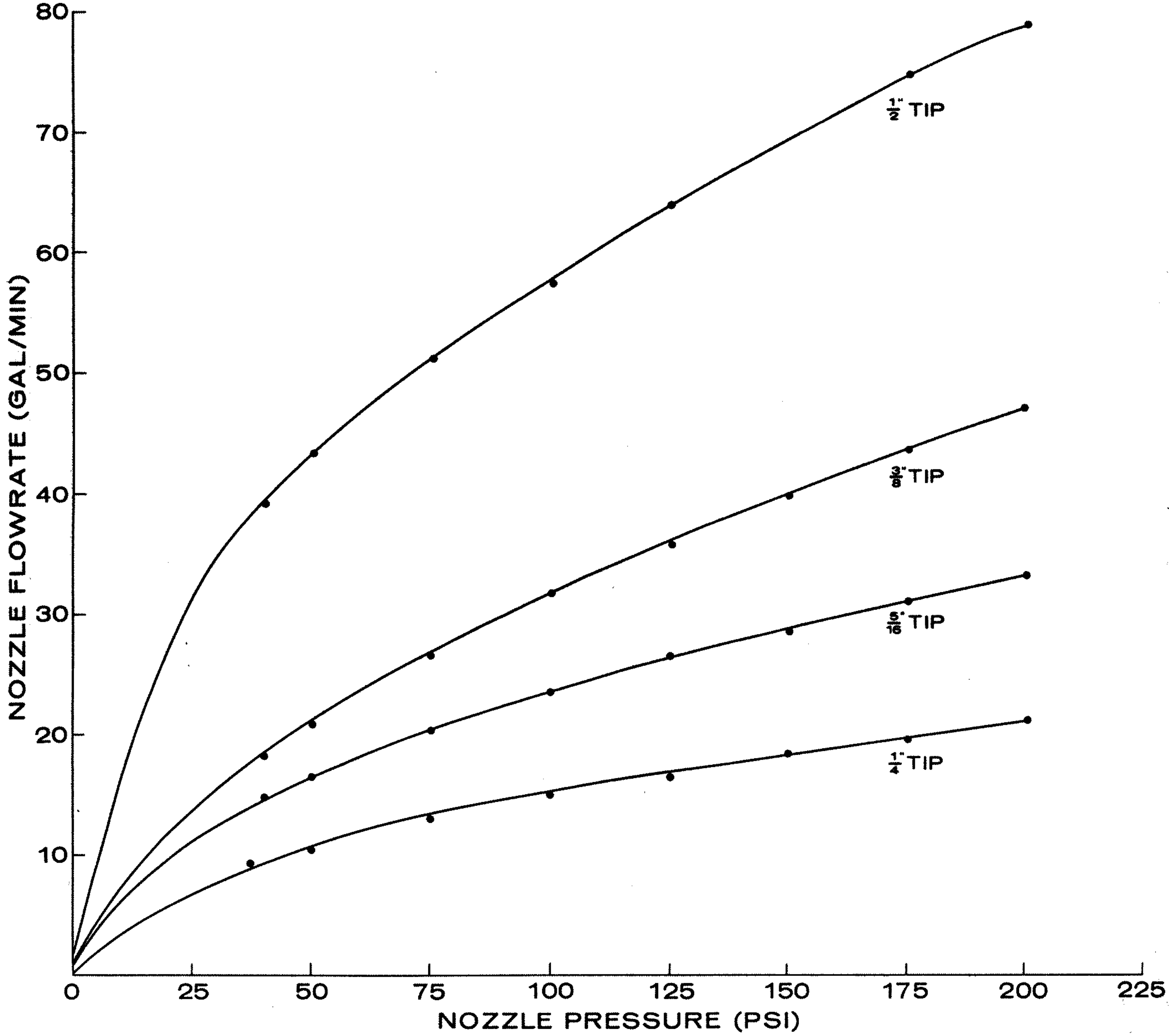
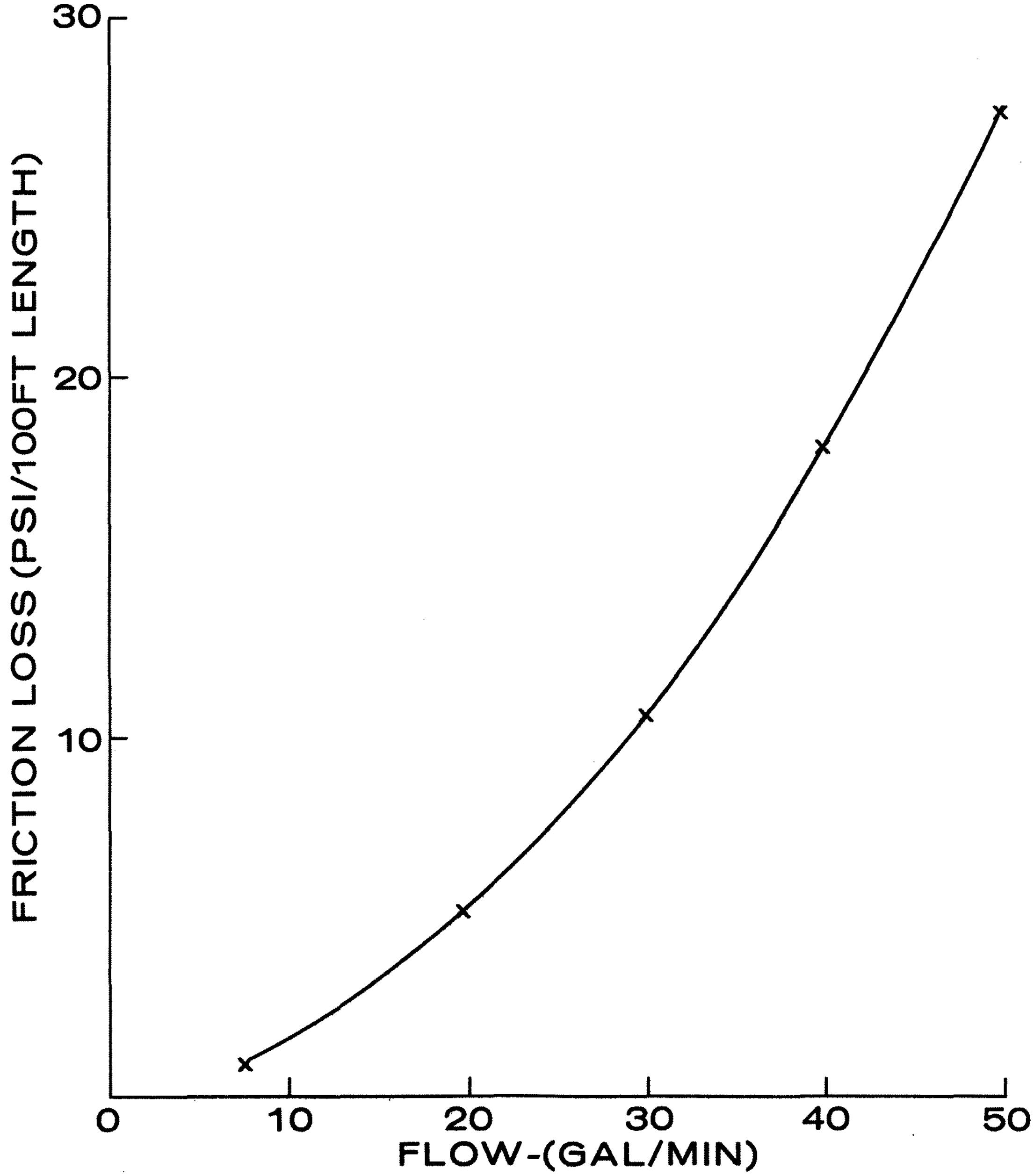


FIGURE 4
FRICTION LOSS IN UNLINED LINEN FIRE HOSE



APPENDIX B

CALCULATED TABLES
FOR
DISCHARGE FLOWRATE AND NOZZLE PRESSURE

TABLE 1A

DISCHARGE - (GALLONS PER MINUTE)

LENGTH OF HOSE

Head (Feet)	0	100	500	1,000	2,000	3,000
			0-FEET - SUCTION LIFT			
			1/2-Inch Nozzle			
0	43.5	41.5	36.0	29.6	23.4	20.0
50	-	39.0	32.7	28.0	22.2	18.6
100	-	-	31.0	26.0	20.6	17.3
200	-	-	26.0	22.0	17.0	14.5
			3/8-Inch Nozzle			
0	33.0	32.5	28.8	25.3	20.9	18.0
50	-	30.3	27.0	23.5	19.5	17.0
100	-	-	25.0	22.3	18.0	15.0
200	-	-	20.5	18.3	15.2	13.3
			5/16-Inch Nozzle			
0	28.0	27.2	25.0	22.6	19.3	17.1
50	-	25.8	23.5	21.3	18.3	16.2
100	-	-	22.0	19.7	16.9	15.5
200	-	-	18.5	16.8	14.5	13.0
			1/4-Inch Nozzle			
0	19.4	19.2	18.4	17.3	15.8	14.5
50	-	18.2	17.3	16.4	14.9	13.7
100	-	-	16.3	15.4	14.0	12.7
200	-	-	14.0	13.1	11.8	10.8

TABLE 1B

NOZZLE PRESSURE - (LBS. PER SQUARE INCH)

Head (Feet)	LENGTH OF HOSE 0	100	500	1,000	2,000	3,000
			0-FEET - SUCTION LIFT			
			1/2-Inch Nozzle			
0	50.0	45.0	34.0	23.0	15.0	11.0
50	-	38.0	29.0	20.5	13.0	10.0
100	-	-	31.0	18.0	11.0	8.0
200	-	-	18.0	12.5	8.5	7.0
			3/8-Inch Nozzle			
0	107.0	106.0	84.0	67.0	47.8	40.0
50	-	94.0	77.5	62.5	43.0	36.0
100	-	-	67.0	53.0	40.0	33.0
200	-	-	50.0	41.0	30.5	23.5
			5/16-Inch Nozzle			
0	141.0	132.5	110.0	93.0	68.5	53.0
50	-	118.0	99.0	82.0	62.0	46.0
100	-	-	87.5	71.0	52.0	40.0
200	-	-	62.5	51.0	36.0	27.5
			1/4-Inch Nozzle			
0	170.0	166.0	150.0	133.0	110.0	93.0
50	-	147.5	133.0	120.0	99.0	84.0
100	-	-	117.5	105.0	87.5	73.0
200	-	-	87.5	78.5	67.0	57.0

TABLE 2A

DISCHARGE - (GALLONS PER MINUTE)

LENGTH OF HOSE

Head (Feet)	0	100	500	1,000	2,000	3,000
15-FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	39.5	38.2	33.2	29.0	23.2	19.7
50	-	36.5	31.6	27.3	21.6	18.3
100	-	-	30.0	25.3	20.0	17.0
200	-	-	25.3	21.0	16.7	14.3
3/8-Inch Nozzle						
0	32.5	32.0	28.1	24.8	20.5	17.7
50	-	29.6	27.1	23.2	19.2	16.7
100	-	-	24.5	21.5	17.7	15.5
200	-	-	20.0	17.7	14.9	13.0
5/16-Inch Nozzle						
0	27.5	26.9	24.5	22.2	19.0	16.9
50	-	25.5	23.1	21.0	18.0	16.0
100	-	-	21.5	19.3	16.7	15.0
200	-	-	18.0	16.5	14.3	12.7
1/4-Inch Nozzle						
0	19.0	18.9	18.0	17.1	15.6	14.4
50	-	17.9	17.0	16.2	14.8	13.5
100	-	-	16.0	15.2	13.7	12.5
200	-	-	13.9	13.0	11.5	10.8

TABLE 2B

NOZZLE PRESSURE - (LBS. PER SQUARE INCH)

Head (Feet)	LENGTH OF HOSE 0	100	500	1,000	2,000	3,000
			15-FEET - SUCTION LIFT			
			1/2-Inch Nozzle			
0	42.0	38.0	29.0	22.5	15.0	11.0
50	-	26.0	27.0	20.0	12.5	9.0
100	-	-	25.0	17.5	12.0	8.5
200	-	-	17.5	12.0	8.0	6.7
			3/8-Inch Nozzle			
0	106.0	102.0	83.0	67.0	47.0	40.0
50	-	91.0	78.0	61.0	44.0	35.0
100	-	-	67.0	51.0	40.0	32.0
200	-	-	47.5	40.0	29.5	23.0
			5/16-Inch Nozzle			
0	137.0	129.0	107.5	89.0	67.0	52.0
50	-	115.0	96.0	80.0	59.0	45.0
100	-	-	83.0	68.5	50.5	39.0
200	-	-	59.0	49.0	34.0	26.5
			1/4-Inch Nozzle			
0	166.0	162.0	145.0	131.0	107.5	92.0
50	-	143.5	130.0	117.5	97.5	82.0
100	-	-	113.0	102.5	85.0	72.0
200	-	-	86.5	77.0	65.0	55.0

TABLE 3A

DISCHARGE - (GALLONS PER MINUTE)

LENGTH OF HOSE

Head (Feet)	0	100	500	1,000	2,000	3,000
20-FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	30.0	28.8	26.8	24.4	21.0	18.4
50	-	27.5	25.2	22.8	19.7	17.2
100	-	-	23.7	21.7	18.6	16.2
200	-	-	21.0	18.7	15.6	13.5
3/8-Inch Nozzle						
0	26.0	25.5	24.0	22.0	19.0	16.9
50	-	24.0	22.2	20.5	18.0	16.0
100	-	-	21.2	19.3	16.3	15.0
200	-	-	17.9	16.5	14.3	12.5
5/16-Inch Nozzle						
0	23.6	23.2	22.0	20.4	18.0	16.3
50	-	22.0	20.6	19.2	17.0	15.5
100	-	-	19.5	18.4	16.1	14.5
200	-	-	16.8	15.5	13.8	12.3
1/4-Inch Nozzle						
0	18.3	18.0	17.2	16.5	15.2	14.0
50	-	17.0	16.4	15.6	14.1	13.0
100	-	-	15.5	14.7	13.3	12.3
200	-	-	13.1	12.5	11.3	10.5

TABLE 3B

NOZZLE PRESSURE - (LBS. PER SQUARE INCH)

LENGTH OF HOSE

Head (Feet)	0	100	500	1,000	2,000	3,000
20-FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	25.0	23.5	19.0	16.5	12.5	9.0
50	-	21.0	17.5	14.5	10.5	8.5
100	-	-	16.0	13.3	9.0	7.5
200	-	-	12.0	9.0	7.5	6.5
3/8-Inch Nozzle						
0	70.0	67.8	63.0	52.0	44.0	36.0
50	-	63.0	57.0	50.0	40.0	32.5
100	-	-	50.0	47.0	32.0	30.0
200	-	-	40.5	35.0	27.0	22.0
5/16-Inch Nozzle						
0	100.0	96.0	87.5	76.0	59.0	47.0
50	-	87.5	77.5	67.5	52.0	42.0
100	-	-	70.0	54.0	45.0	36.0
200	-	-	51.0	42.0	31.5	24.5
1/4-Inch Nozzle						
0	149.0	145.0	132.0	120.0	102.5	87.5
50	-	130.0	120.0	107.5	89.0	76.0
100	-	-	106.0	97.5	80.0	68.0
200	-	-	78.5	72.0	60.0	52.0

TABLE 4A

DISCHARGE - (GALLONS PER MINUTE)

LENGTH OF HOSE

Head (Feet)	0	100	500	1,000	2,000	3,000
25-FEET - SUCTION LIFT						
3/8-Inch Nozzle						
0	19.0	18.8	18.3	17.3	15.6	14.5
50	-	18.0	17.0	16.2	14.5	13.4
100	-	-	16.0	15.0	13.8	12.5
200	-	-	13.6	12.7	11.7	10.5
5/16-Inch Nozzle						
0	18.1	18.0	17.3	16.5	15.3	14.0
50	-	17.3	16.3	15.5	14.2	13.0
100	-	-	15.3	14.5	13.6	12.4
200	-	-	13.3	12.5	11.5	10.5
1/4-Inch Nozzle						
0	15.2	15.1	14.8	14.3	13.0	12.2
50	-	14.3	13.7	13.0	12.2	11.4
100	-	-	12.8	12.3	11.3	10.7
200	-	-	11.0	10.5	10.0	9.4

TABLE 4B

NOZZLE PRESSURE - (LBS. PER SQUARE INCH)

LENGTH OF HOSE

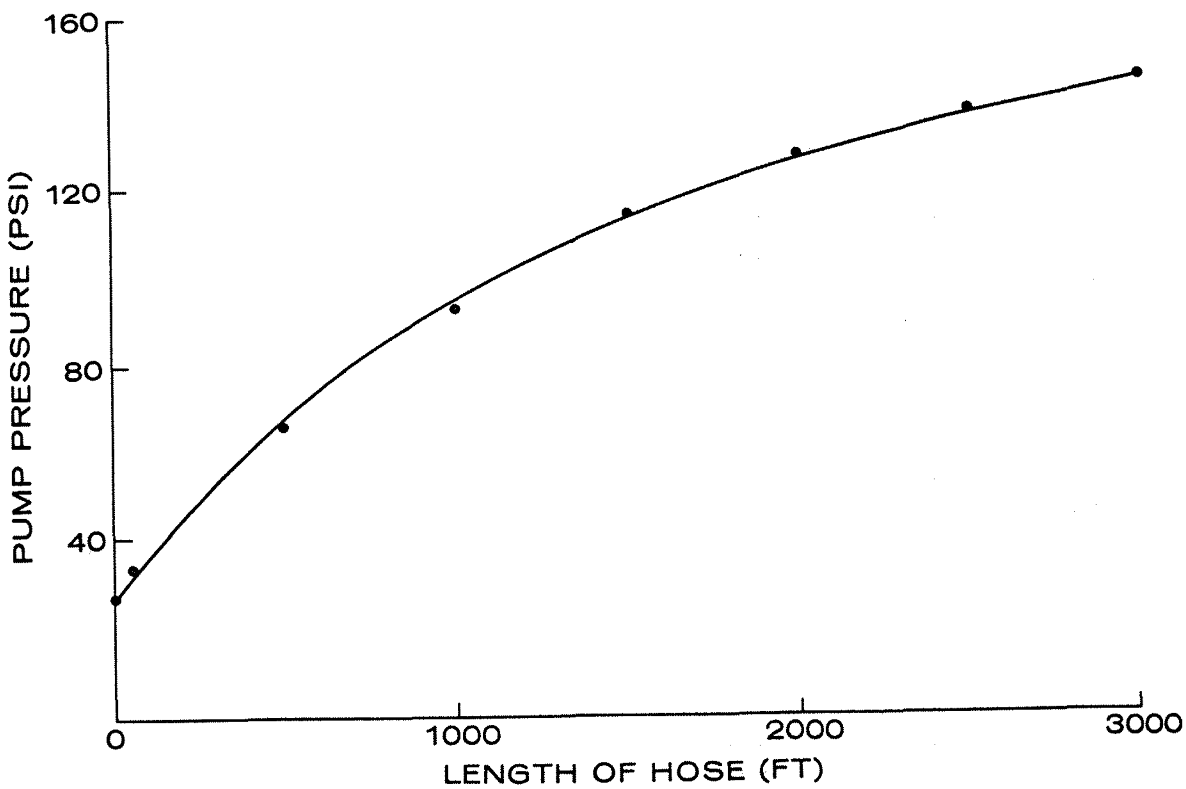
Head (Feet)	0	100	500	1,000	2,000	3,000
25-FEET - SUCTION LIFT						
3/8-Inch Nozzle						
0	49.5	47.0	41.0	37.5	32.0	27.5
50	-	40.0	37.0	32.5	27.5	25.0
100	-	-	32.5	30.0	26.0	22.0
200	-	-	25.0	22.5	19.5	16.5
5/16-Inch Nozzle						
0	60.0	59.0	54.0	49.0	42.5	33.0
50	-	54.0	47.0	42.5	34.0	27.5
100	-	-	42.0	36.0	31.0	25.0
200	-	-	29.0	25.0	22.0	18.0
1/4-Inch Nozzle						
0	103.	102.5	97.5	90.0	77.0	68.0
50	-	90.0	84.0	77.0	68.0	61.0
100	-	-	73.0	68.0	60.0	55.0
200	-	-	57.5	52.0	47.5	42.5

APPENDIX C

PUMP PRESSURES REQUIRED

In the following tables it should be noted that the pump pressure increases as the length of hose and static discharge head are increased, while in Appendix B the nozzle pressure decreases as the length of hose, static suction lift and static discharge head are increased.

The following example illustrates how the pump pressure increases as the length of hose is increased. All other performance factors remain constant. The suction lift remains constant at 20 feet while the static discharge head remains at 0 feet using a 1/2 inch nozzle.



Appendix C includes

Table 5.	Pump Pressure	-	0 Feet Suction Lift
Table 6.	Pump Pressure	-	15 Feet Suction Lift
Table 7.	Pump Pressure	-	20 Feet Suction Lift
Table 8.	Pump Pressure	-	25 Feet Suction Lift

TABLE 5

PRESSURE REQUIRED AT PUMP (LBS. PER SQUARE INCH)

Head (feet)	LENGTH OF HOSE 0	100	500	1,000	2,000	3,000
0-FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	50	65	111	130	157	170
50	-	78	116	140	163	172
100	-	-	125	146	166	177
200	-	-	147	161	175	183
3/8-Inch Nozzle						
0	107	119	136	148	164	172
50	-	127	145	156	169	178
100	-	-	150	160	171	183
200	-	-	164	172	182	187
5/16-Inch Nozzle						
0	141	142	150	159	170	175
50	-	148	156	164	174	179
100	-	-	162	166	175	182
200	-	-	172	176	182	188
1/4-Inch Nozzle						
0	166	171	173	174	180	183
50	-	174	175	179	184	186
100	-	-	179	182	186	188
200	-	-	185	187	192	194

TABLE 6

PRESSURE REQUIRED AT PUMP (LBS. PER SQUARE INCH)

LENGTH OF HOSE

Head (feet)	0	100	500	1,000	2,000	3,000
15-FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	42	55	95	128	153	167
50	-	73	109	135	157	169
100	-	-	123	142	161	172
200	-	-	144	156	172	180
3/8-Inch Nozzle						
0	106	114	133	145	159	169
50	-	124	139	153	166	174
100	-	-	148	155	169	177
200	-	-	160	169	178	184
5/16-Inch Nozzle						
0	137	138	146	153	165	172
50	-	145	153	160	169	175
100	-	-	157	162	172	178
200	-	-	167	173	179	183
1/4-Inch Nozzle						
0	166	167	167	172	176	181
50	-	170	172	176	181	182
100	-	-	174	178	182	184
200	-	-	184	185	188	192

TABLE 7

PRESSURE REQUIRED AT PUMP (LBS. PER SQUARE INCH)

LENGTH OF HOSE

Head (feet)	0	100	500	1,000	2,000	3,000
20-FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	25	34	63	93	129	147
50	-	53	80	105	136	153
100	-	-	96	118	146	159
200	-	-	127	142	162	173
3/8-Inch Nozzle						
0	70	76	100	115	142	156
50	-	92	112	128	150	162
100	-	-	123	140	159	169
200	-	-	149	159	172	177
5/16-Inch Nozzle						
0	100	103	119	131	147	158
50	-	116	127	139	154	164
100	-	-	139	143	160	169
200	-	-	157	162	173	177
1/4-Inch Nozzle						
0	149	150	153	158	168	172
50	-	156	161	163	169	173
100	-	-	166	171	175	177
200	-	-	174	178	181	186

TABLE 8

PRESSURE REQUIRED AT PUMP (LBS. PER SQUARE INCH)

Head (feet)	LENGTH OF HOSE 0	100	500	1,000	2,000	3,000
	25-FEET - SUCTION LIFT					
	3/8-Inch Nozzle					
0	49.5	52	63	78	100	117
50	-	66	79	91	109	125
100	-	-	94	105	124	134
200	-	-	124	132	145	154
	5/16-Inch Nozzle					
0	60	63	75	87	109	117
50	-	80	87	98	114	124
100	-	-	101	109	128	137
200	-	-	128	134	148	155
	1/4-Inch Nozzle					
0	103	106	113	120	127	134
50	-	115	119	124	134	142
100	-	-	128	133	141	151
200	-	-	150	152	161	166

APPENDIX D

THEORETICAL MAXIMUM SUCTION LIFT

Theoretical calculations below show that the maximum possible suction lift can vary as much as three feet depending on the atmospheric pressure and the water temperature.

High Atmospheric Pressure

High atmospheric pressure (barometer reading)	30.10 inches of Hg
Height of pump location above MSL (510 feet)	.50 inches of Hg
	29.60 inches of Hg
Saturation vapour pressure at 45°F	.20
	29.40 inches of Hg

1 inch of water = .0736 inches of Hg at 45°F
Density of H_2O at 45°F = .9999
1 inch of water = .0736 X .9999 = .0736 inches of Hg at 45°F

$$\text{height of water column possible} = \frac{29.40}{.0736} = 399 \text{ inches or } 33.3 \text{ feet.}$$

Low Atmospheric Pressure

Low atmospheric pressure (barometer reading)	29.05 inches of Hg
Height of pump location above MSL (510 feet)	.50 inches of Hg
	28.55 inches of Hg
Saturation vapour pressure at 90°F	1.47
	27.08 inches of Hg

1 inch of water = .0736 inches of Hg at 45°F
Density of H_2O at 90°F = .99497
1 inch of water = .0736 X .995 = .0732 inches of Hg at 90°F

$$\text{height of water column possible} = \frac{27.08}{.0732} = 370 \text{ inches or } 30.8 \text{ feet.}$$