Information Report FF-X-38

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PERFORMANCE OF
WAJAX MARK 26 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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TABLE OF CONTENTS

FOREWORD

This Information Report (FF-X-38) is the third 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.

This book is not intended for the pump operator's use in the field but it may be used for training purposes. If used for training, the two previous reports (FF-X-33 and FF-X-36) in this series 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.

PERFORMANCE OF WAJAX MARK 26 CENTRIFUGAL PUMP WITH RESPECT TO SUCTION LIFT, LENGTH OF HOSE AND DISCHARGE HEAD

D.G. Higgins

INTRODUCTION

Information on the combined effect of suction lift, length of hose and discharge head have on the pump performance has not been readily available. The Forest Fire Research Institute of the Canadian Forestry Service is conducting tests to acquire this useful information for various makes and models of portable forestry fire pumps. This report, dealing with the Wajax Mark 26, is the third in the series and closely adheres to the format followed in Information Reports FF-X-33 and FF-X-36.

During the summer of 1970 a test following the Canadian Government Specification Board's, "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 Canadian Committee on Forest Fire Control of the National Research Council (Ramsey et al, 1970). Data obtained during that test has been used for the preparation of this report.

Similar to the other reports in this series the following characteristics were investigated:

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

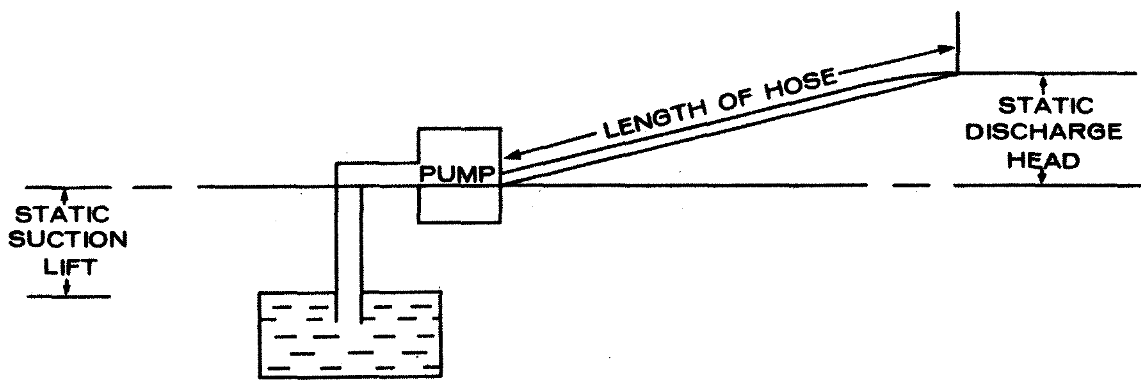
(2) Effect of increased static suction lift on the engine rpm and fuel consumption.

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

In order for a centrifugal pump to pump water there must be a negative pressure (vacuum) at the suction inlet. The initial vacuum is created by priming the pump in order to remove the air from the suction hose, thus forming a negative pressure difference between the pump inlet and the atmosphere. The positive atmospheric pressure on the water source will then force water up the suction hose. As the water enters the pump and the eye of the impeller, and is picked up by the vanes in the rotating impeller and discharged outward due to centrifugal force, a vacuum is created at the eye of the impeller. Due to this vacuum, water continues to flow into the impeller eye replacing the water being discharged. The pump must develop additional vacuum as the static suction lift is increased in order to overcome the friction loss in the suction hose, entrance loss at the combination foot valve and strainer and to provide the energy to accelerate the water. When the pump is in operation the vacuum will vary according to the static suction lift, volume of water being discharged, as well as the size and total length of the suction hose.

If the inlet pressure equals the atmospheric pressure cavitation will occur and a drastic drop in efficiency will result. Theoretically this would occur at a 33-foot lift but because of limitations imposed by pump design, suction hose friction loss and other practical considerations it will occur at lower levels.

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, this is referred to as a negative static suction lift. If the water supply is above the pump the water is aiding the pump thus there 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 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 pump head.

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

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-foot length.

E. Cut-off Point

As the static suction lift is increased a point will be reached where the pump efficiency drops off markedly. This is commonly called the "cut-off point". As illustrated in Figure 2, the smaller nozzle tips have a higher "cut-off point".

DESCRIPTION OF PUMPING UNIT

This engine-driven pump was designated by its manufacturer, Wajax Equipment Limited, as the Wajax Mark 26 Centrifugal. It is a portable forestry fire pump with the total unit weighing 37-1/2 lbs.

The Mark 26 is equipped with a convenient handle for carrying the unit over short distances (Photo No. 1). The carrying handle which is located above the cylinder also acts as a roll bar to protect the cylinder and spark plug from damage should the unit be inadvertently tipped over. A padded carrying pack is provided by the manufacturer for carrying the pump over a considerable distance.

PUMP	Type:	two-stage centrifugal
	Priming:	manual
	Suction:	2 in. NPSH male suction connection for standard CSA Forestry hose couplings*
	Discharge:	1-1/2 in. NPSH male discharge connection for standard CSA Forestry hose couplings
	Weight of Pump End:	10 lbs.
ENGINE	Type:	Rotax, one cylinder, two-cycle, 5 h.p., air-cooled
	Fuel:	1/2 pint of outboard motor oil to 1 gallon of regular automobile gasoline
	Fuel Consumption:	.55 Imperial gallons per hour** .66 U.S. gallons per hour

*Canadian Standards Association, Standard B89-1954.
**Performance tests on Wajax Mark 26, Ramsey et al, 1970.

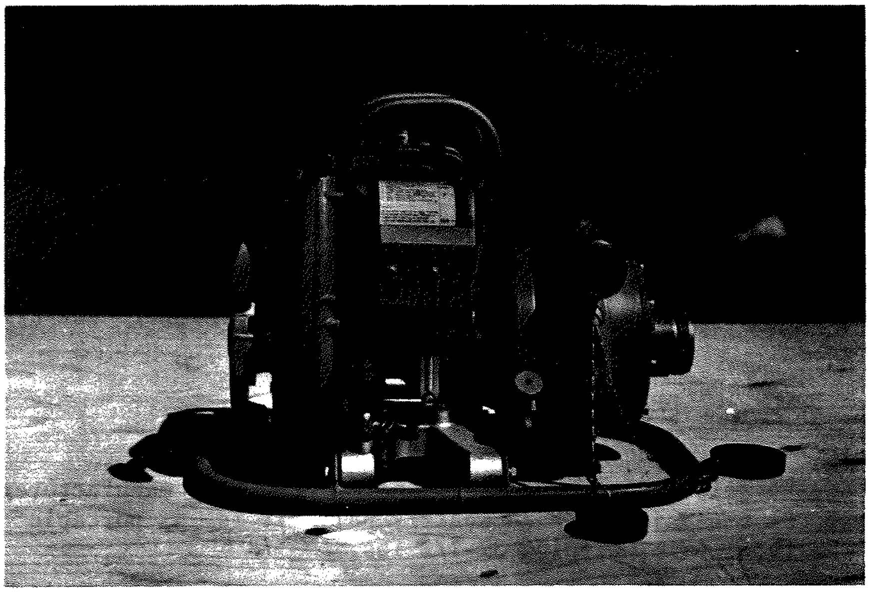


Photo No. 1. Fuel inlet and control side of Wajax Mark 26

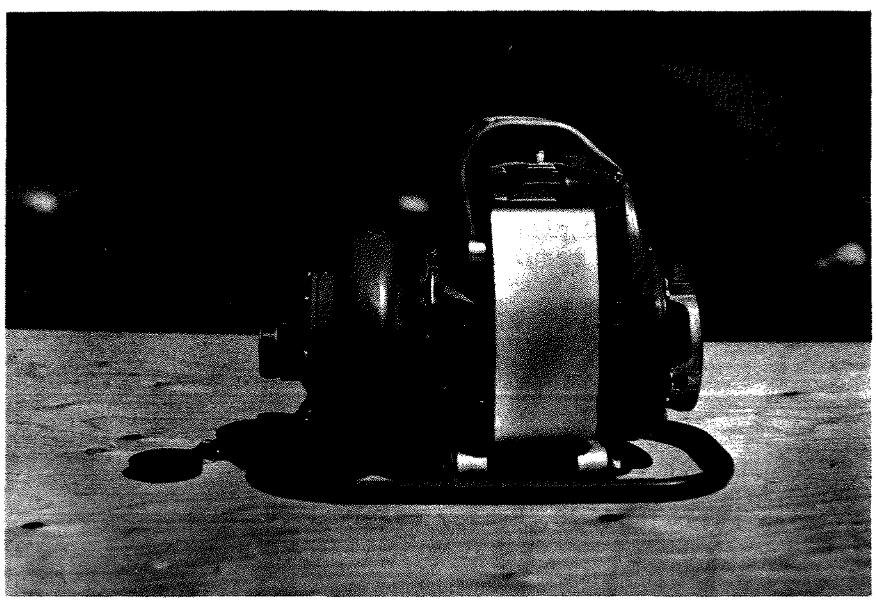


Photo No. 2. Exhaust side of Wajax Mark 26

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 feet 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" consisting of two 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 number of revolutions per minute of the engine.

ACTUAL PERFORMANCE AT VARIED SUCTION LIFTS

The characteristic performance curves for this Wajax Mark 26 at actual suction lifts of 0 feet, 15 feet, 20 feet, and 25 feet are plotted in Figures 1 and 2 (see Appendix).

The performance tests at minimum static suction lift showed that the pumping unit would deliver a maximum of 71 Imperial gallons per minute at near free flow. The discharge flowrate then decreased in a near linear relationship as the discharge pressure was increased until the shut-off pressure of 175 psi was reached.

Static suction lifts up to 20 feet had little effect on the discharge flowrate at pump pressures above 100 psi, whereas at pump pressures below 100 psi an increase in static suction lift lowered the discharge flowrate appreciably at each selected pressure. Maintaining a constant pressure of 25 psi between 0 feet and 25 feet static suction lift, the discharge flowrate dropped 52 per cent or 34 Imperial gallons per minute, whereas with the pressure remaining constant at 150 psi there was a drop of 14 per cent or 2 Imperial gallons per minute.

While operating with a static suction lift above zero it was found that the maximum flowrate developed was not at the free flow rate. The maximum discharge flowrate determined at 15 feet, 20 feet, and 25 feet static suction lift occurred at a pump pressure of approximately 50 psi as illustrated in Figure 1. Below this pressure the pump was unable to create sufficient vacuum for the potential pump flowrate.

In Figure 2 it is evident 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 to 25 feet. However, a cut-off point was found near the 15-foot level for the 3/8 inch and 1/2 inch nozzle tips. This is explained by the fact that with smaller diameter nozzles (1/4 and 5/16 inch) the flow is considerably lower, therefore the work required of the pumping unit is less. With the larger nozzle tips (3/8 and 1/2 inch) the flowrate is greater and the pump must develop a greater vacuum at the intake (as outlined in the Introduction), therefore, the cut-off point occurs at a lower static suction lift.

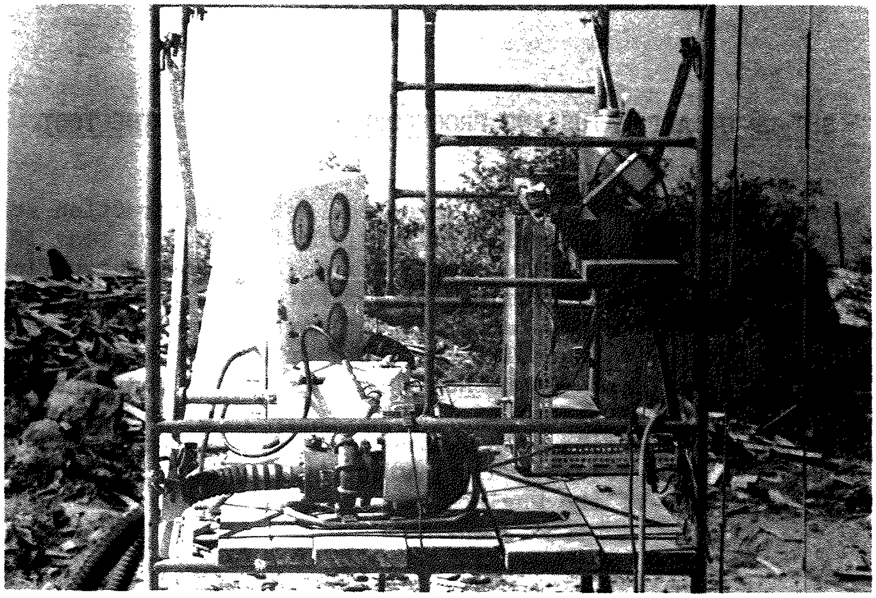


Photo No. 3. Set-up of apparatus on the tower.

Photo No. 4. Tower for suction lift test.

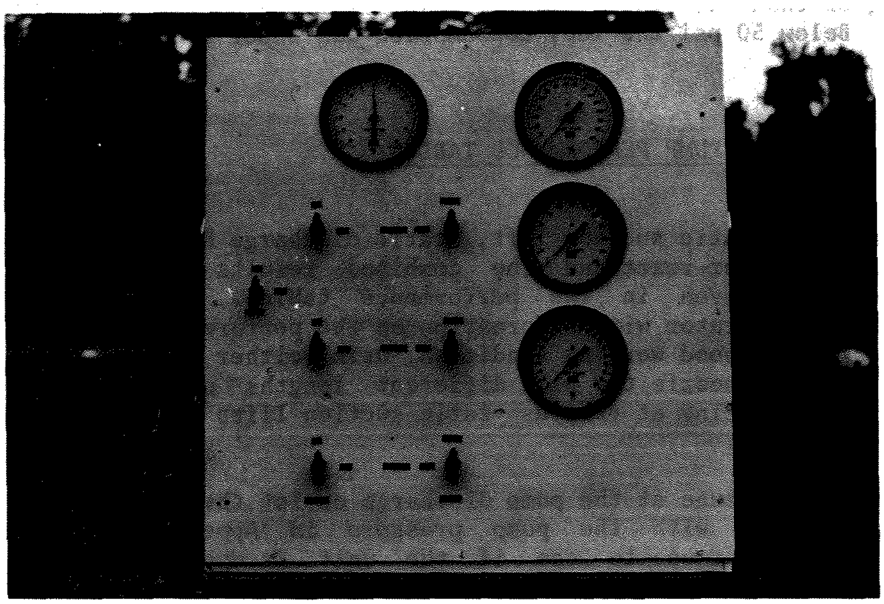


Photo No. 5. Gauge panel used on the tower.

The variation in engine speed (rpm) as the static suction lift was increased is shown for different pressures in Figure 5. The increased static suction lift had a negligible effect on the engine speed at discharge pressures above 100 psi whereas for discharge pressures below this value the revolutions per minute increased considerably. With a static suction lift of 20 feet and a discharge pressure of 25 psi the engine speed was 28 per cent higher than it was at 0 feet static suction lift.

In Figure 6 the fuel consumption at a static suction lift of 20 feet averaged 4 per cent higher than at the 0 foot level for each corresponding pressure above 50 psi. Below 50 psi the fuel consumption was 8 per cent higher at the 20 foot level.

USE OF PUMP PERFORMANCE TABLES

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. The tables in Appendix B and C provide the operator with information on the performance he may expect from a Wajax Mark 26 in good working condition, using either the 1/4 inch, 5/16 inch, 3/8 inch or 1/2 inch nozzle tip with different lengths of 1-1/2-inch unlined linen hose and operating at various static suction lifts and discharge heads.

By placing a pressure gauge at the pump discharge outlet the operator can compare the actual pump pressure with the pump pressure in Appendix C that pertains to his particular set-up to see if the unit is operating at top efficiency. If the performance has dropped drastically he can refer to the trouble chart in the pump manual or if possible replace the unit until there is time for an overhaul.

These tables can also be used when planning efficient pump system utilization as well as in conjunction with the graphs in Figure 1 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 discharge 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

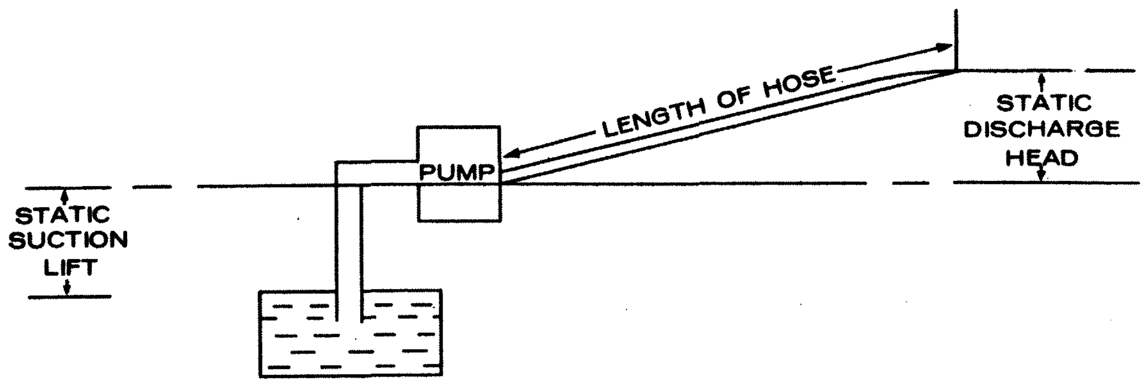
Example

1.	static suction lift	15 feet
2.	static discharge head	100 feet
3.	length of unlined hose line	2,000 feet

If a 1/2 inch nozzle is used, it will be seen from Table No's. 2A, 2B, and 6 that a pump pressure of 138 psi will give a nozzle pressure of 5.1 psi and a flowrate of 19.1 gpm. Flowrates for 3/8-, 5/16-, and 1/4-inch nozzles are given in the following table.

Nozzle Tip	Flowrate	Nozzle Pressure	Pump Pressure
1/2 inch	19.1	5.1	138
3/8 inch	16.6	29.3	144
5/16 inch	15.0	45.4	147
1/4 inch	12.3	66.0	153

SET-UPS CALCULATED IN THE TABLES



Static suction lifts of 0, 15, 20, and 25 feet
Static discharge heads of 0, 50, 100, and 200 feet
Hose lengths of 0, 100, 500, 1,000, 2,000, and 3,000 feet

HOW THE TABLES WERE CALCULATED

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

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

Before the pump equation can be used with a particular pumping unit a performance curve must be developed for each desired static suction lift. This is accomplished by determining the maximum volume produced by the pump at several discharge pressures for each static suction lift (see Set-Up and Procedure, p. 5). These maximum points can then be used for starting points when balancing the above equation by a trial and error method. This method of calculation is explained in Information Report FF-X-33. A computer program has been developed at the Forest Fire Research Institute to calculate the tables from the test data.

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

When using the pump equation (p. 9) 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 0.433 psi for every foot of elevation between the pump and the discharge nozzle. 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-foot length of 1-1/2-inch unlined linen hose and 1-1/2-inch latex lined hose, using different nozzle tip sizes are given in the Table below for a nozzle 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 inch	5/16 inch	3/8 inch	1/2 inch
1-1/2 inch unlined hose	2 psi	4 psi	6 psi	20 psi
1-1/2 inch lined hose	1 psi	2 psi	3 psi	10 psi

Example

It is required to pump through 1,000 feet of unlined linen hose using the 5/16 inch nozzle at a pressure of at least 50 psi. The discharge head is 100 feet 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* + *(4 psi per 100-foot length* X *10 lengths)* + *50*
= *50* + *40* + *50*
= *140 psi*

Therefore, using the rule of thumb values a pump pressure of at least 140 psi is required.

The Mark 26 has a maximum operating pressure of 175 psi but since a 5/16 inch nozzle at 50 psi delivers 17 gpm it is necessary to determine whether the pump can deliver this flowrate at 140 psi. From the performance curve (Fig. 1) it will be seen that this unit will deliver 19.5 gpm at 140 psi and therefore can be used. Using Tables 1B and 5 it is found that the true nozzle pressure would be

61.4 psi and the pump pressure would be 147 psi if the Mark 26 was used. Therefore, the Mark 26 will satisfy the requirement.

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.

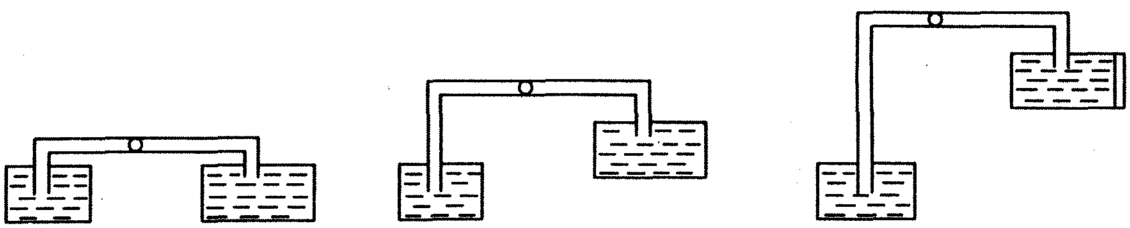
For comparison purposes between the preceding three factors 100 per cent flowrate is taken as occurring with a static suction lift of 0 feet, a static discharge head of 0 feet, and the length of unlined linen hose being 1,000 feet, while using a 3/8 inch nozzle tip.

1. Static Suction Lift

length of hose	1,000 feet
static discharge head	0 feet
nozzle tip	3/8 inch
static suction lift increased from 0 to 25 feet	

STATIC SUCTION LIFT

0 ft. **100% flowrate** | **15 ft.** **100% flowrate** | **25 ft.** **96% flowrate**



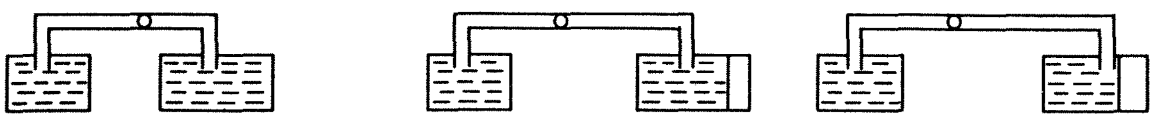
In the above example static suction lift had little effect on the performance of the pumping unit. With a static suction lift of 25 feet the flowrate was 4 per cent less than it was at 0 feet static suction lift. This represented a discharge flowrate drop of 1.2 Imperial gallons per minute.

2. Length of Hose

static discharge head	0 feet
static suction lift	0 feet
nozzle tip	3/8 inch

LENGTH OF HOSE

1000 ft. **100% flowrate** | **2000 ft.** **84% flowrate** | **3000 ft.** **72% flowrate**

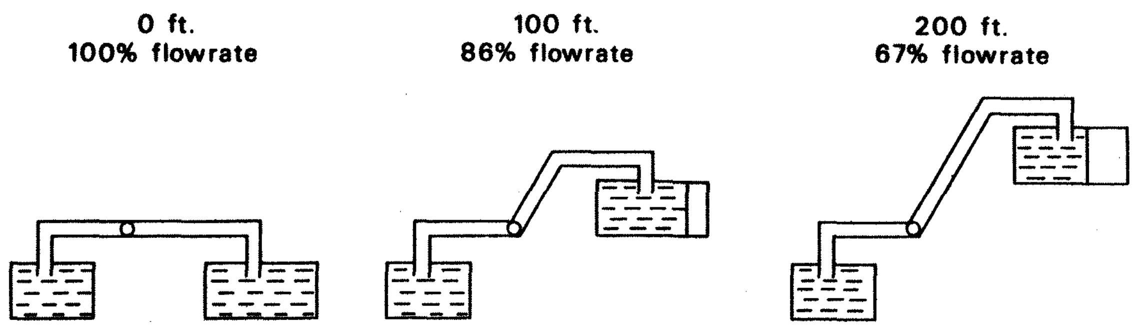


The length of unlined linen hose in the above example had a considerable effect on the flowrate. The flowrate through 3,000 feet of hose was 28 per cent less than through 1,000 feet of hose. This represented a discharge flowrate drop of 6.6 Imperial gallons per minute. As evident from the friction loss curve in Figure 4, unlined linen hose has approximately twice as much friction loss as does lined hose. It is quite apparent that the flowrate drop would be considerably less if lined hose was used. The Tables were calculated for only the 1-1/2-inch unlined linen hose since calculation for all types of hose would make this report very cumbersome.

3. Static Discharge Head

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

STATIC DISCHARGE HEAD



The static discharge head in the preceding example shows a drop in flowrate of 33 per cent between 0 feet and 200 feet static discharge head. This represented a discharge flowrate drop of 7.6 Imperial gallons per minute. As previously mentioned this drop in flowrate is due to the back pressure exerted on the pump by gravity.

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APPENDIX A

PERFORMANCE CURVES

FIGURE 1
MARK 26 PERFORMANCE CHARACTERISTICS AT DIFFERENT STATIC SUCTION LIFTS

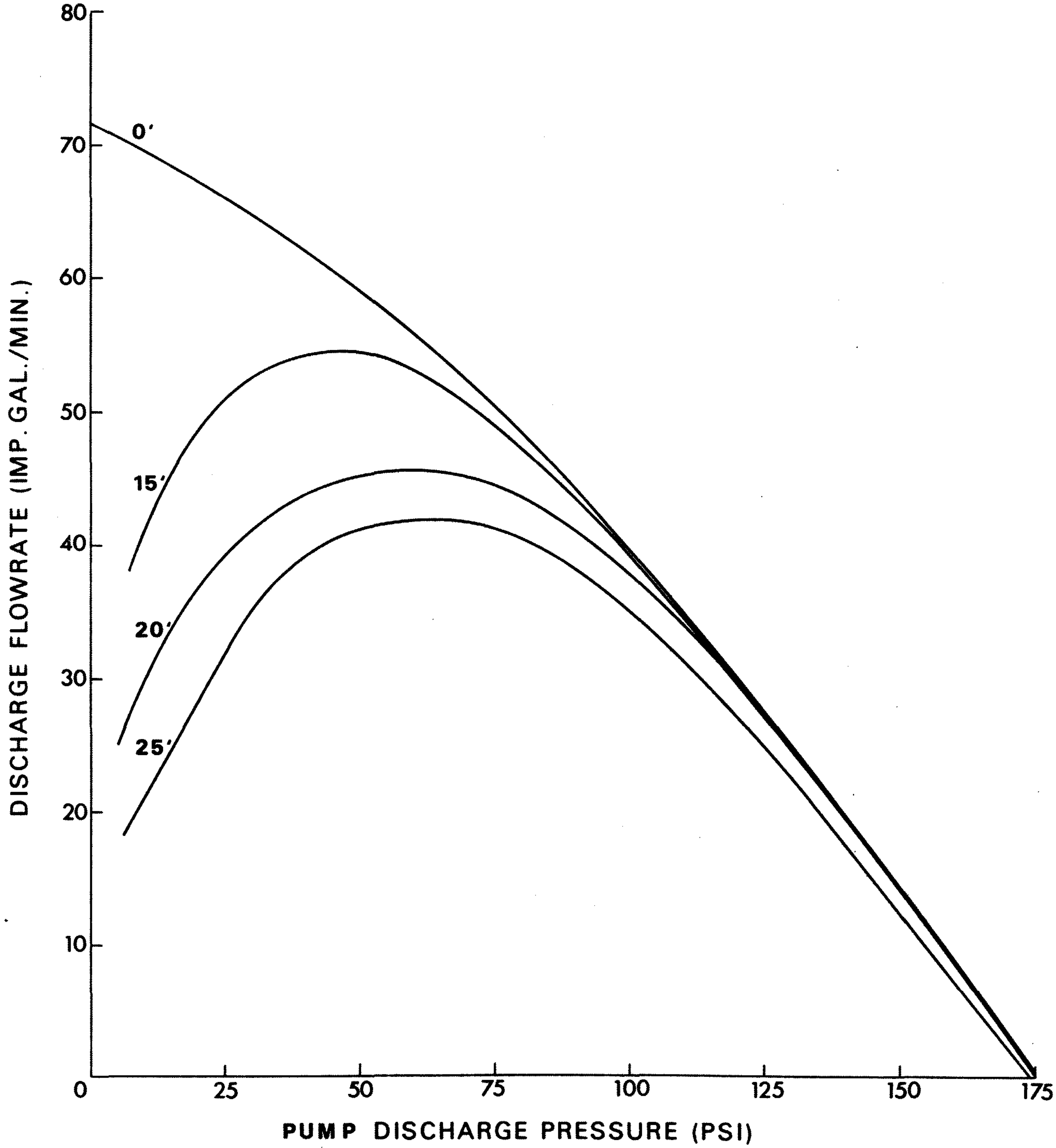


FIGURE 2

PUMP PERFORMANCE USING DIFFERENT NOZZLE TIPS AT VARIED STATIC SUCTION LIFTS

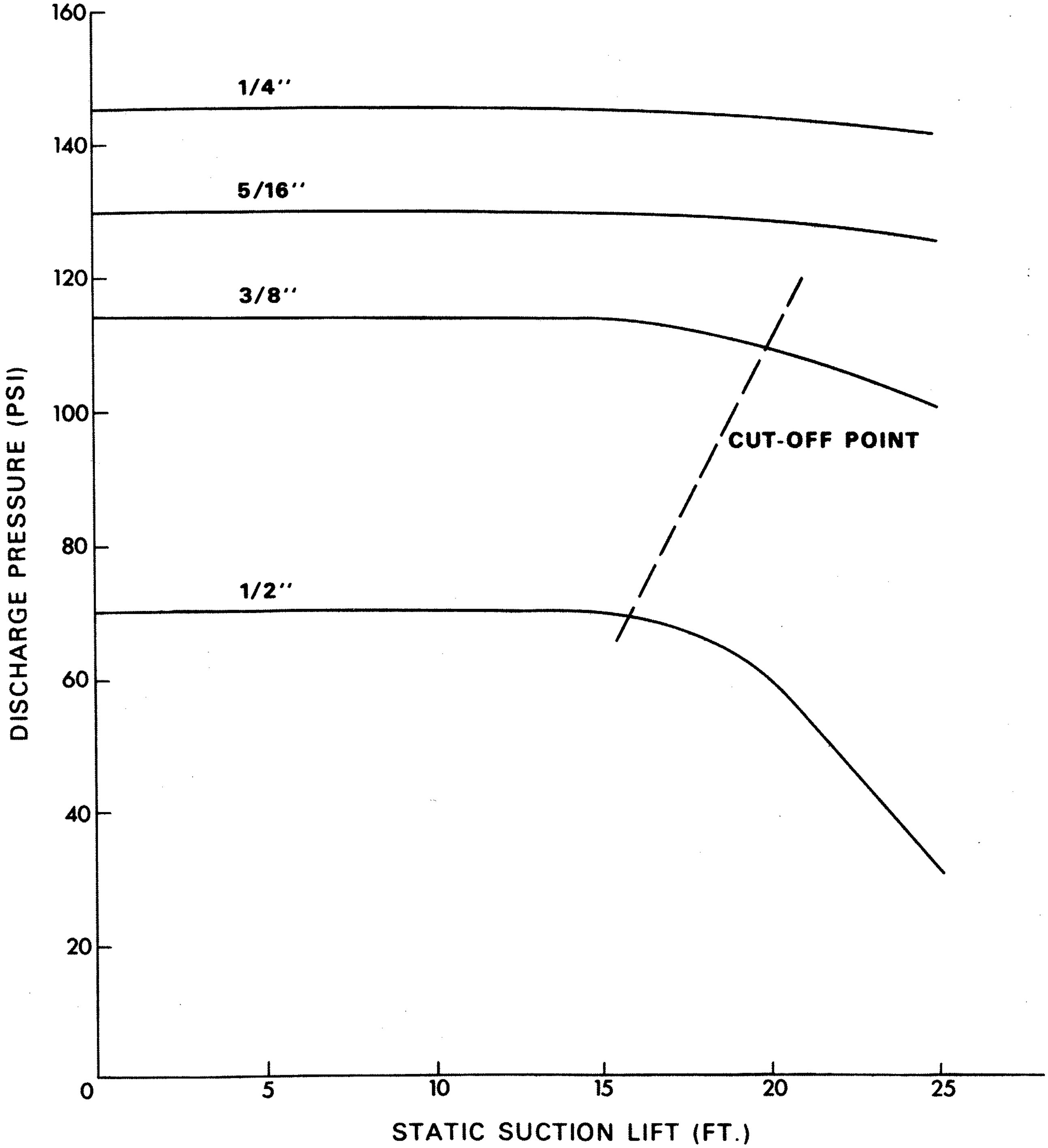


FIGURE 3
NOZZLE DISCHARGE CURVES

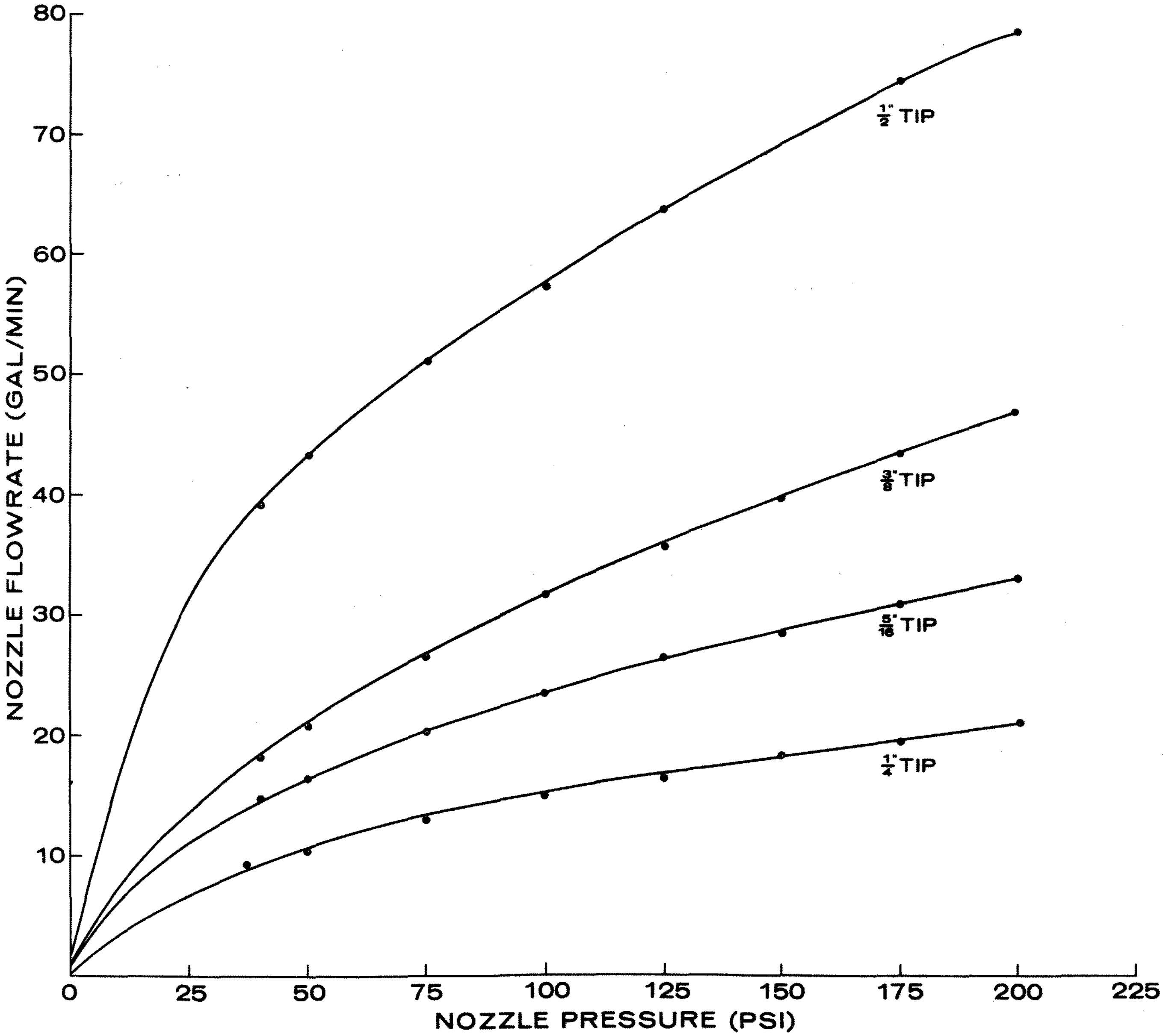


FIGURE 4
FRICTION LOSS IN UNLINED AND LATEX LINED HOSE

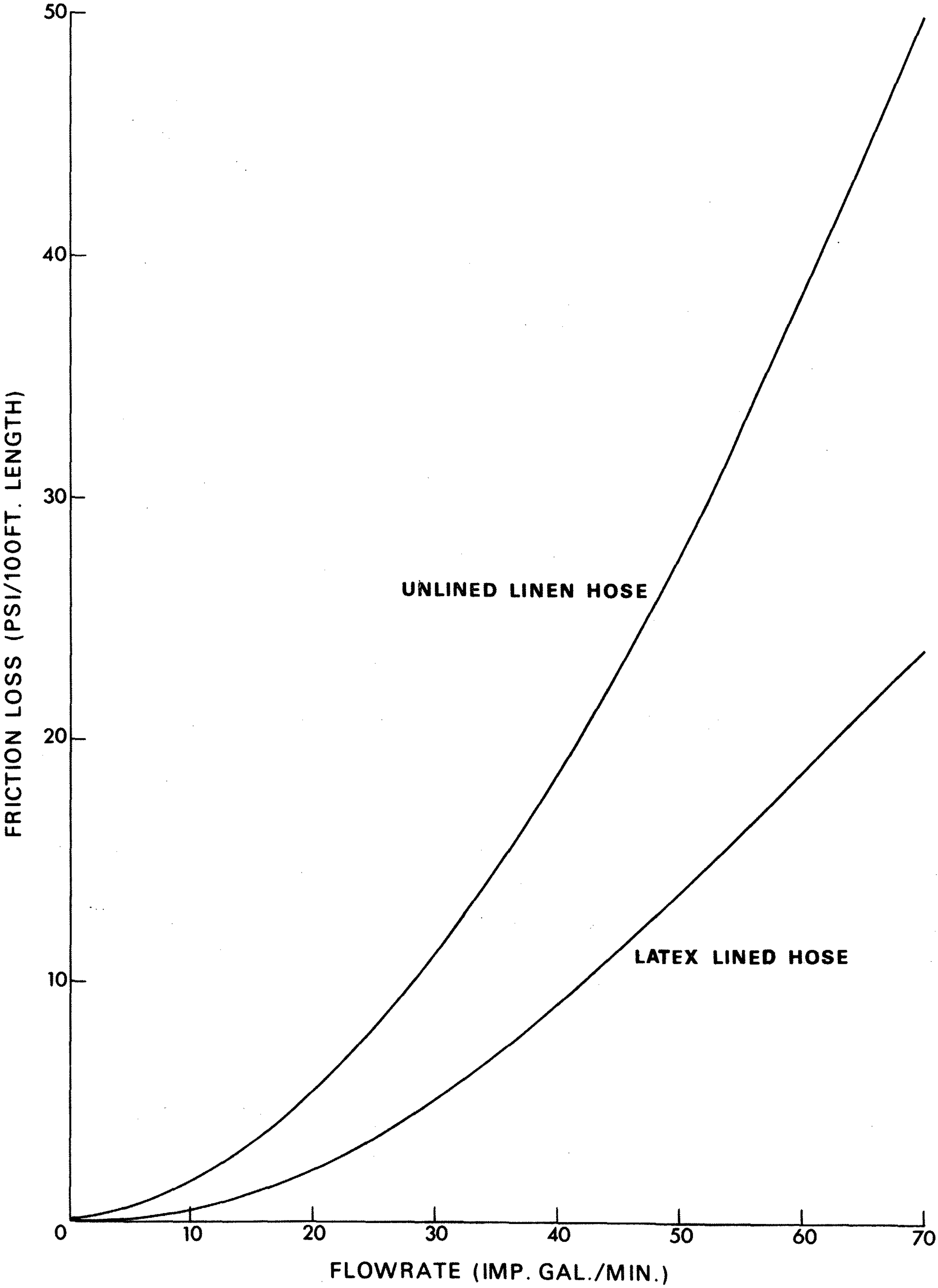


FIGURE 5
EFFECT OF STATIC SUCTION LIFT ON ENGINE RPM

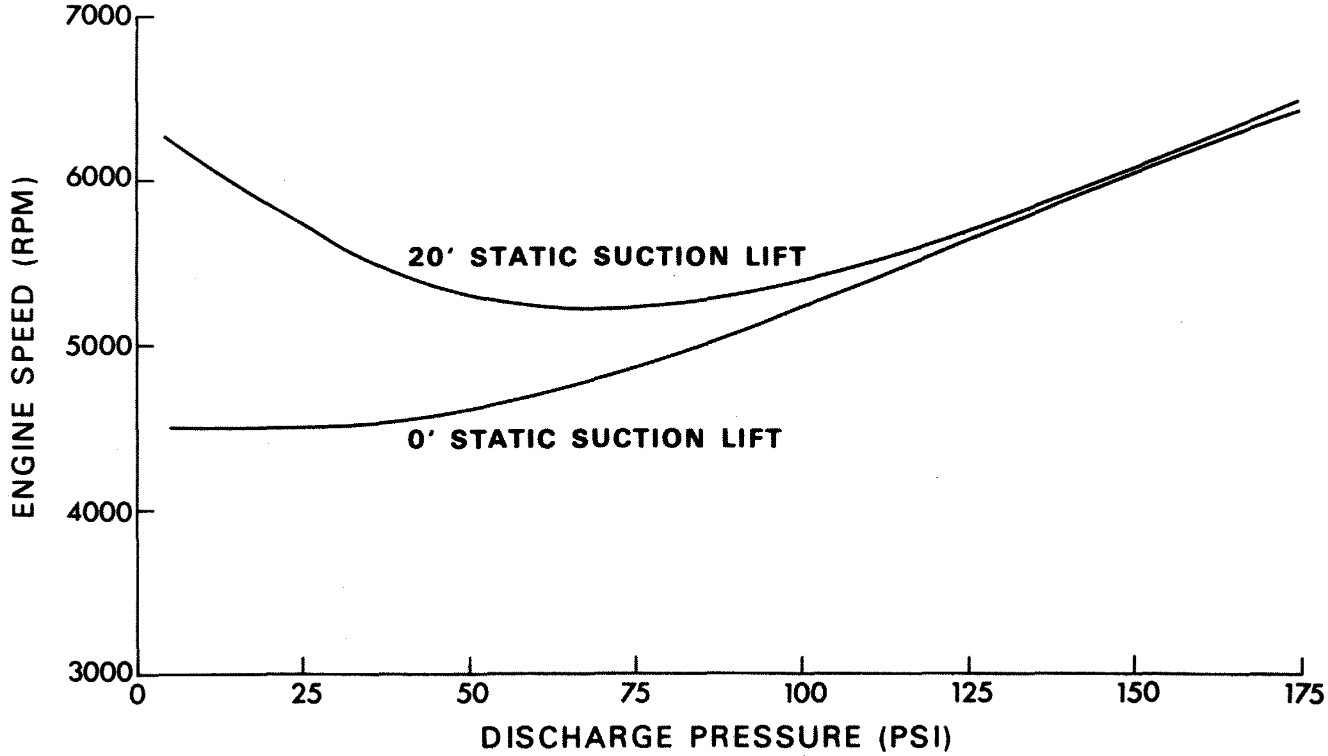
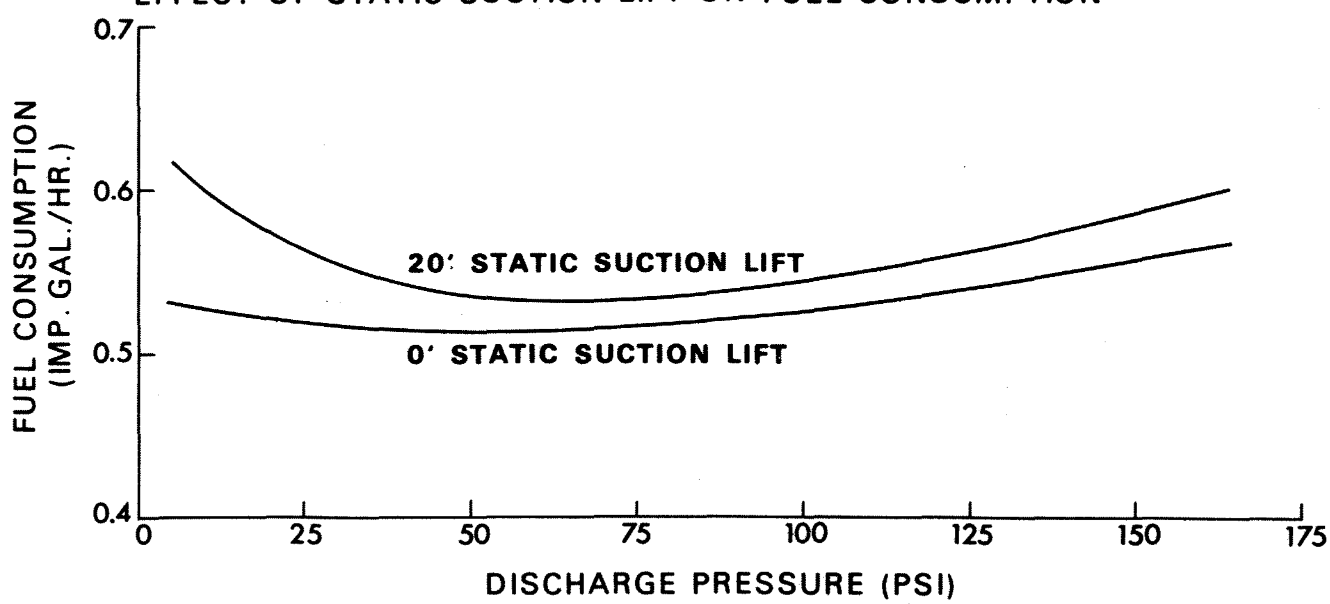


FIGURE 6
EFFECT OF STATIC SUCTION LIFT ON FUEL CONSUMPTION



APPENDIX B

CALCULATED TABLES
FOR
DISCHARGE FLOWRATE AND NOZZLE PRESSURE

TABLE 1A

DISCHARGE FLOWRATE - (GALLONS PER MINUTE)

LENGTH OF UNLINED LINEN HOSE (FEET)

Head (Feet)	0	100	500	1,000	2,000	3,000
0 FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	50.2	46.1	36.5	29.2	22.4	18.7
50	-	42.6	33.2	26.9	20.6	17.3
100	-	38.9	30.2	24.7	18.9	15.7
200	-	-	23.7	19.5	14.4	12.0
3/8-Inch Nozzle						
0	35.2	30.9	26.6	23.2	19.5	16.6
50	-	28.3	24.8	21.9	17.7	15.5
100	-	25.9	22.4	19.9	16.4	13.8
200	-	-	18.0	15.6	12.9	11.4
5/16- Inch Nozzle						
0	25.9	25.1	22.6	21.0	17.7	15.4
50	-	24.2	21.2	19.4	16.3	14.0
100	-	21.7	19.2	17.1	14.7	13.8
200	-	-	14.8	13.0	10.9	9.9
1/4-Inch Nozzle						
0	20.6	17.7	17.3	16.1	15.2	12.7
50	-	17.2	15.4	14.9	13.1	12.4
100	-	15.4	14.2	13.8	12.3	11.4
200	-	-	12.0	10.5	9.9	8.8

TABLE 1B

NOZZLE PRESSURE - (POUNDS PER SQUARE INCH)

LENGTH OF UNLINED LINEN HOSE (FEET)

Head (Feet)	0	100	500	1,000	2,000	3,000
			0 FEET - SUCTION LIFT			
			1/2-Inch Nozzle			
0	69.0	59.8	32.0	18.8	8.8	5.1
50	-	50.6	26.5	15.2	7.1	4.0
100	-	40.6	21.1	11.8	5.3	3.0
200	-	-	11.4	5.7	2.6	1.4
			3/8-Inch Nozzle			
0	113.0	107.3	82.7	63.8	42.4	31.9
50	-	93.0	70.6	53.7	36.8	27.2
100	-	78.2	60.1	45.3	30.4	23.0
200	-	-	36.1	28.3	18.9	13.9
			5/16-Inch Nozzle			
0	120.0	119.5	100.1	80.5	60.7	49.9
50	-	103.2	86.2	70.3	53.5	44.5
100	-	88.3	73.9	61.4	46.6	39.0
200	-	-	48.6	42.1	33.5	28.1
			1/4-Inch Nozzle			
0	145.0	140.7	125.3	112.2	90.6	77.4
50	-	120.9	110.9	96.2	80.0	66.2
100	-	102.8	93.8	81.8	67.1	56.6
200	-	-	59.7	55.1	43.5	37.6

TABLE 2A

DISCHARGE FLOWRATE - (GALLONS PER MINUTE)

LENGTH OF UNLINED LINEN HOSE (FEET)

Head (Feet)	0	100	500	1,000	2,000	3,000
15-FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	50.6	45.6	36.2	28.7	22.5	18.9
50	-	42.6	33.4	27.0	19.8	17.2
100	-	39.1	30.4	24.6	19.1	15.9
200	-	-	22.6	18.0	14.5	12.6
3/8-Inch Nozzle						
0	35.3	30.2	25.7	23.8	19.1	15.7
50	-	27.5	24.5	21.8	16.8	15.3
100	-	26.0	21.5	20.0	16.6	13.3
200	-	-	16.7	15.0	13.4	11.4
5/16-Inch Nozzle						
0	27.0	24.8	22.3	20.4	16.7	14.9
50	-	22.9	20.7	19.6	16.6	13.7
100	-	20.8	18.6	17.6	15.0	12.8
200	-	-	15.2	13.5	10.3	9.6
1/4-Inch Nozzle						
0	20.6	18.3	15.9	16.2	14.6	12.9
50	-	16.8	15.0	14.9	13.8	12.2
100	-	15.3	14.0	13.3	12.3	11.2
200	-	-	12.2	10.8	9.5	8.8

TABLE 2B

NOZZLE PRESSURE - (POUNDS PER SQUARE INCH)

LENGTH OF UNLINED LINEN HOSE (FEET)

Head (Feet)	0	100	500	1,000	2,000	3,000
			15' FEET - SUCTION LIFT			
			1/2-Inch Nozzle			
0	70.0	60.4	31.6	18.5	8.5	4.9
50	-	49.4	25.7	14.6	6.8	3.8
100	-	39.0	20.0	11.2	5.1	2.8
200	-	-	10.4	5.8	5.0	1.2
			3/8-Inch Nozzle			
0	114.0	105.4	81.0	61.0	41.6	31.5
50	-	90.6	68.4	52.3	36.2	26.5
100	-	73.8	58.0	43.4	29.3	22.5
200	-	-	36.1	27.5	17.9	13.7
			5/16-Inch Nozzle			
0	130.0	118.8	97.5	79.4	60.3	48.8
50	-	102.1	83.9	68.2	52.2	43.9
100	-	86.0	71.3	58.4	45.4	38.4
200	-	-	45.9	35.0	33.4	27.7
			1/4-Inch Nozzle			
0	145.0	136.0	125.3	109.4	89.4	76.9
50	-	118.0	108.2	95.0	77.2	65.0
100	-	100.2	91.4	79.5	66.0	56.1
200	-	-	45.9	35.0	33.4	27.7

TABLE 3A

DISCHARGE FLOWRATE (GALLONS PER MINUTE)

Head (Feet)	LENGTH OF UNLINED LINEN HOSE (FEET) 0	100	500	1,000	2,000	3,000
20 FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	47.9	43.6	33.7	28.4	21.7	18.0
50	-	40.8	31.0	26.2	20.0	16.8
100	-	36.7	28.0	22.4	17.0	15.1
200	-	-	21.1	17.0	12.7	10.7
3/8-Inch Nozzle						
0	34.4	29.2	25.0	22.8	18.8	16.7
50	-	26.5	24.4	20.0	17.6	15.2
100	-	24.9	21.1	17.9	14.6	14.0
200	-	-	16.4	14.4	11.3	9.8
5/16-Inch Nozzle						
0	26.8	25.5	21.8	20.5	16.8	15.3
50	-	23.1	19.8	17.6	15.3	13.7
100	-	19.9	17.6	15,8	14.2	12.0
200	-	-	12.8	11.2	9.8	9.4
1/4-Inch Nozzle						
0	20.5	16.7	16.2	15.3	13.7	13.4
50	-	15.6	14.5	14.1	12.9	11.9
100	-	14.2	12.9	13.3	11.6	10.9
200	-	-	10.9	9.4	8.9	8.6

TABLE 3B

NOZZLE PRESSURE (POUNDS PER SQUARE INCH)

Head (Feet)	LENGTH OF UNLINED LINEN HOSE (FEET)					
	0	100	500	1,000	2,000	3,000
			20 FEET - SUCTION LIFT			
			1/2-Inch Nozzle			
0	63.0	50.2	30.0	16.9	7.8	4.5
50	-	42.2	24.2	13.3	6.0	3.4
100	-	34.9	18.7	10.5	4.6	2.4
200	-	-	8.8	4.6	1.9	1.0
			3/8-Inch Nozzle			
0	109.0	99.7	76.7	58.0	39.0	28.9
50	-	85.1	63.3	50.0	32.8	24.3
100	-	68.6	53.3	41.3	27.6	19.9
200	-	-	30.6	23.4	16.0	12.0
			5/16-Inch Nozzle			
0	128.0	110.1	92.2	74.7	56.8	46.4
50	-	94.4	79.3	65.6	49.7	41.2
100	-	79.9	66.6	55.5	42.4	35.9
200	-	-	42.3	36.7	29,4	24.8
			1/4-Inch Nozzle			
0	143.0	130.5	115.8	103.7	84.4	70.3
50	-	111.6	100.8	88.3	72.0	60.7
100	-	93.2	84.7	73.4	60.4	50.8
200	-	-	50.8	46.5	38.7	32.0

TABLE 4A

DISCHARGE FLOWRATE - (GALLONS PER MINUTE)

LENGTH OF UNLINED LINEN HOSE (FEET)

Head (Feet)	0	100	500	1,000	2,000	3,000
25 FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	31.9	35.4	33.8	27.6	22.2	18.7
50	-	36.7	31.2	25.3	19.5	16.9
100	-	34.4	27.9	22.8	18.7	14.6
200	-	-	21.8	17.8	13.7	11.3
3/8-Inch Nozzle						
0	32.8	28.9	26.3	22.2	19.4	15.8
50	-	26.5	23.2	20.6	17.8	15.7
100	-	24.7	21.7	18.7	16.3	12.9
200	-	-	16.4	14.5	11.7	10.2
5/16-Inch Nozzle						
0	26.5	24.4	22.2	20.0	16.5	15.3
50	-	22.4	20.1	19.2	16.3	13.3
100	-	20.3	18.3	16.2	15.0	13.1
200	-	-	13.7	12.4	11.5	10.1
1/4-Inch Nozzle						
0	20.5	17.6	16.3	15.9	14.2	13.5
50	-	15.6	15.4	15.0	13.5	12.4
100	-	14.3	14.1	12.5	12.4	10.8
200	-	-	11.8	10.2	9.8	8.3

TABLE 4B

NOZZLE PRESSURE (POUNDS PER SQUARE INCH)

LENGTH OF UNLINED LINEN HOSE (FEET)

Head (Feet)	0	100	500	1,000	2,000	3,000
			25 FEET - SUCTION LIFT			
			1/2-Inch Nozzle			
0	31.0	30.4	26.2	17.1	8.1	4.7
50	-	32.6	22.3	14.0	6.6	3.7
100	-	30.3	18.6	11.0	4.8	2.9
200	-	-	9.7	5.4	2.3	1.3
			3/8-Inch Nozzle			
0	101.0	98.4	75.5	60.5	40.5	31.1
50	-	85.6	66.6	51.8	34.7	25.9
100	-	70.6	55.2	43.2	28.9	22.3
200	-	-	35.3	27.2	18.5	13.8
			5/16-Inch Nozzle			
0	126.0	114.3	94.4	78.1	59.7	48.6
50	-	98.9	82.5	67.0	51.7	43.7
100	-	83.8	70.0	59.0	44.8	37.7
200	-	-	47.0	40.3	31.6	27.2
			1/4-Inch Nozzle			
0	143.0	135.1	123.0	108.4	88.9	74.4
50	-	118.6	104.8	93.4	76.5	64.7
100	-	100.8	88.3	81.2	64.8	55.5
200	-	-	57.1	52.5	42.4	37.1

APPENDIX C

PUMP PRESSURES REQUIRED

TABLE 5

PRESSURE REQUIRED AT PUMP - (POUNDS PER SQUARE INCH)

LENGTH OF UNLINED LINEN HOSE (FEET)

Head (Feet)	0	100	500	1,000	2,000	3,000
0 FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	69	84	106	121	135	143
50	-	93	113	125	139	145
100	-	101	120	130	142	149
200	-	-	134	141	152	156
3/8-Inch Nozzle						
0	113	119	128	135	141	147
50	-	125	131	136	145	149
100	-	127	134	137	146	151
200	-	-	144	148	151	156
5/16-Inch Nozzle						
0	120	128	136	138	145	149
50	-	132	138	141	147	152
100	-	138	143	147	150	154
200	-	-	151	155	148	159
1/4-Inch Nozzle						
0	145	146	146	148	150	154
50	-	147	150	151	154	155
100	-	149	152	153	155	157
200	-	-	156	160	161	162

TABLE 6

PRESSURE REQUIRED AT PUMP - (POUNDS PER SQUARE INCH)

Head (Feet)	LENGTH OF UNLINED LINEN HOSE (FEET)					
	0	100	500	1,000	2,000	3,000
			15 FEET - SUCTION LIFT			
			1/2-Inch Nozzle			
0	70	84	105	120	132	139
50	-	91	111	130	137	142
100	-	99	116	127	138	145
200	-	-	131	141	147	153
			3/8-Inch Nozzle			
0	114	117	125	129	138	146
50	-	122	128	133	143	146
100	-	125	134	137	144	151
200	-	-	144	146	151	156
			5/16-Inch Nozzle			
0	130	127	132	136	143	145
50	-	131	135	137	144	150
100	-	135	139	141	147	152
200	-	-	147	149	158	159
			1/4-Inch Nozzle			
0	145	140	145	146	148	151
50	-	143	147	148	150	152
100	-	146	149	150	153	156
200	-	-	154	155	160	162

TABLE 7

PRESSURE REQUIRED AT PUMP (POUNDS PER SQUARE INCH)

Head (Feet)	LENGTH OF UNLINED LINEN HOSE (FEET) 0	100	500	1,000	2,000	3,000
	20 FEET - SUCTION LIFT					
	1/2-Inch Nozzle					
0	63.0	70.9	100.8	112.2	125.3	132.2
50	-	81.9	106.7	116.7	128.4	134.5
100	-	93.7	112.9	124.0	134.0	137.6
200	-	-	126.3	134.1	142.1	145.7
	3/8-Inch Nozzle					
0	190.0	110.6	118.9	123.2	130.6	134.7
50	-	116.0	120.1	128.4	132.9	137.3
100	-	119.2	126.5	132.3	138.5	139.7
200	-	-	135.2	138.9	144.7	147.5
	5/16-Inch Nozzle					
0	128.0	117.9	125.1	127.5	134.4	137.1
50	-	122.7	128.9	132.9	137.2	140.2
100	-	128.6	132.9	136.3	139.3	143.3
200	-	-	141.8	144.9	147.6	148.4
	1/4-Inch Nozzle					
0	143.0	134.6	134.3	137.2	140.o	140.8
50	-	136.7	138.6	138.8	141.6	143.5
100	-	139.2	141.7	142.4	144.0	145.5
200	-	-	145.4	148.3	150.8	151.0

TABLE 8

PRESSURE REQUIRED AT PUMP - (POUNDS PER SQUARE INCH)

Head (Feet)	LENGTH OF UNLINED LINEN HOSE (FEET) 0	100	500	1,000	2,000	3,000
25 FEET - SUCTION LIFT						
1/2-Inch Nozzle						
0	31.0	44.7	90.6	113.2	128.1	136.8
50	-	69.1	101.4	119.7	134.7	140.9
100	-	87.7	112.4	126.6	136.8	146.3
200	-	-	129.0	138.9	148.4	153.7
3/8-Inch Nozzle						
0	101.0	109.1	117.1	128.2	135.1	143.7
50	-	116.5	125.5	132.0	138.9	143.8
100	-	121.4	129.3	136.6	142.4	150.2
200	-	-	142.2	146.6	152.9	156.2
5/16-Inch Nozzle						
0	126.0	122.4	128.0	133.5	142.0	144.7
50	-	127.4	133.3	135.4	142.4	149.2
100	-	132.8	137.6	142.6	145.5	149.7
200	-	-	148.4	151.4	153.3	156.4
1/4-Inch Nozzle						
0	143.3	139.4	142.5	143.3	147.3	148.8
50	-	143.9	143.2	145.4	148.8	151.3
100	-	147.1	145.8	151.1	151.3	154.8
200	-	-	152.7	156.3		