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PERFORMANCE OF WAJAX MARK 3 CENTRIFUGAL PUMP WITH RESPECT TO SUCTION LIFT, LENGTH OF HOSE AND DISCHARGE HEAD

by

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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

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FOREWORD

This Information Report (FF-X-36) is the second in a series of reports dealing with portable forestry fire pumps. These reports provide the fire control officer with useful information on a pumping unit before he assigns it, with a crew, to a particular fire. They answer 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 somewhat 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.

When any pump unit is used on a fire, it must be considered as only one component of a complete system designed to deliver water to a fire. The hose, both intake and discharge, and nozzles inter-react with the pump to determine overall performance. The tables in this book provide a means of determining the system's output provided the characteristics of the particular pump unit are known.

This book is not intended for the pump operator's use in the field but may be used when training pump operators. If used for training, the first report in the series (FF-X-33) should be consulted as different situations and illustrations are used to explain the technique of using the tables and performing pump calculations. This will provide a broader base for training. It should be noted that all units for flowrates are imperial gallons per minute.

PERFORMANCE OF WAJAX MARK 3 CENTRIFUGAL PUMP
WITH RESPECT TO SUCTION LIFT, LENGTH OF HOSE AND DISCHARGE HEAD

D. G. Higgins

INTRODUCTION

The Forest Fire Research Institute of the Canadian Forestry Service is conducting tests to determine what effect static suction lift has on the performance of various makes and models of pumps used in forest fire control. These tests are being carried out at the Institute's Hydraulics Laboratory located on the Petawawa Forest Experiment Station, Chalk River, Ontario. This report deals with the Wajax Mark 3 Centrifugal Pump. In the United States this pump is known as the Pacific Pumper Model Mark 3.

Some of the information in this report is similar in many respects to the first report of this series, Information Report FF-X-33, but it was felt that it should be included for coherence as some fire control organizations might be interested only in this model of pump.

The following characteristics were investigated:

(1) Pump discharge flowrates using various pressures between free flow and shutoff at static suction lifts between 0 ft and 25 ft.

(2) Effect of increased static suction lift on the engine rpm and fuel consumption.

(3) Effect of static discharge head and hose length on the performance of the pumping unit at various static suction lifts.

The actual performance of the pumping unit is governed by four hydraulic forces which are: (1) static suction lift, (2) friction loss in the hose line, (3) static discharge head, and (4) nozzle discharge pressure.

Governed by the design, every centrifugal pump will have a point of maximum volume for a certain pressure at each suction lift. These maximum volumes along with the corresponding pressures form the performance curve of the pumping unit at each level. Once the performance curve at each suction lift is known, the required pump pressure for a given situation can be checked against these performance curves to see if the unit will supply the required pressure. The required pump pressure is obtained by adding the last three hydraulic forces in the preceding paragraph. These hydraulic forces form the well known pump equation (Macleod, 1947):

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

The Institute is developing a computer program for solving this pump equation, if the basic pump performance curve at each suction lift is known for the unit. It will be useful for calculating how much hose can be used with a particular pumping unit at different static discharge heads and suction lifts.

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, and this is referred to as a negative static suction lift. If the water supply is above the pump the water is aiding the unit 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 simply 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.*"

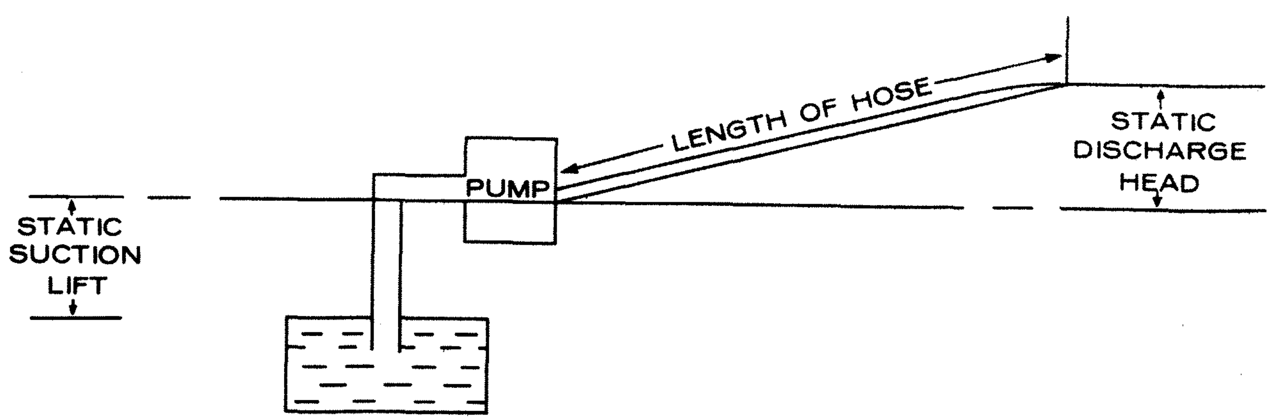
This is frequently called discharge line, discharge hose or simply hose line.

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 discharge lift or simply, pump head.

D. Friction Loss

Friction loss is the amount of pressure lost due to the resistance between the inside wall of the hose and the flowing water. Friction loss in forestry hose is usually measured in psi per 100 ft length.



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

DESCRIPTION OF PUMPING UNIT

The Wajax Mark 3 Centrifugal Pump (Photos No. 1 and 2) is a high pressure unit with the pump coupled to the power head by a quick action clamp assembly. The total weight of the unit is 55 lbs. A padded canvas pump harness is provided for backpacking.

Pump	Type:	four-stage centrifugal
	Priming:	manual
	Suction:	2" NPSH male suction connection for standard forestry hose couplings
	Discharge:	1-1/2" NPSH male discharge connection for standard forestry hose couplings*
	Weight of Pump End:	15 lbs
Engine	Type:	Rotax, one-cylinder, two-cycle, 9 h.p., air-cooled engine
	Fuel:	mixture ratio should be 16:1 (4 gallons of regular automotive gasoline to 1 quart of outboard motor oil SAE 30/40 mildly detergent)
	Carburetor:	Tillotson all-position diaphragm type with integral fuel pump and filter
	Weight of Engine:	40 lbs
	Dimensions of Complete Unit:	Height: 16-1/4 inches Width: 12 inches Length: 23 inches

One new feature on this Mark 3 pump unit is a decompressor valve. The purpose of this valve is to facilitate starting of the unit by bypassing part of the compression directly into the exhaust port and thereby, greatly reducing the effort required to start the engine.

SET-UP OF APPARATUS AND PROCEDURE FOLLOWED FOR THE TEST

A tower (Photo No. 4) was erected using construction scaffolding to provide several platforms for actual suction lifts from 0 to 30 feet. At each level a series of calibrated nozzle tips (known discharge flowrate at any given pressure) were used in succession for 5-minute intervals to determine the flowrate developed by the pump at different working pressures. A "bypass box",

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* Canadian Standards Association, Standard B89-1954.

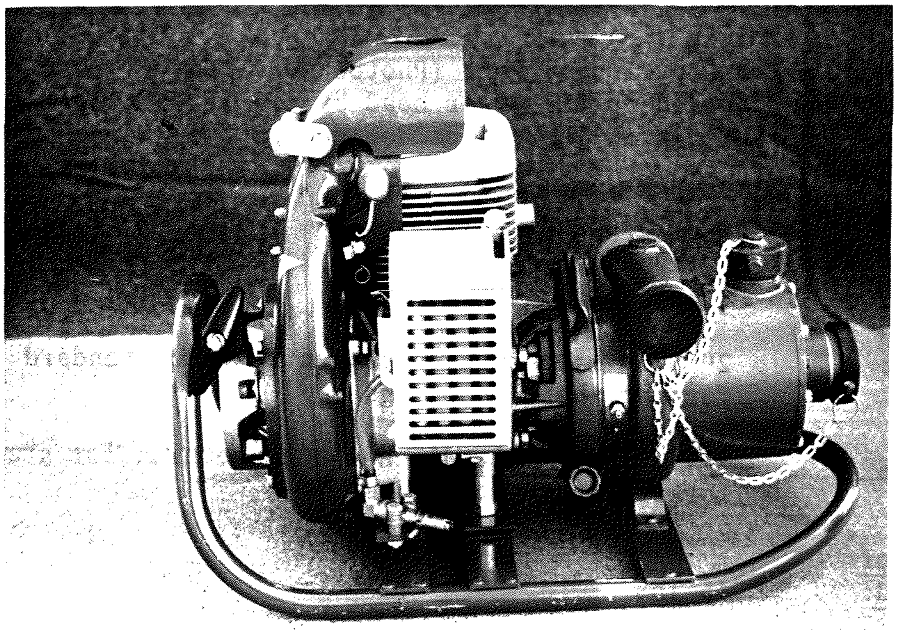


Photo No. 1. Fuel inlet and control side of Wajax Mark 3.

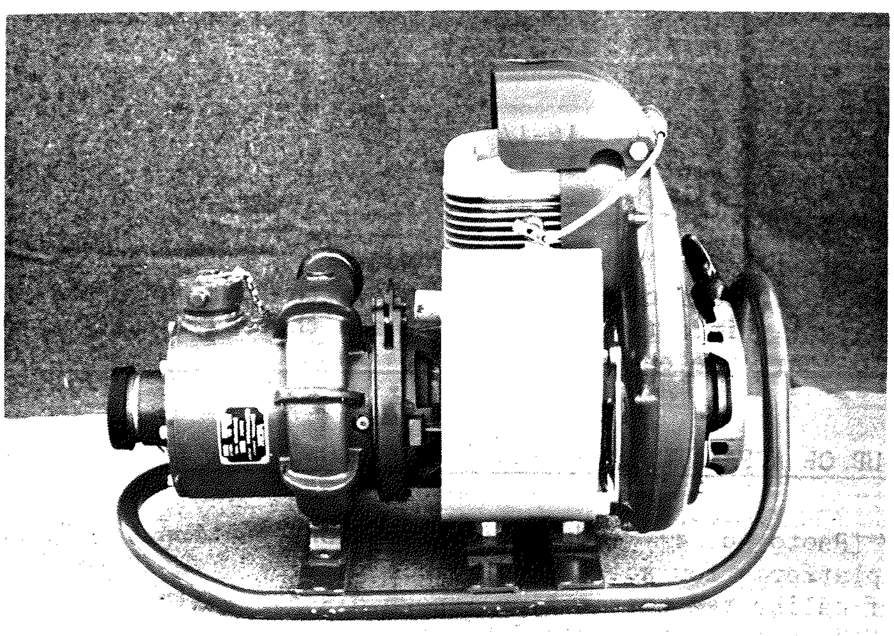


Photo No. 2. Exhaust side of Wajax Mark 3.

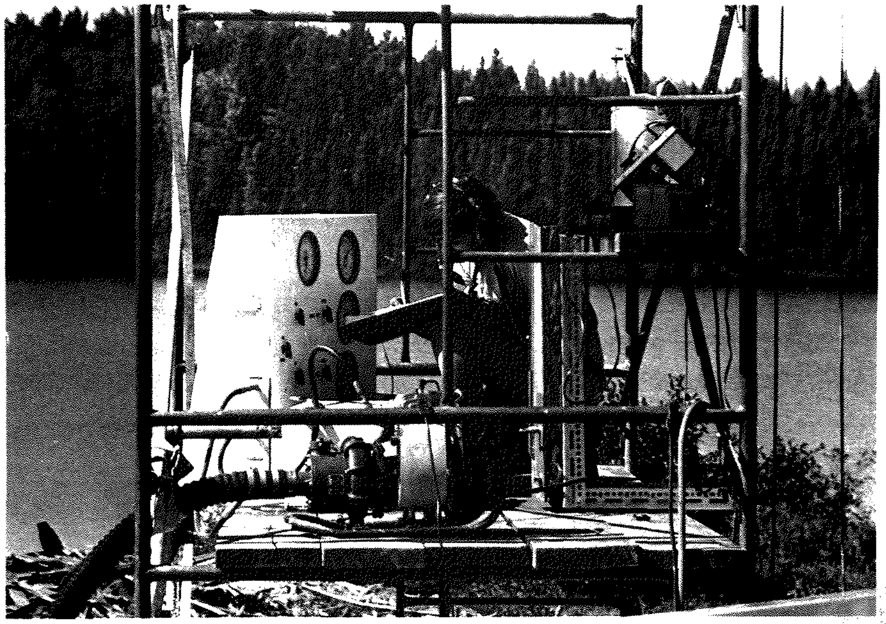


Photo No. 3. Set-up of apparatus on the tower.

Photo No. 4. Tower for suction lift test.

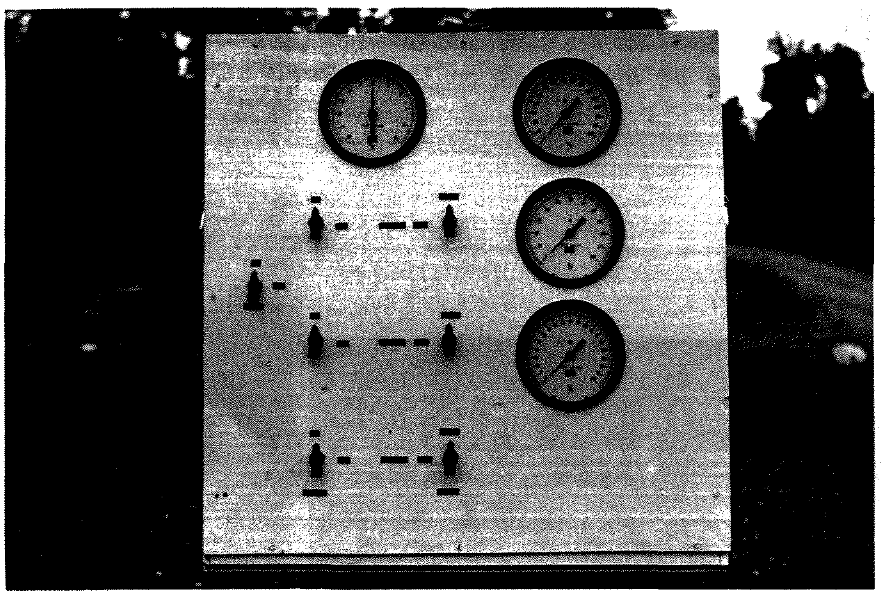


Photo No. 5. Gauge panel used on the tower.

consisting of 2 ball valves, enabled the operator to divert the flow from the nozzle to an overflow line (Photo No. 3). This allowed the operator to change nozzle tips without interrupting engine operation, after the 5-minute test interval was completed. During each 5-minute interval the discharge pressure and vacuum gauge readings were recorded along with the fuel consumption and the revolutions per minute of the engine.

ACTUAL PERFORMANCE AT VARIED SUCTION LIFTS

The characteristic performance curves for this Wajax Mark 3 at actual suction lifts of 0 ft, 15 ft, 20 ft, and 25 ft are plotted in Figures 1 and 2.

The performance tests at minimum static suction lift showed that the pumping unit would deliver a maximum of 78 gallons of water per minute at near free flow. The shut-off pressure was found to be 295 psi. It should be noted that the static suction lift up to 20 ft had little effect on the discharge flowrate at pressures above 160 psi whereas at pressures below 160 psi an increase in static suction lift lowered the discharge flowrate appreciably with the greatest loss occurring at the lower pressures. Maintaining a constant pressure of 40 psi, between 0 ft and 25 ft static suction lift the discharge flowrate dropped 50%, whereas, with the pressure remaining constant at 200 psi there was a drop of only 9%.

Note in Figure 2 that there was no decrease in pressure for either the 1/4 inch or 5/16 inch nozzle tips as the static suction lift was increased. However, a cut-off point was found at the 20-foot level for the 3/8 inch nozzle tip and at the 12-foot level for the 1/2 inch nozzle tip. An explanation of the cut-off point will be found in Information Report FF-X-33.

In Figure 5 the variation in engine speed (rpm), as the static suction lift increased, is shown for different pressures. The suction lift had a negligible effect on the engine speed at discharge pressures above 160 psi but for discharge pressures below this value the revolutions per minute increased with higher suction lifts. For example, with a static suction lift of 20 feet and a discharge pressure of 50 psi the engine speed was 18% higher than it was at 0 ft static suction lift. As illustrated in Figure 6 the fuel consumption at the 20 ft level is on the average 18% higher than at the 0 ft level for each corresponding pressure.

USE OF PUMP PERFORMANCE TABLES

The tables in Appendix B and Appendix C were developed using the pump equation as outlined in the first report of this series. These tables along with the performance curves will assist the pump operator or fire control staff in planning efficient pump system utilization.

The tables in Appendix B and Appendix C provide the operator with information on the performance he may expect from a Wajax Mark 3 Centrifugal Pump in good working condition, using either the 1/4", 5/16", 3/8" or 1/2" nozzle tip and operating at various static suction lifts and discharge heads, with varying lengths of 1-1/2" unlined linen hose. The pump capacity, static suction lift, static discharge head, friction loss and nozzle pressure all inter-react and the combined results under these different circumstances are given in the performance tables.

Most experienced operators know the limitations of their pumping units and therefore will not place them in a position where the required pressure and gallonage cannot be delivered. However, inexperienced operators may waste time setting up the pump system only to find that very little water is flowing from the nozzle.

Operators often assume that their pumping units are operating 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. By inserting a pressure gauge on the hose line at the pump discharge outlet the operator 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 warn him if the performance of the pumping unit was deteriorating. If the performance has dropped drastically he can refer to the trouble chart in the pump manual or if possible replace the unit.

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

1. static suction lift
2. static discharge head
3. length and type of hose

Example: It is required to pump water through 2,000 ft of unlined linen hose. The difference in elevation between the pump and the nozzle (discharge head) is 200 ft. The minimum pressure acceptable is 50 psi and the static suction lift is 15 ft. What nozzle should be used?

From Table 2B (Appendix B):

Nozzle Tip	Nozzle Pressure
1/2"	13
3/8"	46
5/16"	61
1/4"	100

It can readily be seen that the 1/4" and 5/16" nozzle tips will give the desired pressure whereas the 1/2" and 3/8" tips will not.

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 and flowrate the following rule of thumb values can be used.

Static Discharge Head

The static discharge head or back pressure exerted at the pump is 0.433 psi for every foot of elevation the discharge nozzle is above the pump. Conversely, if the discharge nozzle is below the pumping unit, the pump is aided .433 psi for each foot of drop. Therefore, this "forward pressure" is subtracted in the pump equation. For field calculations these values are usually rounded off to 0.5 psi for each foot of elevation.

Friction Loss

Approximate friction losses per 100 ft length of 1-1/2" unlined hose and 1-1/2" 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" unlined hose	2 psi	4 psi	6 psi	20 psi
1-1/2" lined hose	1 psi	2 psi	3 psi	10 psi

Example: It is required to pump through 2,000 ft of unlined linen hose using the 3/8" nozzle at a pressure of at least 50 psi. The discharge head is 100 ft and the suction lift is zero. What pump pressure is required and can the unit satisfy this requirement?

Rule of Thumb:

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

= *50* + *(6 psi per 100 ft length X 20 lengths)* + *50*

= *50* + *120* + *50*

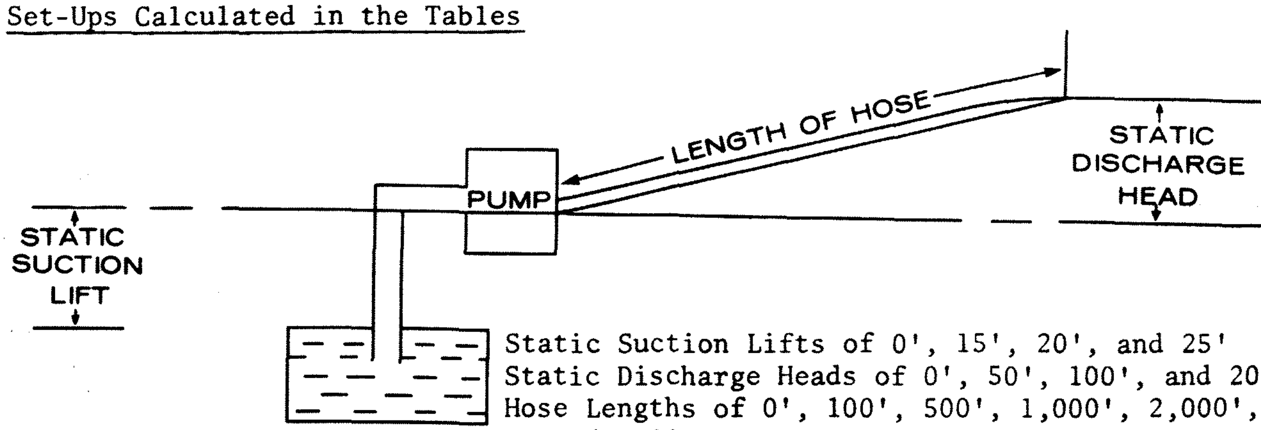
= *220 psi*

Therefore, using the rule of thumb values a pump pressure of at least 220 psi is required.

Using Tables 1B (Appendix B) and 5 (Appendix C) it is found that the true nozzle pressure would be 56 psi and the pump pressure would be 231 psi if the Wajax Mark 3 was used. Therefore, the Mark 3 will satisfy the requirement.

The preceding examples are only a few of the many uses of the tables or the rule of thumb procedure. The tables can also be used to determine what is the maximum length of hose possible and still have the desired nozzle pressure and flowrate. In a tandem system these tables along with the performance curves will aid in determining where each pump should be placed.

Set-Ups Calculated in the Tables



Static Suction Lifts 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 using the tables and show the effects static suction lift, length of hose-lay and static discharge head have on the amount of water delivered to a fire by a pump system. For comparison purposes between the preceding three factors 100% flowrate is taken as occurring with a static suction lift of 0 ft, a static discharge head of 0 ft, and the length of unlined linen hose being 1,000 ft using a 3/8 inch nozzle tip.

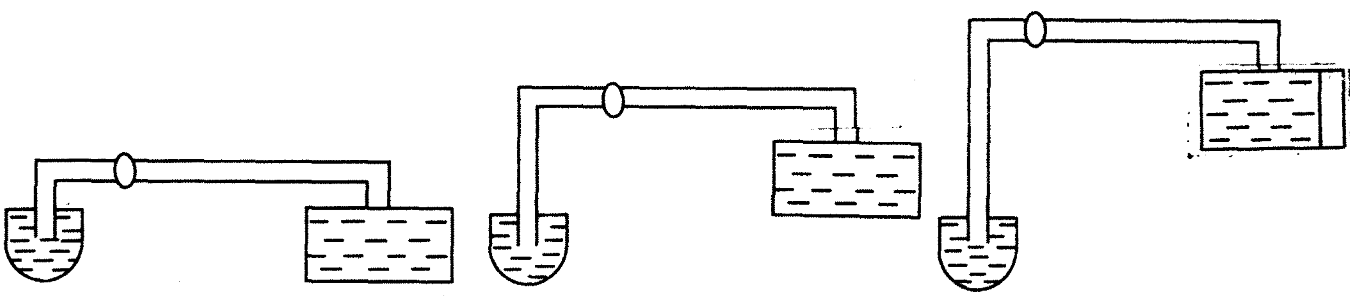
1. Static Suction Lift

Length of hose	1,000 ft
Static discharge head	0 ft
Nozzle tip	3/8 inch

Static suction lift increased from 0 ft to 25 ft

STATIC SUCTION LIFT

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



In the above example static suction lift had little effect on the performance of the pumping unit. With a static suction lift of 25 ft the flowrate was 2% less than it was at 0 ft static suction lift.

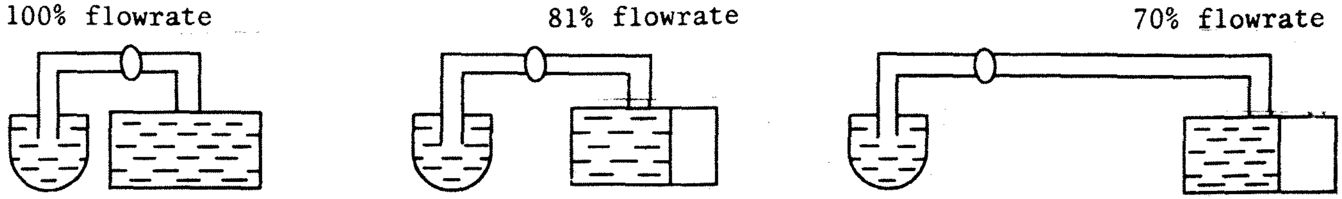
2. Length of Hose

Static discharge head	0 ft
Static suction lift	0 ft
Nozzle tip	3/8 inch

Length of hose increased from 1,000 ft to 3,000 ft

LENGTH OF HOSE

1,000 ft	2,000 ft	3,000 ft
100% flowrate	81% flowrate	70% flowrate



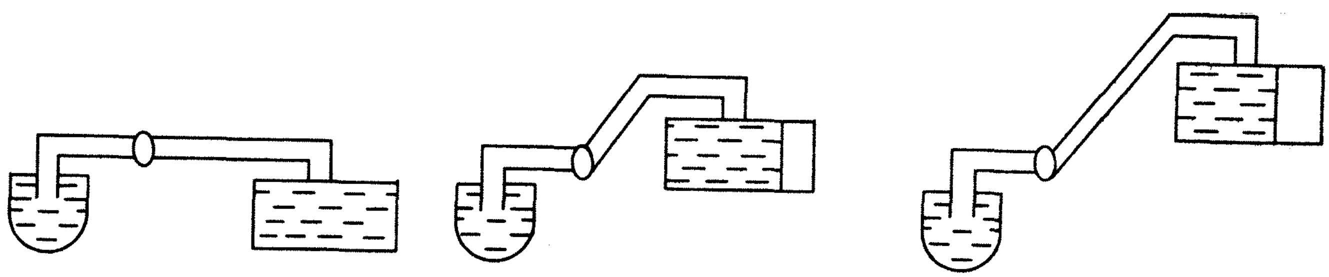
The length of unlined linen hose in the above example had a considerable effect on the flowrate. The flowrate through 3,000 ft of hose was 30% less than through 1,000 ft of hose. This represented a discharge flowrate drop of 9.2 gpm. As evident from the friction loss curve in Figure 4, unlined linen hose has a high friction loss. However, this friction loss is reduced considerably (approximately 1/2) by using lined hose. The tables were calculated for only the unlined linen hose since calculation for all types of hose would make this report very cumbersome for general use.

3. Static Discharge Head

Length of hose	1,000 ft
Static suction lift	0 ft
Nozzle tip	3/8 inch
Static discharge head increased from 0 ft to 200 ft	

STATIC DISCHARGE HEAD

0 ft	100 ft	200 ft
100% flowrate	90% flowrate	80% flowrate



The static discharge head in the preceding example shows a drop in flowrate of 10% for each 100 feet of discharge head. Between 0 feet and 100 feet the flowrate dropped 3 gpm with the same drop occurring between 100 feet and 200 feet. As previously mentioned this drop in flowrate is due to the back pressure exerted on the pump by gravity.

REFERENCES

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APPENDIX A

PERFORMANCE CURVES

Figure 1. Mark 3 Performance Characteristics at Different Static Suction Lifts

Figure 2. Pump Performance Using Different Nozzle Tips at Varied Static Suction Lifts

Figure 3. Nozzle Discharge Curves

Figure 4. Friction Loss in Unlined Linen Fire Hose

Figure 5. Effect of Static Suction Lift on Engine rpm

Figure 6. Effect of Static Suction Lift on Fuel Consumption

FIGURE 1
MARK 3 PERFORMANCE CHARACTERISTICS
AT DIFFERENT STATIC SUCTION LIFTS

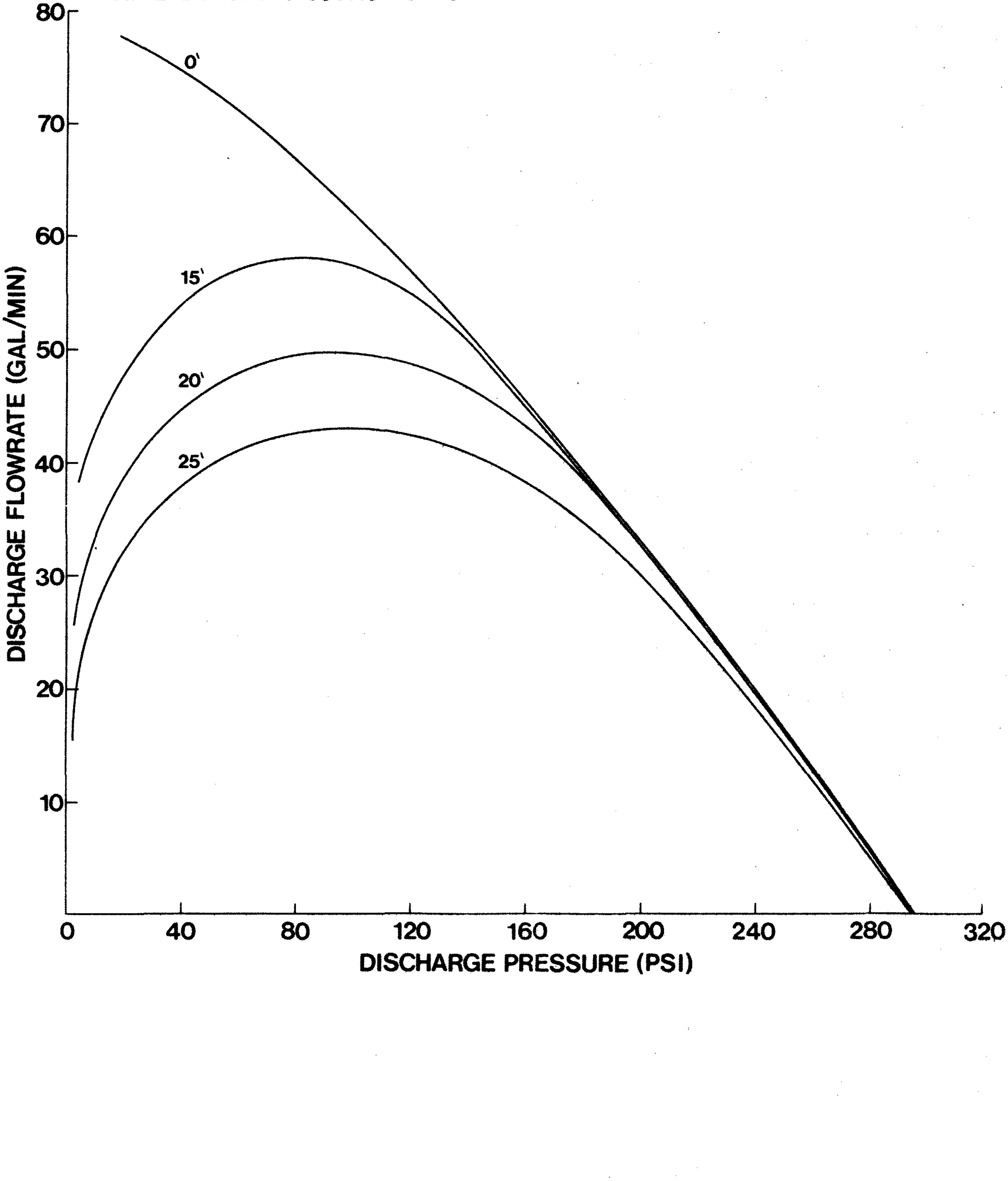


FIGURE 2
PUMP PERFORMANCE USING DIFFERENT NOZZLE TIPS AT VARIED STATIC SUCTION LIFTS

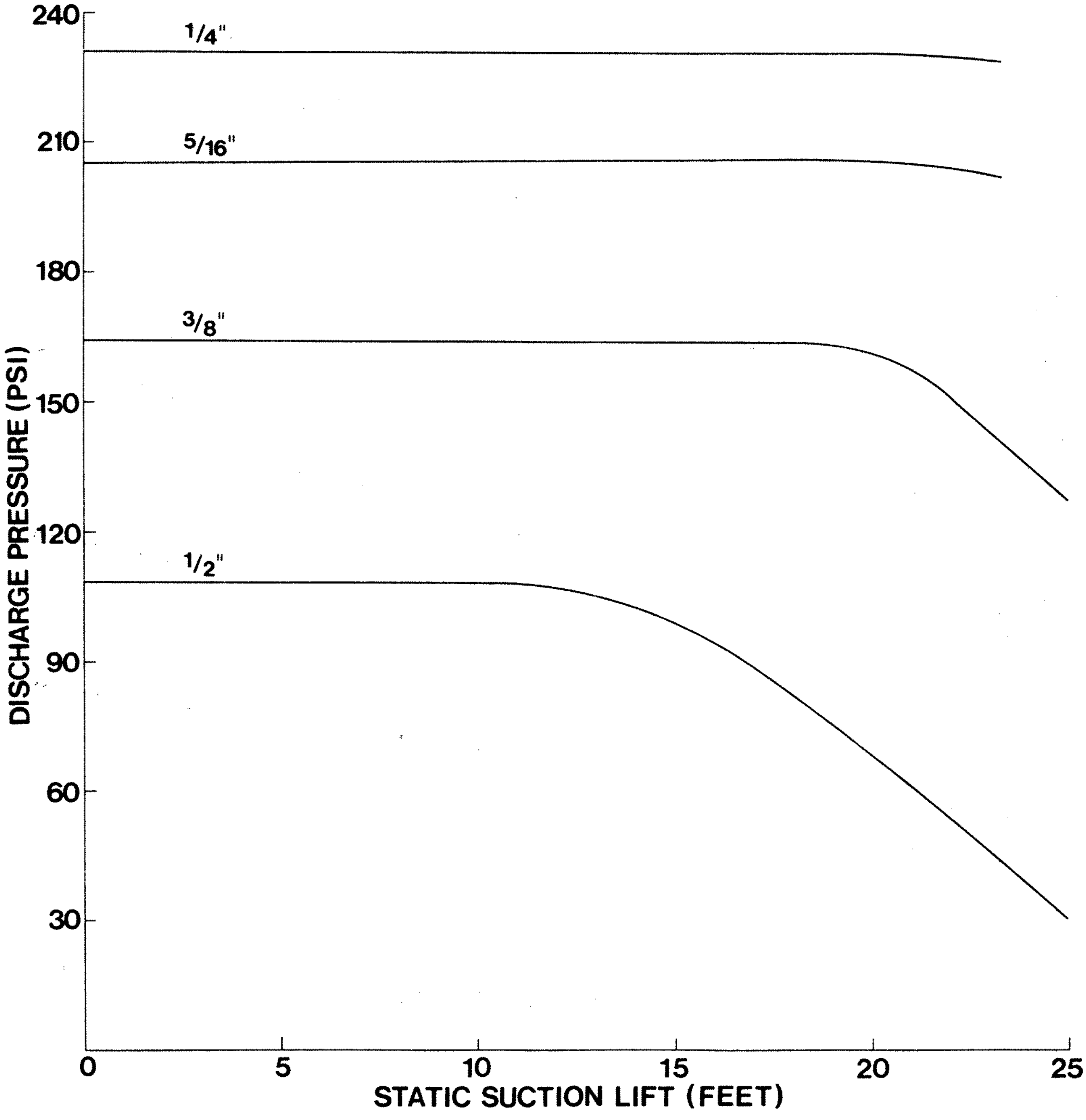


FIGURE 3
NOZZLE DISCHARGE CURVES

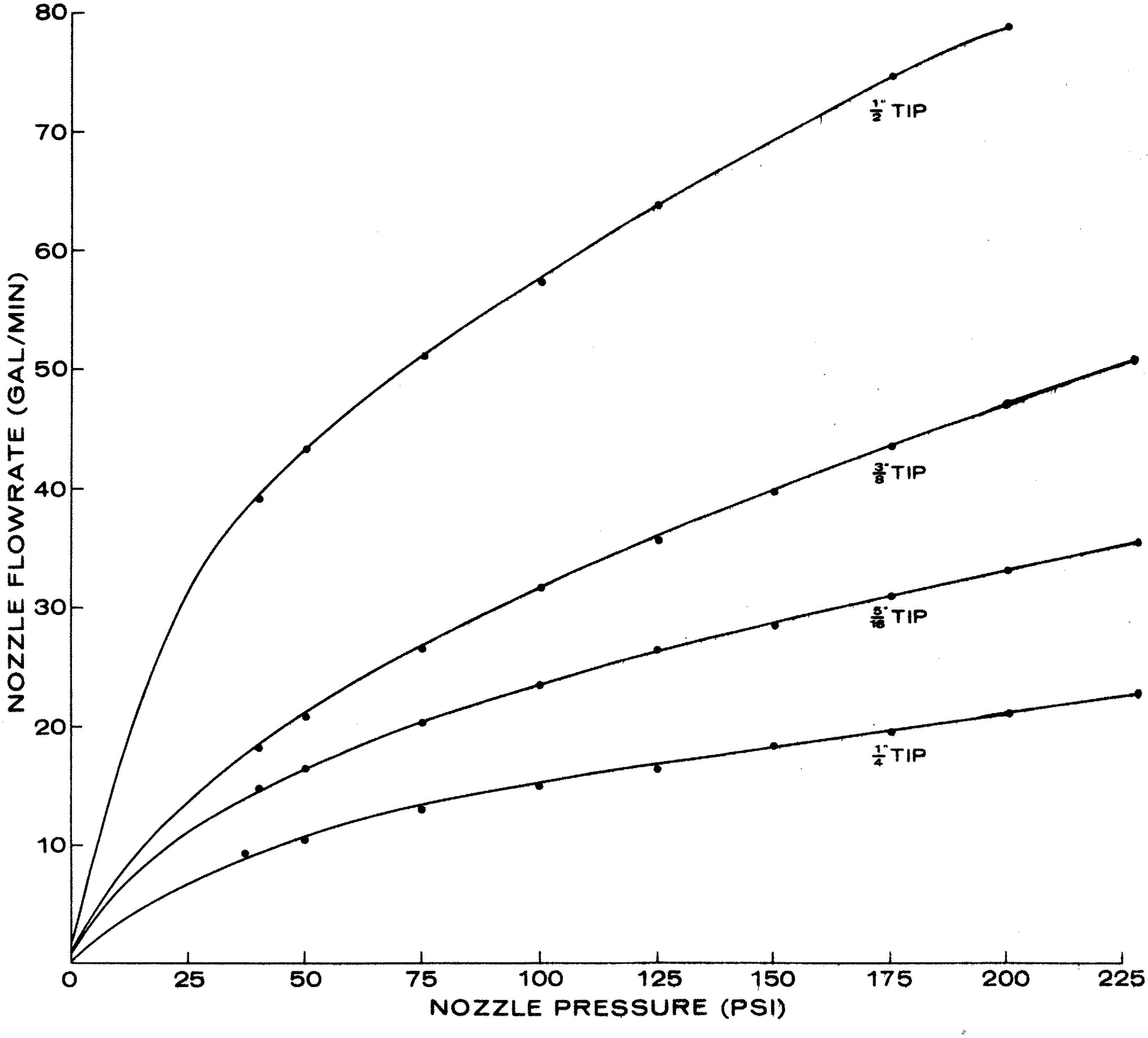


FIGURE 4
FRICTION LOSS IN UNLINED LINEN FIRE HOSE

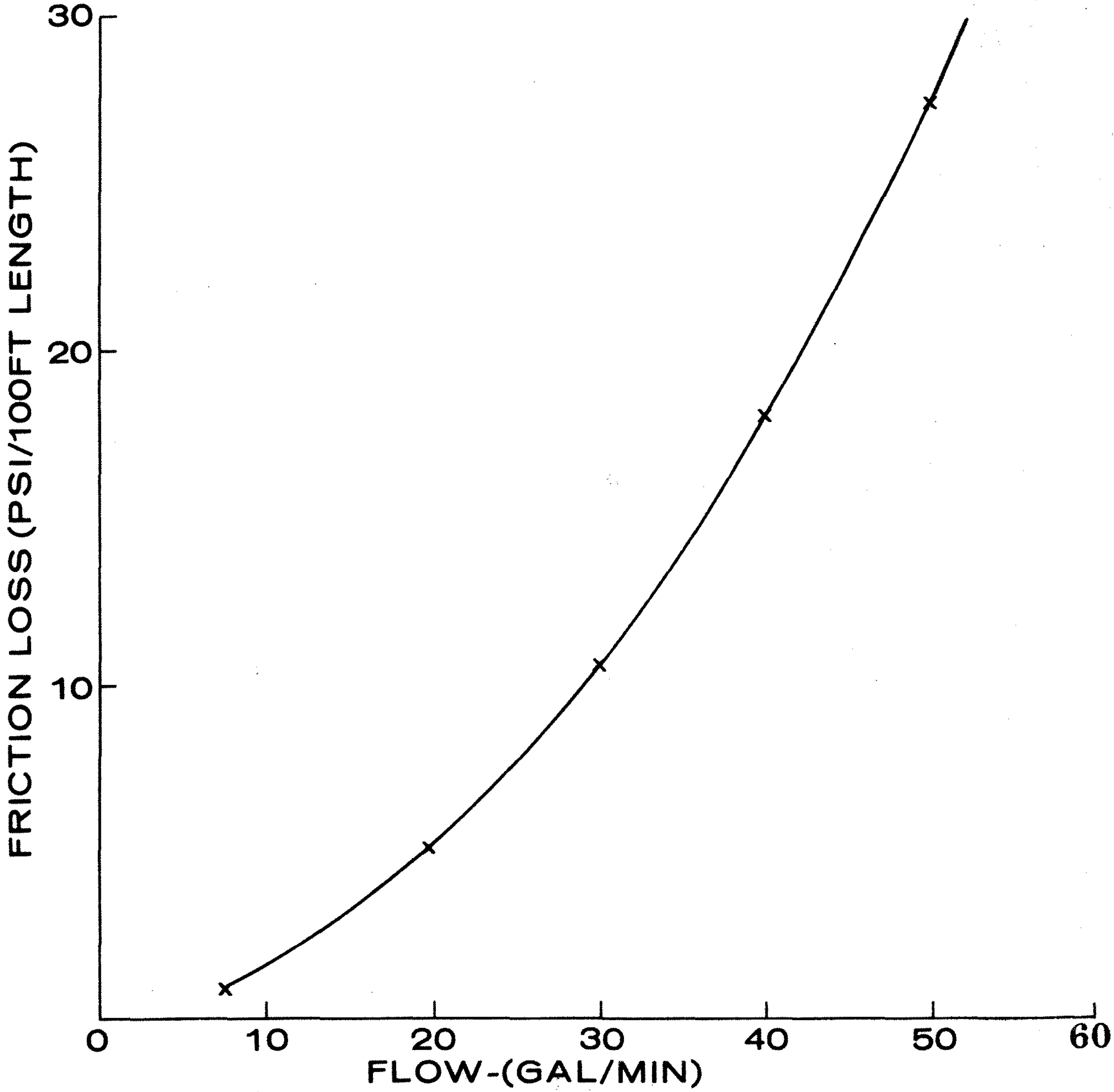


FIGURE 5
EFFECT OF STATIC SUCTION LIFT ON ENGINE RPM

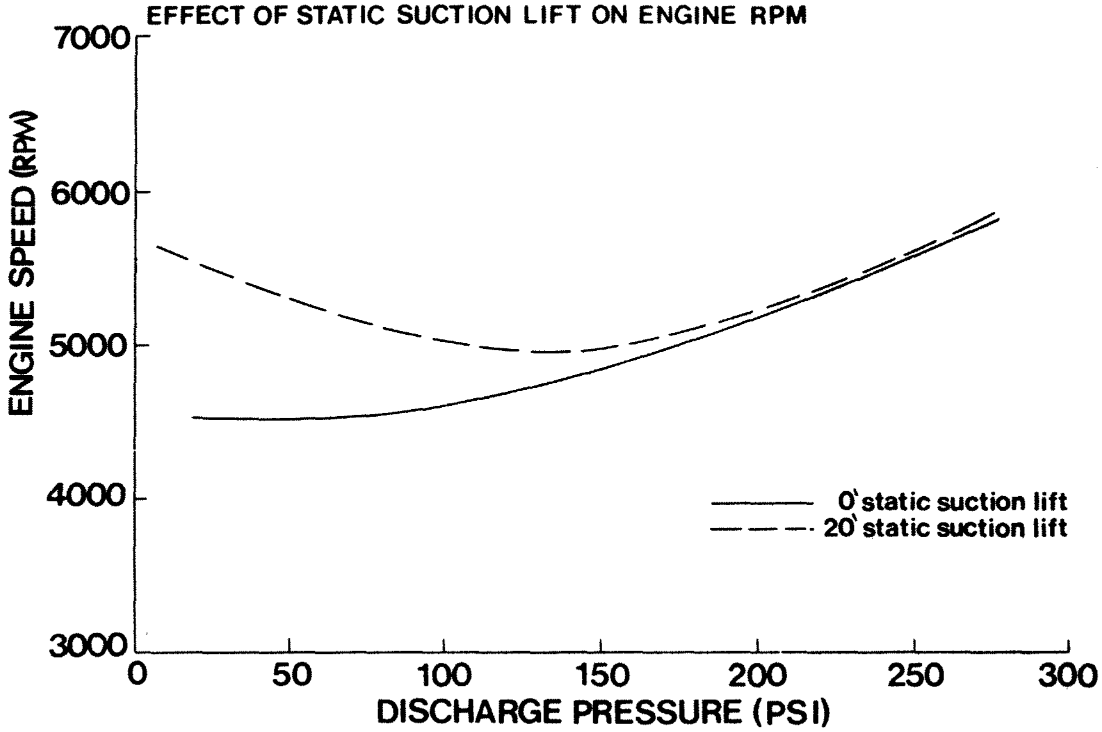
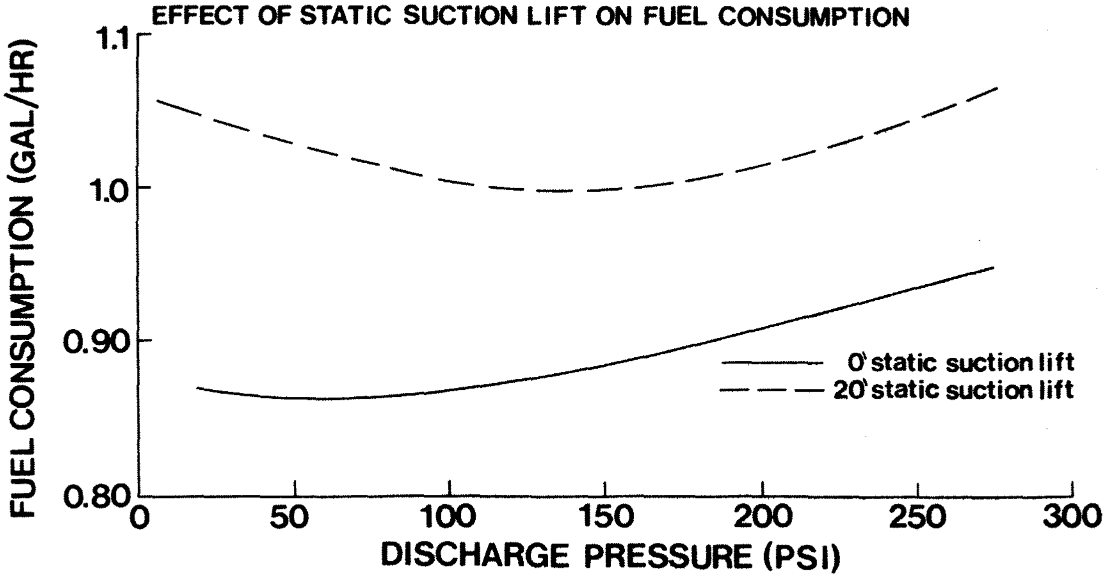


FIGURE 6
EFFECT OF STATIC SUCTION LIFT ON FUEL CONSUMPTION



APPENDIX B

CALCULATED TABLES

FOR

DISCHARGE FLOWRATE AND NOZZLE PRESSURE

Table 1A.	Discharge Flowrate	-	0 Feet Suction Lift
Table 1B.	Nozzle Pressure	-	0 Feet Suction Lift
Table 2A.	Discharge Flowrate	-	15 Feet Suction Lift
Table 2B.	Nozzle Pressure	-	15 Feet Suction Lift
Table 3A.	Discharge Flowrate	-	20 Feet Suction Lift
Table 3B.	Nozzle Pressure	-	20 Feet Suction Lift
Table 4A.	Discharge Flowrate	-	25 Feet Suction Lift
Table 4B.	Nozzle Pressure	-	25 Feet Suction Lift

TABLE 1A

DISCHARGE FLOWRATE - (GALLONS PER MINUTE)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
0 FEET - SUCTION LIFT						
1/2 - Inch Nozzle						
0	59.0	56.0	44.5	36.5	28.0	23.5
50	-	53.0	42.0	34.5	26.5	22.5
100	-	50.0	40.0	32.5	25.5	21.3
200	-	-	35.0	29.0	22.5	19.0
3/8 - Inch Nozzle						
0	42.0	40.7	35.0	30.7	25.0	21.5
50	-	38.5	33.5	29.0	23.3	20.5
100	-	36.7	31.7	27.5	22.5	19.5
200	-	-	28.0	24.5	20.0	17.3
5/16 - Inch Nozzle						
0	33.6	32.5	29.5	26.8	22.8	20.2
50	-	30.8	28.0	25.5	21.7	19.2
100	-	29.5	27.0	24.4	20.7	18.4
200	-	-	24.0	21.7	18.3	16.5
1/4 - Inch Nozzle						
0	22.6	22.5	21.5	20.5	18.5	17.0
50	-	21.5	20.5	19.5	17.2	16.0
100	-	20.7	19.5	18.5	17.0	15.5
200	-	-	17.5	16.7	15.3	14.0

TABLE 1B

NOZZLE PRESSURE - (POUNDS PER SQUARE INCH)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
0 FEET - SUCTION LIFT						
1/2 - Inch Nozzle						
0	105	93	53	34	20	13
50	-	81	45	30	18	12
100	-	69	41	27	16	11
200	-	-	31	22	13	9
3/8 - Inch Nozzle						
0	165	155	118	94	67	52
50	-	141	110	86	59	49
100	-	129	100	78	56	45
200	-	-	81	64	46	37
5/16 - Inch Nozzle						
0	205	193	157	128	93	73
50	-	172	141	116	84	68
100	-	157	130	107	77	62
200	-	-	104	84	61	49
1/4 - Inch Nozzle						
0	230	226	201	183	150	127
50	-	201	183	166	138	113
100	-	186	166	150	127	104
200	-	-	135	118	100	83

TABLE 2A

DISCHARGE FLOWRATE - (GALLONS PER MINUTE)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
15 FEET - SUCTION LIFT						
1/2 - Inch Nozzle						
0	58.0	55.5	44.0	36.0	27.5	23.5
50	-	52.5	41.5	34.5	26.5	22.5
100	-	51.0	40.0	32.5	25.5	21.3
200	-	-	35.5	29.0	22.5	19.0
3/8 - Inch Nozzle						
0	42.0	40.7	35.0	30.7	25.0	21.5
50	-	38.5	33.5	29.0	23.3	20.5
100	-	36.7	31.7	27.5	22.5	19.5
200	-	-	28.0	24.5	20.0	17.3
5/16 - Inch Nozzle						
0	33.6	32.3	29.3	26.8	22.9	20.2
50	-	30.8	28.0	25.5	21.7	19.2
100	-	29.6	27.0	24.4	20.7	18.4
200	-	-	24.0	21.7	18.3	16.5
1/4 - Inch Nozzle						
0	22.6	22.5	21.5	20.5	18.5	17.0
50	-	21.5	20.5	19.5	17.7	16.6
100	-	20.7	19.5	18.5	17.0	15.5
200	-	-	17.5	16.7	15.3	14.0

TABLE 2B

NOZZLE PRESSURE - (POUNDS PER SQUARE INCH)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
15 FEET - SUCTION LIFT						
1/2 - Inch Nozzle						
0	101	91	52	33	19	13
50	-	78	44	30	18	12
100	-	73	41	27	16	11
200	-	-	32	22	13	9
3/8 - Inch Nozzle						
0	163	155	118	94	67	52
50	-	141	110	86	59	49
100	-	129	100	78	56	45
200	-	-	81	64	46	37
5/16 - Inch Nozzle						
0	204	192	155	128	94	73
50	-	172	141	116	84	68
100	-	157	130	107	77	62
200	-	-	104	84	61	49
1/4 - Inch Nozzle						
0	231	226	201	183	150	127
50	-	201	183	166	138	113
100	-	186	166	150	127	104
200	-	-	135	118	100	83

TABLE 3A

DISCHARGE FLOWRATE - (GALLONS PER MINUTE)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
20 FEET - SUCTION LIFT						
1/2 - Inch Nozzle						
0	47.9	48.5	44.0	36.0	28.0	23.5
50	-	48.0	42.0	34.5	26.5	22.5
100	-	47.0	40.0	32.3	25.5	21.3
200	-	-	35.0	29.0	22.5	19.0
3/8 - Inch Nozzle						
0	42.4	40.5	35.0	30.5	24.7	21.5
50	-	38.0	33.0	28.7	22.7	20.3
100	-	36.5	31.5	27.3	22.3	19.3
200	-	-	27.7	24.0	19.8	17.3
5/16 - Inch Nozzle						
0	33.5	32.4	29.3	26.8	22.8	20.2
50	-	30.8	28.0	25.5	21.7	19.2
100	-	29.5	26.7	24.4	20.7	18.4
200	-	-	24.0	21.7	18.5	16.5
1/4 - Inch Nozzle						
0	22.4	22.2	21.5	20.5	18.5	17.0
50	-	21.5	20.5	19.5	17.7	16.6
100	-	20.7	19.5	18.5	17.0	15.5
200	-	-	17.5	16.7	15.3	14.0

TABLE 3B

NOZZLE PRESSURE - (POUNDS PER SQUARE INCH)

LENGTH OF HOSE (FEET)

20 FEET - SUCTION LIFT

HEAD (FEET)	0	100	500	1000	2000	3000
1/2 - Inch Nozzle						
0	63	69	50	33	20	13
50	-	62	45	30	18	12
100	-	59	41	26	16	11
200	-	-	31	22	13	9
3/8 - Inch Nozzle						
0	166	153	118	94	65	52
50	-	137	107	84	56	47
100	-	128	99	77	55	44
200	-	-	79	62	46	37
5/16 - Inch Nozzle						
0	203	189	155	128	93	73
50	-	172	141	116	84	68
100	-	157	127	107	77	62
200	-	-	104	84	62	49
1/4 - Inch Nozzle						
0	225	224	201	183	150	127
50	-	201	183	166	138	113
100	-	186	166	150	127	104
200	-	-	135	118	100	83

TABLE 4A

DISCHARGE FLOWRATE - (GALLONS PER MINUTE)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
			25 FEET - SUCTION LIFT			
			1/2 - Inch Nozzle			
0	39.6	41.0	40.5	35.0	27.5	23.0
50	-	42.0	40.0	34.0	26.0	22.5
100	-	43.0	38.0	32.0	25.0	21.0
200	-	-	34.0	28.0	22.0	18.5
			3/8 - Inch Nozzle			
0	37.3	38.3	34.5	30.0	24.5	21.2
50	-	36.7	32.7	28.3	23.5	20.3
100	-	35.0	31.0	27.0	22.3	19.3
200	-	-	27.2	24.0	19.8	17.0
			5/16 - Inch Nozzle			
0	33.2	31.5	29.0	26.6	22.6	20.0
50	-	30.5	27.8	25.3	21.5	19.0
100	-	29.0	26.5	24.2	20.6	18.3
200	-	-	23.7	21.5	18.3	16.3
			1/4 - Inch Nozzle			
0	22.3	22.1	21.5	20.3	18.3	16.8
50	-	21.3	20.5	19.5	17.5	16.5
100	-	20.7	19.5	18.5	16.8	15.5
200	-	-	17.5	16.7	15.3	14.0

TABLE 4B

NOZZLE PRESSURE - (POUNDS PER SQUARE INCH)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
25 FEET - SUCTION LIFT						
1/2 - Inch Nozzle						
0	38	43	42	31	19	13
50	-	45	41	29	17	12
100	-	48	37	26	15	10
200	-	-	29	20	12	9
3/8 - Inch Nozzle						
0	133	139	115	91	64	51
50	-	129	106	83	60	47
100	-	118	96	76	55	44
200	-	-	77	62	46	35
5/16 - Inch Nozzle						
0	190	179	152	126	92	72
50	-	168	138	115	83	66
100	-	152	125	105	76	61
200	-	-	101	83	61	48
1/4 - Inch Nozzle						
0	224	220	201	178	147	123
50	-	205	183	166	135	108
100	-	186	166	150	120	104
200	-	-	135	118	100	83

APPENDIX C

PRESSURE REQUIRED AT PUMP

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

TABLE 5

PRESSURE REQUIRED AT PUMP - (POUNDS PER SQUARE INCH)

LENGTH OF HOSE (FEET)

0 FEET - SUCTION LIFT

HEAD (FEET)	0	100	500	1000	2000	3000
			1/2 - Inch Nozzle			
0	105	127	163	189	216	229
50	-	134	167	195	218	235
100	-	140	177	206	223	237
200	-	-	189	213	233	242
			3/8 - Inch Nozzle			
0	165	174	191	209	227	235
50	-	180	200	212	228	239
100	-	188	205	217	231	241
200	-	-	216	227	240	244
			5/16 - Inch Nozzle			
0	205	206	211	218	229	235
50	-	207	212	221	230	239
100	-	211	219	227	234	243
200	-	-	227	237	239	249
			1/4 - Inch Nozzle			
0	230	233	234	239	244	247
50	-	234	235	240	246	252
100	-	235	236	241	250	253
200	-	-	243	244	252	256

TABLE 6

PRESSURE REQUIRED AT PUMP - (POUNDS PER SQUARE INCH)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
15 FEET - SUCTION LIFT						
1/2 - Inch Nozzle						
0	101	124	162	187	207	229
50	-	130	164	195	218	235
100	-	145	177	206	223	236
200	-	-	193	213	233	242
3/8 - Inch Nozzle						
0	163	174	191	209	227	235
50	-	180	200	212	228	239
100	-	188	205	217	231	241
200	-	-	216	227	240	244
5/16 - Inch Nozzle						
0	204	205	209	219	232	235
50	-	206	212	221	233	240
100	-	210	219	227	234	242
200	-	-	227	232	239	249
1/4 - Inch Nozzle						
0	231	232	234	239	244	247
50	-	233	235	240	246	252
100	-	235	236	241	250	253
200	-	-	243	244	252	256

TABLE 7

PRESSURE REQUIRED AT PUMP - (POUNDS PER SQUARE INCH)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
			20 FEET - SUCTION LIFT			
			1/2 - Inch Nozzle			
0	63	95	155	187	216	229
50	-	111	167	195	218	230
100	-	126	177	200	223	234
200	-	-	189	213	233	242
			3/8 - Inch Nozzle			
0	166	172	191	208	218	234
50	-	176	194	209	221	237
100	-	187	202	214	228	240
200	-	-	213	222	238	246
			5/16 - Inch Nozzle			
0	203	204	208	218	229	235
50	-	206	212	221	230	239
100	-	211	215	227	234	242
200	-	-	227	232	242	249
			1/4 - Inch Nozzle			
0	225	230	232	239	244	247
50	-	231	233	240	246	252
100	-	235	236	241	250	251
200	-	-	243	244	252	256

TABLE 8

PRESSURE REQUIRED AT PUMP - (POUNDS PER SQUARE INCH)

LENGTH OF HOSE (FEET)

HEAD (FEET)	0	100	500	1000	2000	3000
25 FEET - SUCTION LIFT						
1/2 - Inch Nozzle						
0	38	62	136	176	209	220
50	-	87	156	186	211	226
100	-	112	165	194	218	227
200	-	-	183	204	224	236
3/8 - Inch Nozzle						
0	133	156	187	203	218	231
50	-	167	192	205	226	234
100	-	176	198	211	228	237
200	-	-	210	222	238	241
5/16 - Inch Nozzle						
0	190	191	204	215	224	233
50	-	201	208	219	227	235
100	-	205	212	224	231	242
200	-	-	223	230	239	244
1/4 - Inch Nozzle						
0	224	226	232	233	239	240
50	-	233	234	241	242	244
100	-	235	236	242	243	249
200	-	-	243	244	252	255