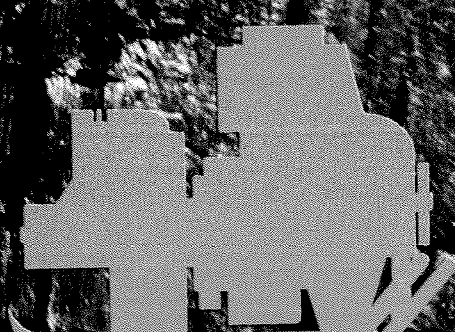
# 1 fireline equipment

D.M. TOWNSEND

# POWER PUMPS



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Misc Report FF-Y-5

# FIRELINE EQUIPMENT – POWER PUMPS

by

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# FOREWORD

The purpose of this report is to acquaint the reader with the various makes and models of portable forestry fire pumps currently in use in Canada. Several of the early models of forestry fire pumps have been included since a survey of fire control supervisors has shown that many of these earlier pumps are still in operation. A number of other makes of fire pumps were sold for forestry use, for example, the Porto, Bluejack, Thibeau, and Paramount Chief, but although some may still be in use, the total number sold was small in relation to the units described.

The usefulness of a pumping unit should not be determined by discharge performance alone. Other factors such as portability, cost, and maintenance will be important considerations to be weighed when purchasing a unit. Lower pressure units are more adaptable to short hose lays and may be more suitable for mounting on a slip-on tanker. The higher pressure units, however, are necessary for longer hose lays and higher discharge heads which might be associated with major fire line operations.

No effort has been made to give a direct comparison between different pumping units. Naturally, each model will have its own performance characteristics as will each individual pump of that series. The performance curves presented in this report show fuel consumption, rpm, and discharge in gpm and are from results obtained during tests conducted at the Institute's Fire Hydraulics Laboratory located at the Petawawa Forest Experiment Station, Chalk River, Ontario. The factors affecting engine and pump performance are briefly described in the report. It can be seen that the performance of pumping units can change considerably depending on environmental conditions and the condition of the pump engine at the time of operation.

Because this report deals with equipment that was available prior to the switch to *Metric* measurement, dimensions are given in inch/pound units. Where gallonage figures are quoted, the amounts are Imperial gallons. Conversions to SI units *(Metric)* are given below for some of the common measurements quoted in the text; in many cases the *Metric* units are given in brackets throughout the report.

| | | |
|---|---|---|
| 1-1/2 inches | = | 38 millimetres |
| 2 inches | = | 51 millimetres |
| 1 Imp. gallon | = | 5.4 litres |
| 1 Imp. gallon | = | 1.2 gallon (U.S.) |

## ABSTRACT

The characteristics and transportation of eleven portable forestry fire pumps and major pump accessories currently used in Canada are described. Weight of each unit and major accessories, and unit dimensions are given. The operating principles of the two-cycle engine, environmental factors affecting engine performance, choice of engine oil, the ignition system, and carburetion are discussed. Causes related to faulty engine performance are listed and sections on centrifugal pumps and factors affecting pump performance are included.

## RESUME

Ce rapport décrit les caractéristiques de onze motopompes portatives et des principaux accessoires de pompes utilisés au Canada. On présente des spécifications techniques sur le poids, l'encombrement et la maniabilité de chaque pompe ainsi que sur ses principaux accessoires. On discute des principes de fonctionnement du moteur à deux temps, des facteurs qui influent sur le rendement du moteur, du choix de l'huile à moteur, du système d'allumage et de la carburation. Les derniers chapitres traitent des principales causes de perte de rendement du moteur, des pompes centrifuges et des facteurs qui influent sur le rendement des pompes.

# INTRODUCTION

Mr. H.C. Johnson, a fire inspector for the Board of Railway Commissioners of Canada, designed the first Canadian portable forestry fire pump in 1915. This gasoline-powered, positive-displacement pump revolutionized methods of forest fire fighting. Prior to the introduction of portable pumps, forest fires were controlled and checked by fire lines constructed using dry methods. The construction of fire lines by hydraulic means increased the efficiency of the fire crew and in many cases shortened fire line construction time considerably. It was estimated at that time, a crew of seven men equipped with one of these portable pumps could surpass the efforts of a crew of seventy who were constructing a fire line with hand tools.

The original pump, as designed by Mr. Johnson, was manufactured by the Fairbanks Morse Company. The unit comprised a four-to-five horsepower, water-cooled, two-cycle, twin-cylinder engine directly connected by a flexible rubber coupling to a bronze rotary pump. It could deliver water to fire sites at a rate of twenty gallons per minute and this was deemed adequate for most fire control conditions. Further improvements to the units' performance were introduced by Mr. Johnson as a result of practical field experience.

Pioneer work in pump use and testing by Mr. J.G. Wright of the Dominion Forest Service and Mr. D.T. Hewson of the National Research Council led to the development of specifications for an ideal forestry pump. These encouraged Canadian designers and manufacturers and rapid progress was made in the development of improved pumps. Canadian forestry pumps, as a result, are among the best of their type and are sold throughout the world. Seven of the more recent and popular models are described in this report.

The Forest Fire Research Institute of the Canadian Forestry Service, Department of the Environment has been conducting a series of performance and endurance tests on portable forestry fire pumps, hoses, nozzles and other related equipment. Under controlled conditions at the Fire Hydraulics Laboratory, it is possible to obtain logistic data on fire suppression equipment that would be difficult to obtain under fire line conditions. Test results obtained have been made available to several forest fire control organizations and operational research projects. Some of these tests, at the request of the National Research Council's Canadian Committee on Forest Fire Control, were undertaken in compliance with the Canadian Government Specification Board specification, 28-GP-5. Specification 28-GP-5 outlines procedures for performance, endurance, muddy water and other related tests to determine the capabilities of forest fire pumping units.

Modern testing facilities have been developed at the Fire Hydraulics Laboratory for the evaluation of newly developed fire suppression equipment and to conduct Specification Board tests on recently introduced pumping units. Suggestions or inquiries from fire control organizations concerning fire pump, hose, and nozzle testing are welcome.

# CURRENT PORTABLE FORESTRY

# FIRE PUMPS IN CANADA

## *WAJAX MARK 1*

The Wajax Mark 1 is a four-stage centrifugal pump coupled to a nine-horsepower, two-cycle, twin-cylinder, air-cooled Mercury engine. Carburetion is provided by a Tillotson float-type carburetor and the fuel is gradually fed from either the auxillary tank mounted above the engine or from a separate fuel supply tank. A fuel mixture of 1/2 pint of oil to 1 gallon of gasoline is recommended by the manufacturer. Ignition is supplied by a Bendix-Scintilla high-tension flywheel-type magneto. The engine is controlled by a choke lever, throttle lever, an on-off switch and has an automatic-rewind starter. To protect the engine from excessive speed an automatic cut-off switch has been incorporated into the engine fan housing. The switch senses air pressure from the cooling fan and at approximately 6500 rpm the switch closes, grounding ignition. Straight exhaust pipes are supplied with the unit but mufflers are available as an option.

The engine is mounted on a tubular-steel base frame. The bolts holding the engine to the base frame pass through rubber bushings which help in dampening engine vibration. The pump is attached to the engine by a lever-operated clamp, and the drive is provided through a rubber coupling buffer. The 2-inch *(51 mm)* inlet (suction) connection and the 1-1/2-inch *(38 mm)* outlet (discharge) connection are both made to standard forestry thread specifications (Canadian Standards Association, Standard B89-1954).

**Weight of pumping unit and major accessories**

| | | | |
|---|---|---|---|
| Dry pumping unit | 58 lbs. | 0 oz. | (26.31 kg) |
| Suction hose (8-foot) (2.4 m) | 17 lbs. | 8 oz. | (7.93 kg) |
| Foot valve and strainer | 1 lb. | 9 oz. | (0.71 kg) |
| Hand primer | 2 lbs. | 8 oz. | (1.13 kg) |
| 4-1/2 gallon (20.5 litre) capacity fuel supply tank (including fuel supply line) | 8 lbs. | 3 oz. | (3.71 kg) |
| Maintenance tool kit (including grease gun) | Weight not available. | | |
| Pump carrying pack | Weight not available. | | |
| Spring mounted base | 13 lbs. | 10 oz. | (6.18 kg) |

**Dimensions of pumping unit**

| | | |
|---|---|---|
| Height | 14 inches | (35.5 cm) |
| Width | 18-3/4 inches | (47.6 cm) |
| Length | 29 inches | (73.6 cm) |

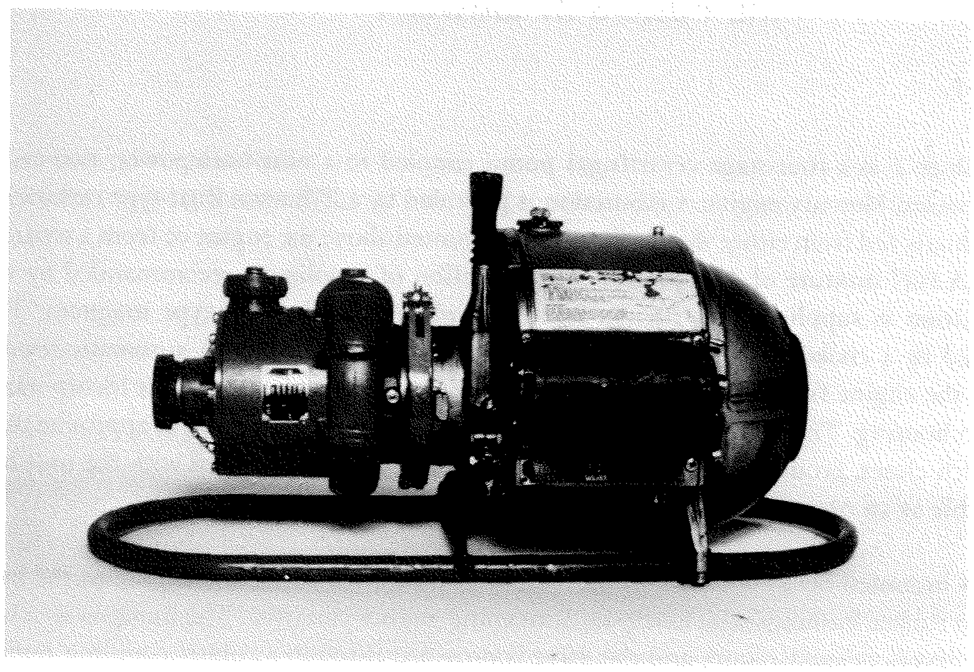


*Fig. 1. Fuel inlet and control side of Wajax Mark 1.*

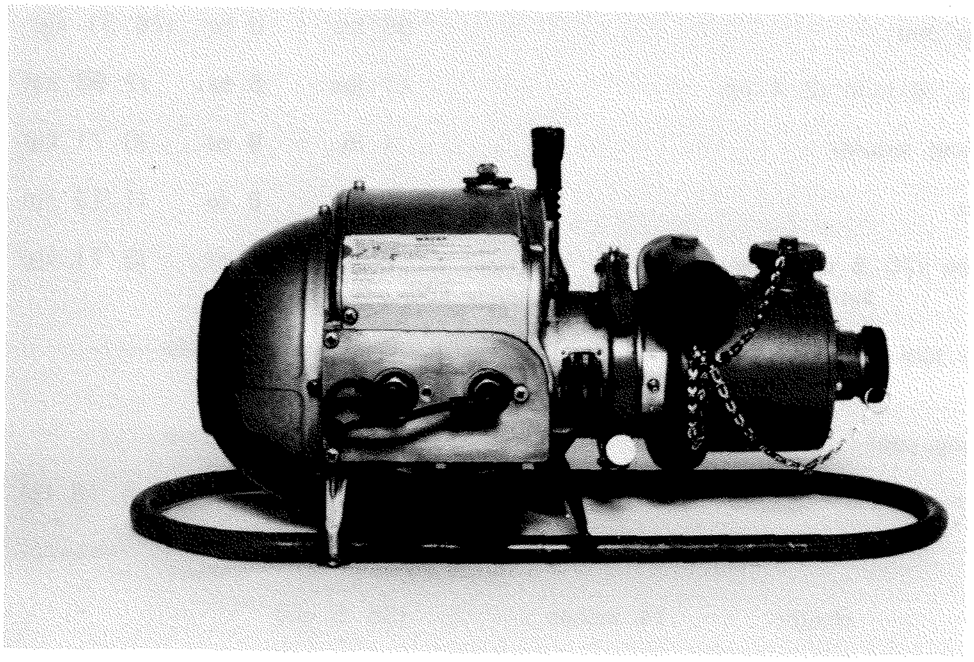


*Fig. 2 Exhaust side of Wajax Mark 1.*

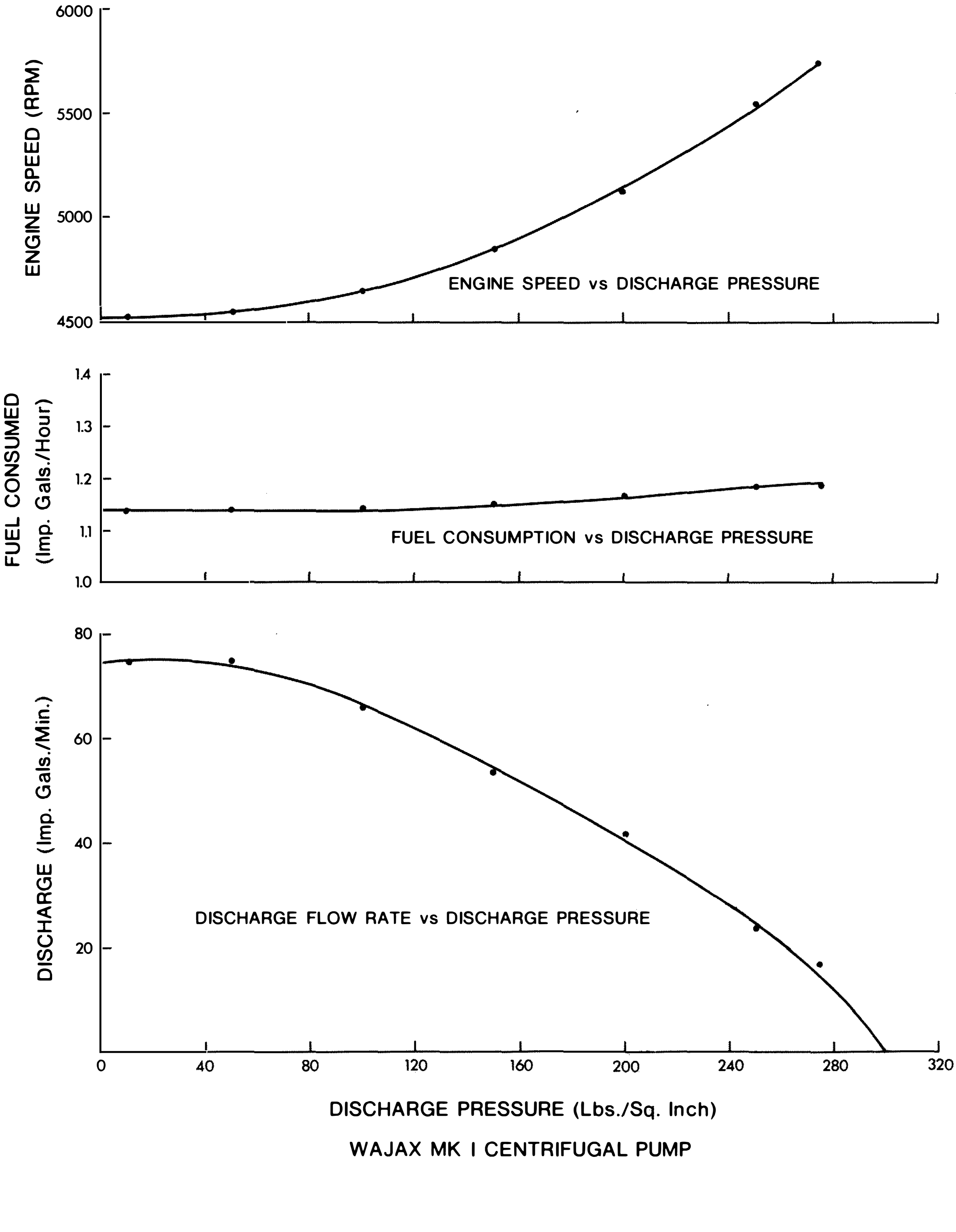



*Fig. 3. Performance curve of Wajax Mark 2.*

**Transportation**

The pumping unit is not conveniently carried by hand over long distances because of the size and weight. However, the pump can be mounted on a Wajax carrying pack. The pack is designed to hold the unit in a vertical position by securing the base frame to the pack with four evenly spaced clasps.

To fit the Wajax Mark 1 into a standard cargo drop container will necessitate the removal of the air cleaner. The air cleaner is located adjacent to the throttle and choke-control levers, and is held in place by four Philips screws. The upper right hand screw is longer than the others, therefore, it should be identified in some manner so as to avoid improper reassembly.

## *WAJAX MARK 2 & 2M*

Wajax introduced the Mark 2 in 1961, and production continued on this model until 1962. Changes were then made to the base frame, engine cowling, carburetor and muffler. The triangular-shaped frame was replaced by the more familiar backpacking type of frame. The new base frame does not have to be removed in order for the pump to fit into a standard cargo drop container as was the case with the original Mark 2. The Bing centre-float carburetor was replaced by a Tillotson all-position, diaphragm-type carburetor similar to that found on other Wajax pumps. The engine cowling was extended to provide more protection for the cooling fins and spark plug. The spark plug cover and carburetor shroud resembled that presently being used on the Wajax Mark 3.

The unit was reintroduced in 1963 as the Wajax Mark 2M. It retained the single-cylinder, eight-horsepower, air-cooled Rotax engine with Bosch magneto. Both units are equipped with automatic-rewind starters, manual-starter-rope pulleys, quick-connect fuel supply lines and separate fuel supply tanks. The Rotax engine is controlled by a choke lever, throttle lever and a push button kill switch. The recommended fuel mixture is 1/2 pint of oil to 1 gallon of gasoline. (16:1). The engine is protected by an automatic high-speed cut-out switch similar to that used on the Mark 1. Both models use the Wajax four-stage centrifugal pump introduced with the Mark 1, which is connected to the engine by a lever-operated clamp, with the drive provided through a rubber coupling buffer. The pump's 2-inch *(51 mm)* inlet (suction) connection and the 1-1/2-inch *(38 mm)* outlet (discharge) connection are both made to standard forestry thread specifications.

**Weight of pumping unit and major accessories**

| | | | |
|---|---|---|---|
| Dry pumping unit | 60 lbs. | 0 oz. | (27.22 kg) |
| Suction hose (8-foot) (2.4 m) | 17 lbs. | 8 oz. | (7.93 kg) |
| Foot valve and strainer | 1 lb. | 9 oz. | (0.71 kg) |
| Hand primer | 2 lbs. | 8 oz. | (1.13 kg) |
| 4-1/2 gallon (20.5 litre) capacity fuel supply tank (including fuel supply line) | 8 lbs. | 3 oz. | (3.71 kg) |
| Maintenance tool kit (including grease gun) | Weight not available. | | |
| Pump carrying pack | 3 lbs. | 10 oz. | (1.64 kg) |
| Spring mounted base | 13 lbs. | 10 oz. | (6.18 kg) |

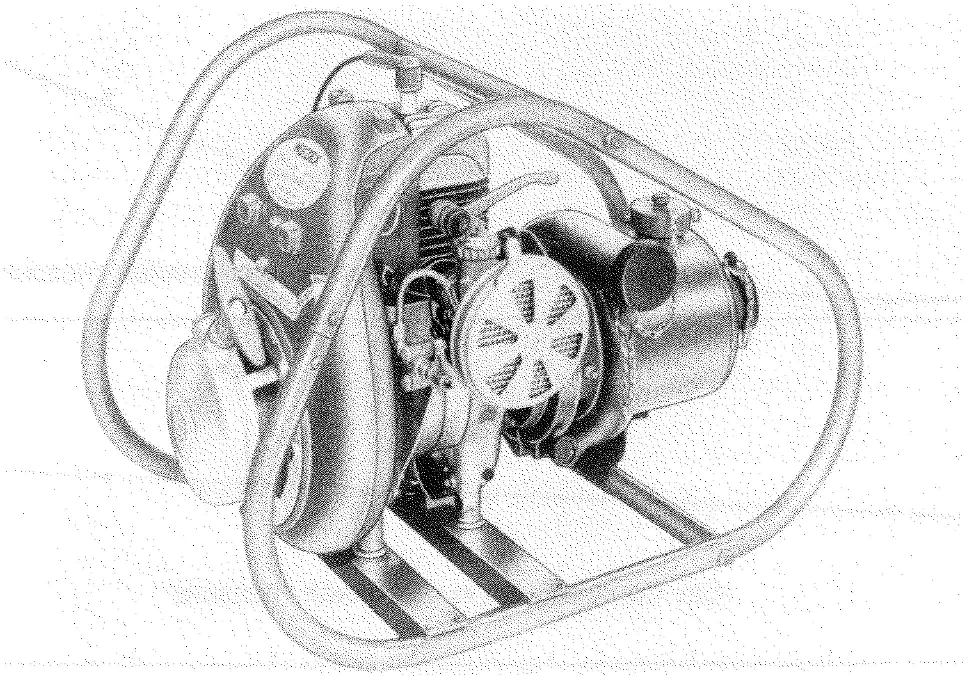


*Fig. 4. Fuel inlet and control side of Wajax Mark 2.*

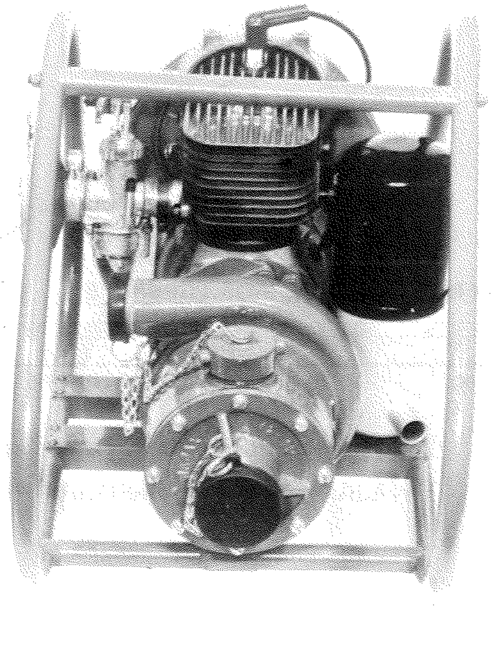


*Fig. 5. Pump end view of Wajax Mark 2.*

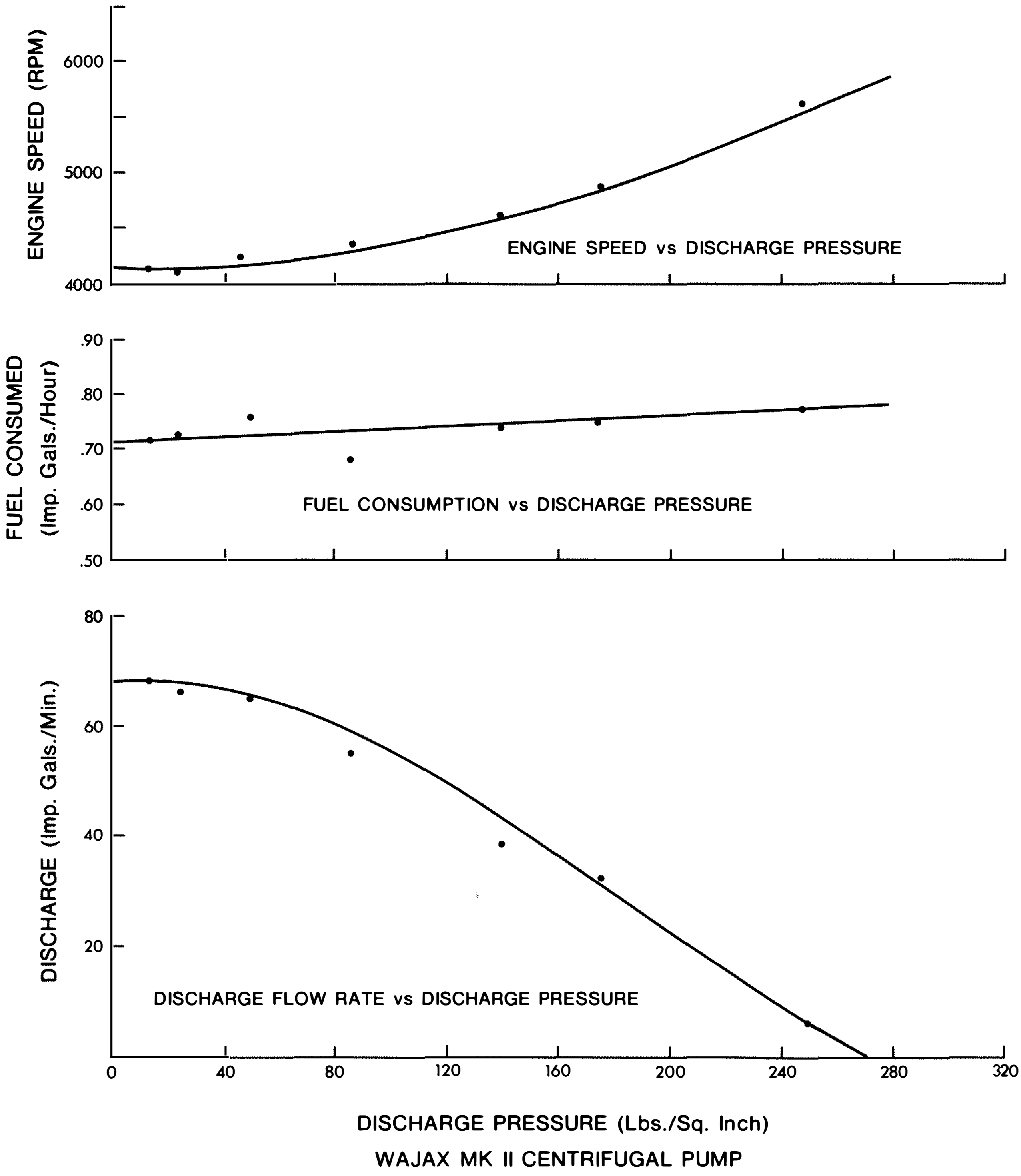



*Fig. 6. Performance curve of Wajax Mark 2.*

**Dimensions of pumping unit**

| | | |
|---|---|---|
| Height | 16-1/2 inches | (41.9 cm) |
| Width | 15 inches | (38.1 cm) |
| Length | 22 inches | (55.9 cm) |

**Transportation**

The Wajax Mark 2M is easily carried in the field by one man. It can either be hand held by the tubular-steel frame or the unit can be mounted on a pump carrying pack. The carrying pack, made of heavy canvas duck, is waterproofed and equipped with shoulder straps and waist belt. The design of the pack is the same as those manufactured for the Mark 26 and Mark 3. To fit the Wajax Mark 2M into a standard cargo drop container will require the removal of the spark plug and spark plug protector cap. The spark plug protector cap is bolted to the engine cylinder head by two cap screws and may be removed with the use of a 3/8-inch wrench.

## *WAJAX MARK 26*

The Wajax Mark 26 is a two-stage centrifugal pump coupled to a five-horsepower, two-cycle, single-cylinder air-cooled Rotax engine. The engine is equipped with an automatic-rewind starter and manual-starter-rope pulley. A Tillotson all-position, diaphragm-type carburetor, with integral fuel pump and filter, is used, as on other Wajax units. The fuel is supplied from a separate 2-gallon *(9 l)* fuel supply tank with a quick-connect fuel line. The engine uses a fuel mixture of 1/2 pint of oil to 1 gallon of gasoline. Engine controls consist of a choke lever, throttle lever and push button kill switch. The ignition system for the Wajax Mark 26 uses a Bosch high-tension flywheel-type magneto. To protect the engine from excessive speed an automatic cut-out switch has been incorporated into the engine fan housing.

The engine is bolted onto a subframe mounted to a tubular-steel frame by four bolts passing through rubber bushings. The pump is attached to the engine by a lever-operated clamp, and the drive is provided through a rubber coupling buffer. The 2-inch *(51 mm)* inlet (suction) and 1-1/2-inch *(38 mm)* outlet (discharge) connections are both made to standard forestry thread specifications.

**Weight of pumping unit and major accessories**

| | | | |
|---|---|---|---|
| Dry pumping unit | 37 lbs. | 8 oz. | (17.01 kg) |
| Suction hose (8-foot) (2.4 m) | 17 lbs. | 8 oz. | (7.93 kg) |
| Foot valve and strainer | 1 lb. | 9 oz. | (0.71 kg) |
| Hand primer | 2 lbs. | 8 oz. | (1.13 kg) |
| 2-gallon (9.1 litre) capacity fuel supply tank (including fuel supply line) | 7 lbs. | 3 oz. | (3.26 kg) |
| Maintenance tool kit (including grease gun) | 2 lbs. | 0 oz. | (0.90 kg) |

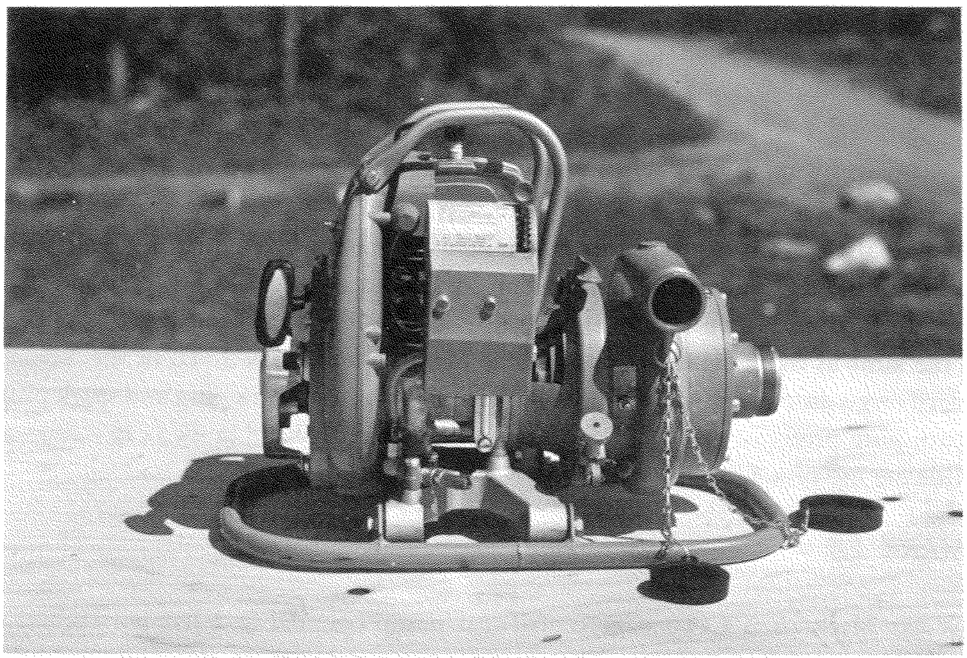


Fig. 7. Fuel inlet and control side of Wajax Mark 26.

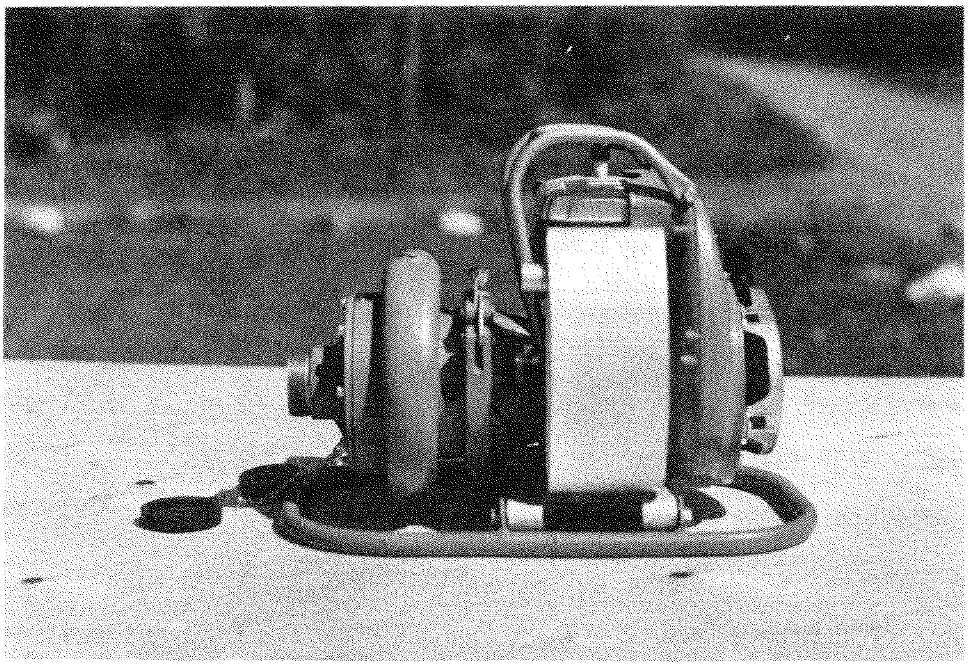
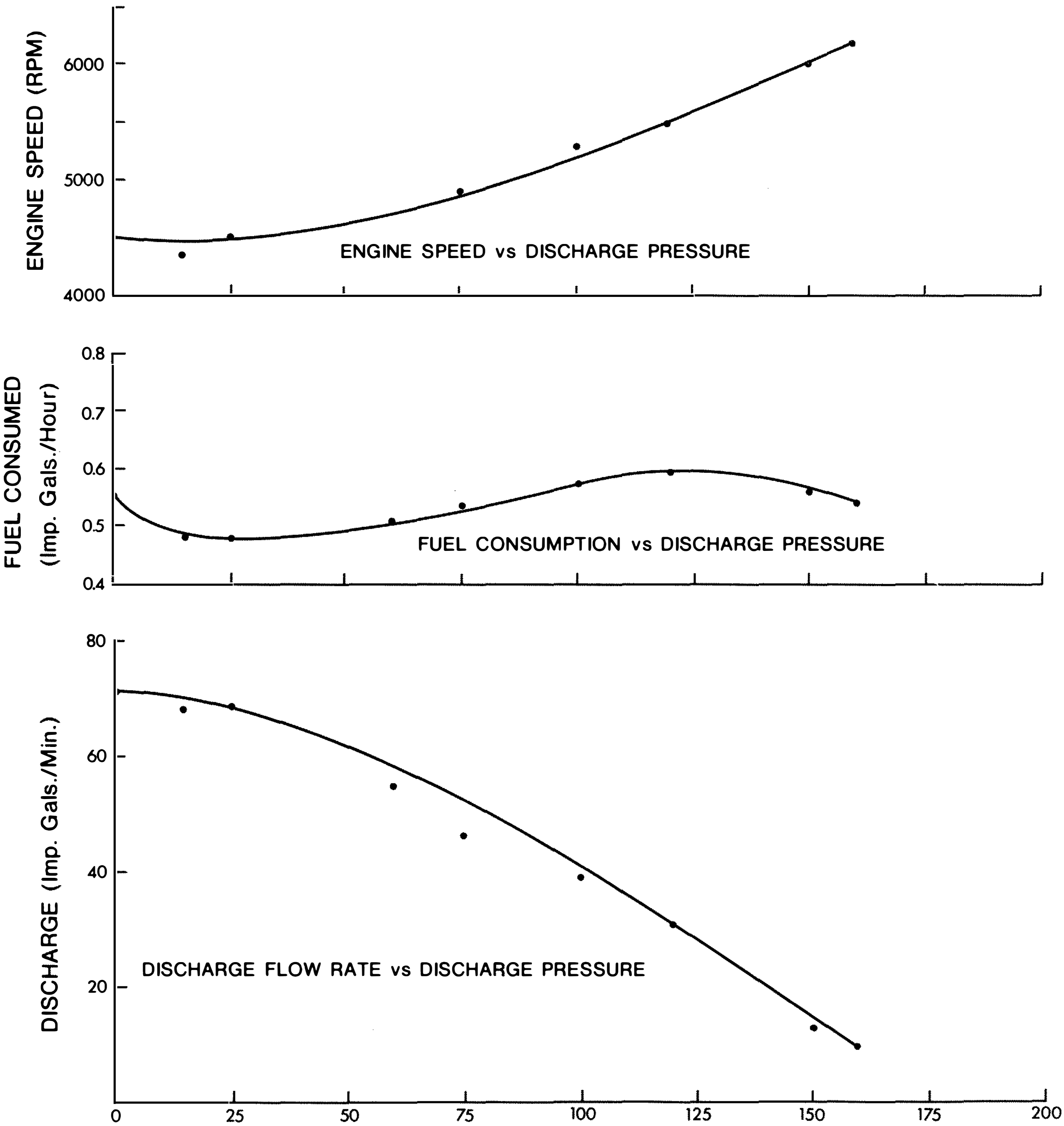


Fig. 8. Exhaust side of Wajax Mark 26.




DISCHARGE PRESSURE (Lbs./Sq. Inch)

WAJAX MK 26 CENTRIFUGAL PUMP

*Fig. 9. Performance curve of Wajax Mark 26.*

| | | | |
|---|---|---|---|
| Pump carrying pack | 3 lbs. | 10 oz. | (1.64 kg) |
| Spring mounted base | 13 lbs. | 10 oz. | (6.18 kg) |

**Dimensions of pumping unit**

| | | |
|---|---|---|
| Height | 13-1/2 inches | (34.3 cm) |
| Width | 10-3/4 inches | (27.3 cm) |
| Length | 18-1/2 inches | (47.0 cm) |

**Transportation**

The Mark 26 is provided with a convenient handle for carrying over short distances. The carrying handle, which is located over the cylinder head, also acts as a roll bar to protect cooling fins and spark plug should the unit be accidently tipped over. The carrying pack supplied by the manufacturer is constructed of padded canvas duck and is equipped with clip-on 1-1/2-inch shoulder straps and a 2-inch waist belt. The unit is held in a vertical position with one end of the frame fitting into a pouch and secured by safety straps. To fit the Mark 26 into a standard cargo drop container, it will be necessary to remove the roll bar carrying handle and spark plug.

## *WAJAX MARK 3*

Wajax Mark 3, a popular firefighting unit, was first introduced in 1965. In the United States it is marketed as the Pacific Mark 3. The Mark 3 is a four-stage centrifugal pump connected to an 8.5-horsepower, two-cycle, single-cylinder, air-cooled Rotax engine. The engine is equipped with an automatic-rewind starter and manual-starter-rope pulley. The fuel is supplied from a separate fuel supply tank with a quick-connect fuel line to a Tillotson all-position, diaphragm-type carburetor. The carburetor has an integral fuel pump and filter. The ignition system uses a Bosch high-tension flywheel-type magneto. The engine is controlled with a choke lever, throttle lever and push button kill switch. The fuel mixture recommended for the Mark 3 is 1/2 pint of oil to 1 gallon of gasoline.

More recent models of this engine have been fitted with a decompression valve. This valve facilitates starting of the unit by passing part of the compressed fuel charge directly into the exhaust port, thereby reducing the effort required to pull the starter rope.

The engine is protected from excessive speed by an automatic cut-out switch similar to other Wajax pumps. The engine is mounted on the base frame by two bolts from the engine crankcase. A rubber pad between the engine and frame helps to dampen vibration. The pump, like other Wajax units, is attached to the engine by a lever-operated clamp, the drive being provided through a rubber coupling buffer. The pump is further supported at the discharge volute by a rubber vibration pad attached to the frame. The diffusers and impellers of the pump's four stages are constructed from an abrasion resistant aluminum alloy. The 2-inch *(51 mm)* inlet (suction) and 1-1/2-inch *(38 mm)* outlet (discharge) are both made to standard forestry thread specifications.

**Weight of pumping unit and major accessories**

| | | | |
|---|---|---|---|
| Dry pumping unit | 55 lbs. | 0 oz. | (24.95 kg) |
| Suction hose (8-foot) (2.4 m) | 17 lbs. | 8 oz. | (7.94 kg) |
| Foot valve and strainer | 1 lb. | 9 oz. | (0.71 kg) |
| Hand primer | 2 lbs. | 8 oz. | (1.13 kg) |
| 4-1/2-gallon (20.5 litre) capacity fuel supply tank (Including fuel supply line) | 8 lbs. | 3 oz. | (3.71 kg) |
| Maintenance tool kit (including grease gun) | 1 lb. | 15 oz. | (0.88 kg) |
| Pump carrying pack | 3 lbs. | 10 oz. | (1.64 kg) |
| Spring mounted base | 13 lbs. | 10 oz. | (6.18 kg) |

**Dimensions of pumping unit**

| | | |
|---|---|---|
| Height | 14 inches | (35.5 cm) |
| Width | 11 inches | (27.9 cm) |
| Length | 23 inches | (58.4 cm) |

**Transportation**

The tubular-steel base frame which arches up at each end of the pump provides natural handles for positioning the pump or carrying it over short distances. The Mark 3 uses the same pump carrying harness as the Mark 26 and Mark 2M, holding the pump vertically, with the pump end of the frame fitting into a pouch and being further secured by two safety straps.

To fit the Wajax Mark 3 into a standard cargo drop container, it will be necessary to remove the spark plug protector cap and spark plug. The cap is held in place by two 3/8-inch cap screws. After the cap has been removed, the two cap screws should be returned to the cylinder head to prevent their loss. Remove the spark plug and stuff a clean rag into the spark plug hole to prevent dust from entering the cylinder while the pump is being transported.

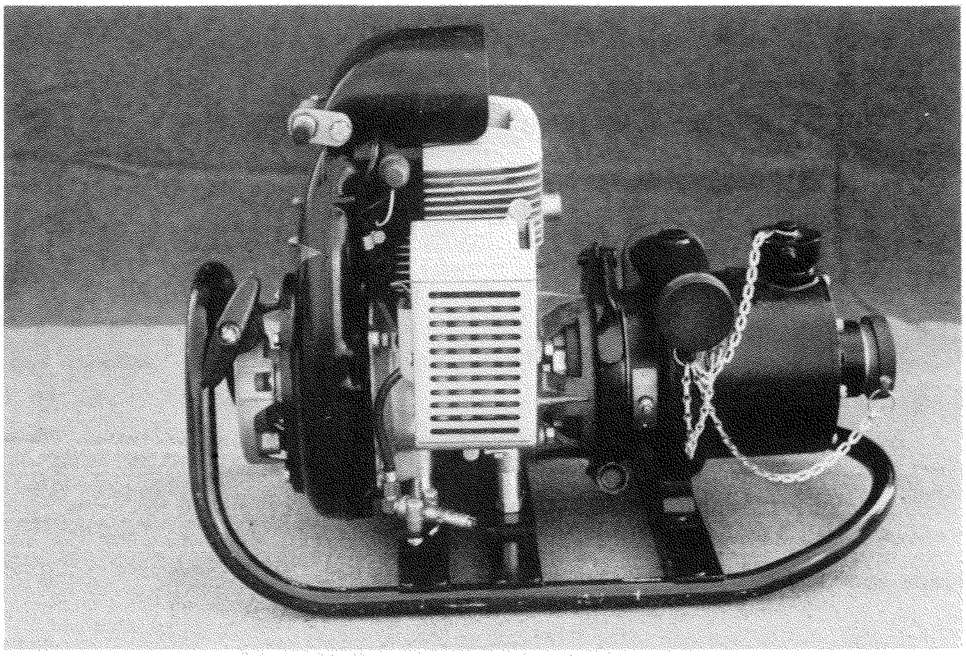


*Fig. 10. Fuel inlet and control side of Wajax Mark 3.*

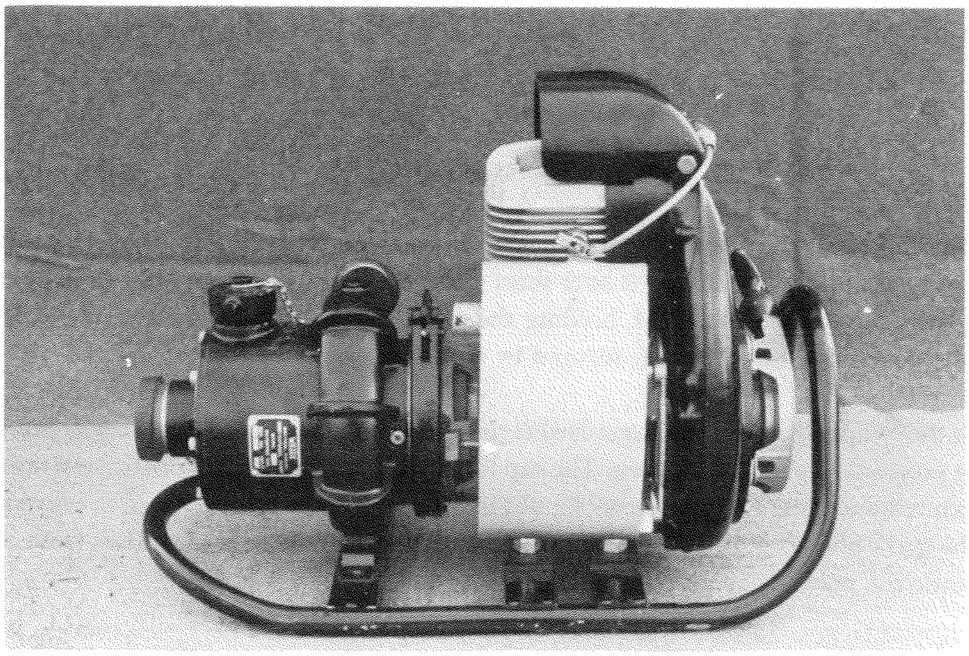


*Fig. 11. Exhaust side of Wajax Mark 3.*

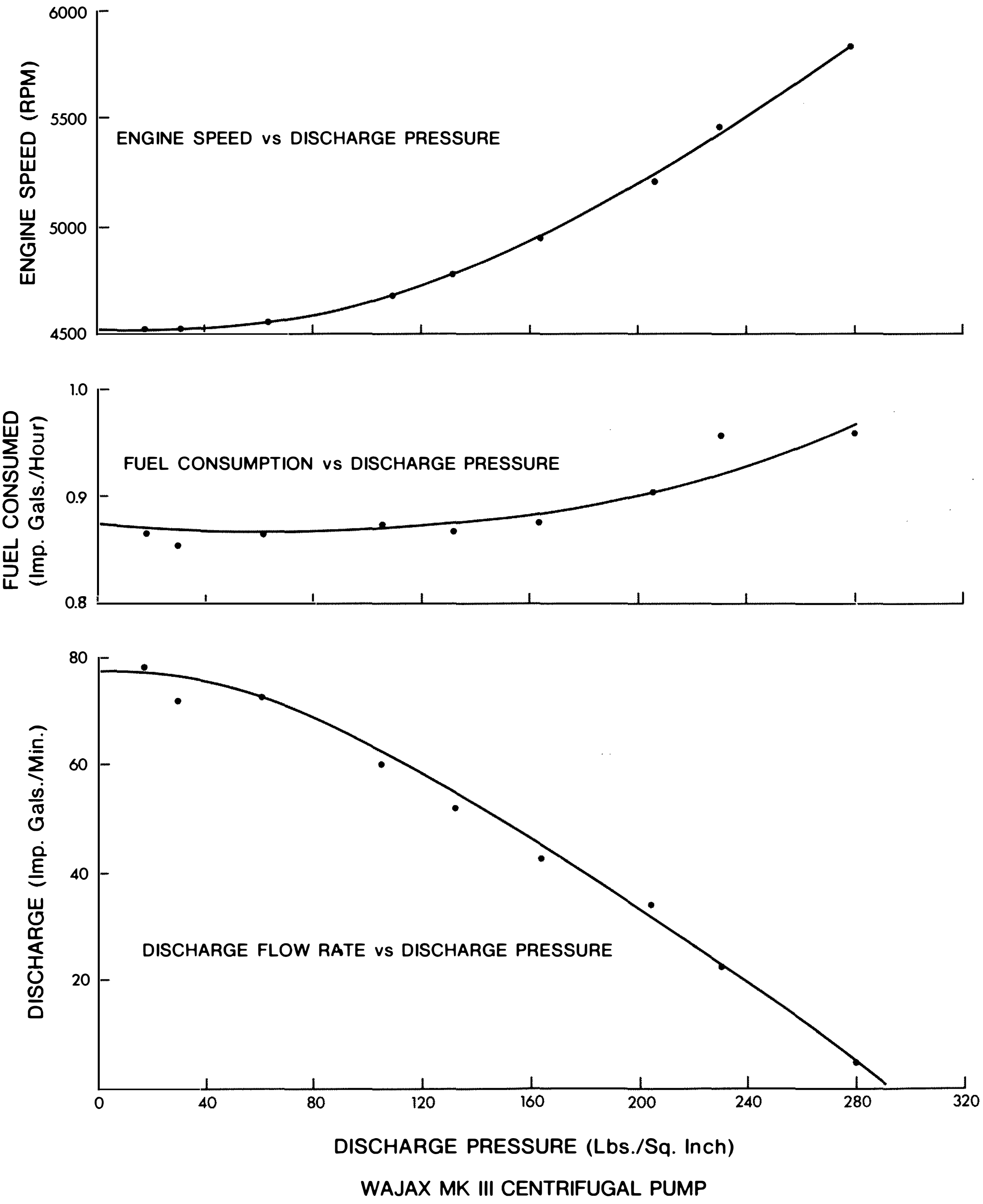



*Fig. 12. Performance curve of Wajax Mark 3.*

## *TERRY T-7*

The Terry T-7, sometimes called the Homelite, is no longer manufactured by Terry Industries, although replacement parts for both pump and engine are still available. The Terry T-7 is a four-stage centrifugal pump coupled to a seven-horsepower, single-cylinder, two-cycle, air-cooled, Homelite engine. The engine is equipped with a manual starter rope pulley. Controls for the engine include an on-off switch and a choke-control lever. There is no throttle control or automatic high speed cut-out switch provided, as both engine speed and throttle opening are controlled by a spring-loaded governor. Engine carburetion, is provided by a Tillotson all-position diaphragm-type carburetor with integral fuel pump and filter. The engine requires a fuel mixture of 3/4 pint of oil to 1 gallon of gasoline. Engine ignition is supplied from a high-tension flywheel-type magneto. The flywheel, engine cylinder head and spark plug are completely enclosed by a protective air shroud which will prevent damage to engine parts during transportation.

The Terry T-7 pump end consists of four aluminum impellers within a five piece pump housing. The pump housing is bolted together by four metal studs which pass through the intermediate stages, pump inlet and outlet bodies. The pump's 1-1/2-inch *(38 mm)* inlet (suction) and 1-1/2-inch *(38 mm)* outlet (discharge) connections are both made to CSA standard forestry thread specifications.

**Dimensions of pumping unit**

| | | |
|---|---|---|
| Height | 17 inches | (43.2 cm) |
| Width | 16 inches | (40.6 cm) |
| Length | 19-1/4 inches | (48.9 cm) |
| Weight of dry pumping unit | 37 lbs. | (16.78 kg) |

**Transportation**

The light-weight and small-size Terry T-7 is easily carried by one man. A tote handle attached to the pump end facilitates carrying by hand. The Terry T-7 may also be transported by the use of a pump carrying pack. The pack is not supplied with the unit, but can be purchased from the manufacturer.

Fitting the Terry T-7 into a standard cargo drop container does not require removal of any engine or frame components.

## *TERRY T-5*

The Terry T-5 is an extremely light weight portable pumper; however, like the T-7 it is no longer manufactured by Terry Industries Limited. The T-5 is a two-stage centrifugal pump directly connected to a five-horsepower, two-cycle, single-cylinder Homelite engine. Although similar in design and appearance to the T-7, the pump performance of the T-5 is somewhat less than that of the T-7. The two-stage centrifugal pump makes use of abrasive resistant aluminum impellers and housings, rotating on a stainless steel pump shaft. The pump's 1-1/2-inch *(38 mm)* inlet (suction) and 1-1/2-inch *(38 mm)* outlet (discharge) connections are both made to standard forestry thread specifications.

Controls for the engine include an on-off switch and choke-control lever. There is no throttle control or automatic high speed cut-out switch provided, as both engine speed and throttle opening are controlled by a spring-loaded governor. The engine is equipped with an automatic-rewind starter. The fuel, a mixture of 3/4 pint of oil to 1 gallon of gasoline, is supplied from either the engine fuel tank or a separate 3.3 gallon *(15 l)* fuel supply tank to a Tillotson all-position, diaphragm-type carburetor with integral fuel pump and filter. Engine ignition is supplied from a high-tension flywheel-type magneto.

The flywheel, engine cylinder head and spark plug are completely enclosed by a protective air shroud which prevents damage to the unit during transportation. The engine and pump are spring-mounted on a tubular-aluminum frame which is detachable if the unit is to be trailer mounted. The unit requires no modification to fit a standard cargo drop container.

**Dimensions of pumping unit**

| | | |
|---|---|---|
| Height | 12-3/4 inches | (32.4 cm) |
| Width | 13-3/4 inches | (34.9 cm) |
| Length | 16-3/4 inches | (42.5 cm) |
| Weight of dry pumping unit | 29 lbs. | (13.15 kg) |

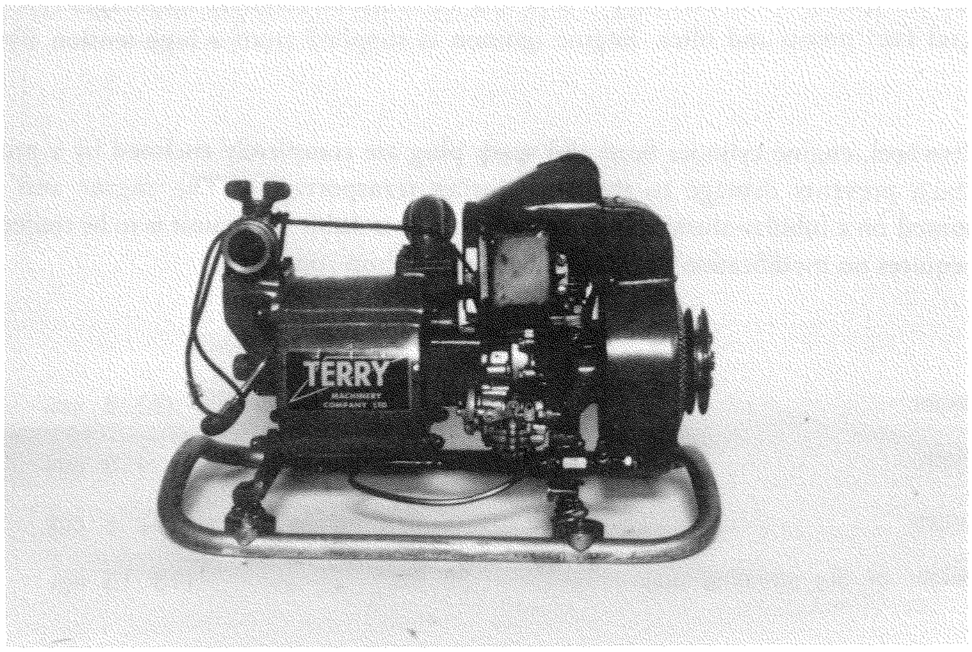



*Fig. 13. Fuel inlet and control side of Terry T-7.*

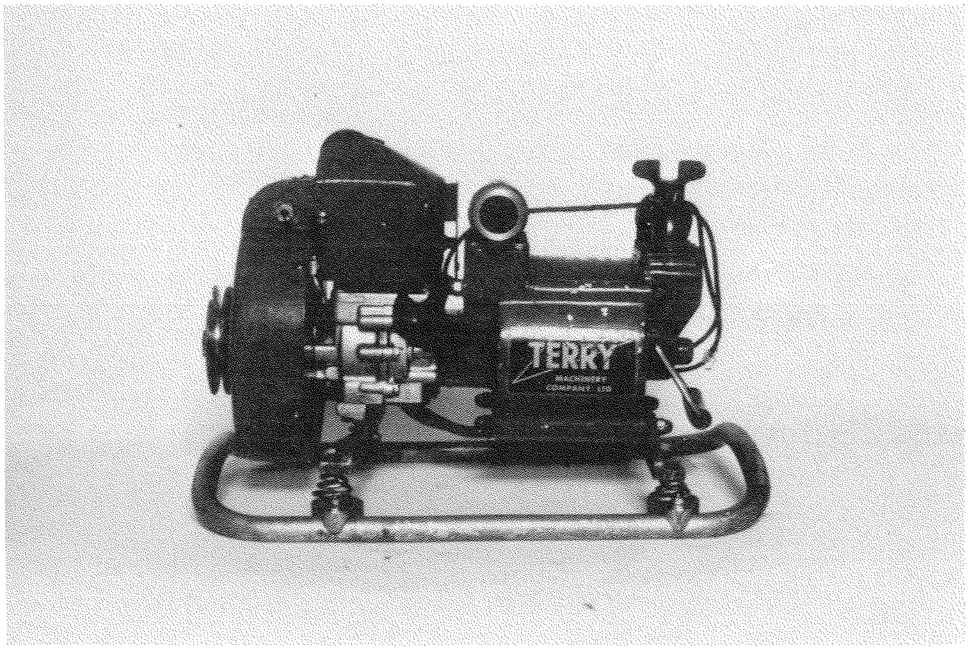



*Fig. 14. Discharge side of Terry T-7.*

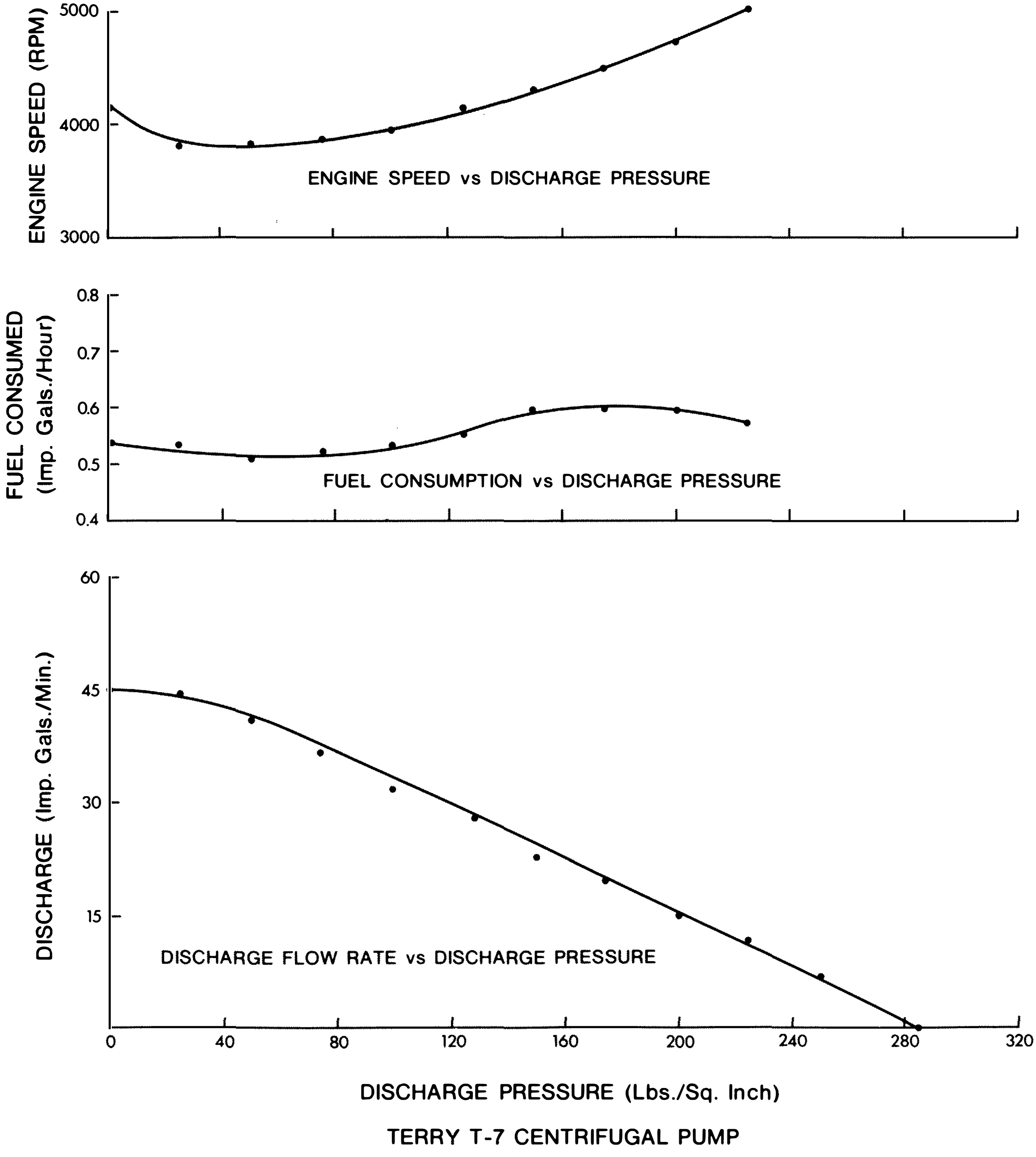



*Fig. 15. Performance curve of Terry T-7.*

## *GORMAN-RUPP BACKPACK*

The Backpack is a widely used firefighting unit. It was designed in Canada and introduced in Canada and the United States by Gorman-Rupp in 1963. This single-stage centrifugal pump is powered by a Westbend air-cooled, two-cycle, single-cylinder engine which develops eight horsepower and is equipped with an automatic-rewind starter. The engine is controlled with a choke lever, throttle lever and on-off ignition switch. It is equipped with a Tillotson all-position, diaphragm-type carburetor, with integral fuel pump and filter. Choices of fuel tank (with fuel hose and quick-connector) are as follows: 4-gallon *(18 l)* backpacking fuel supply tank, including carrying straps; 2-gallon *(9 l)* backpacking fuel supply tank, including carrying straps; or 3.5-gallon, *(16 l)* side carry fuel caddy. The recommended fuel mixture is 1/2 pint of oil to 1 gallon of gasoline. Engine ignition uses a Wico high-tension flywheel-type magneto. The engine is protected from excessive speed by a diaphragm pressure switch mounted on the frame and connected to the engine fan housing. The switch senses air pressure from the engine fan and will ground the ignition at approximately 9,000 rpm.

The pumping unit is secured to the tubular-steel base frame by three rubber vibration mounts. Two are located at the bottom of the pump casing with the third being located on the base of the engine crank case. The pump is coupled to the engine by means of an intermediate bracket which is bolted to the engine crankcase. The pump case is held to the intermediate bracket by a retaining ring. The 1-1/2-inch *(38 mm)* inlet (suction) connection and the 1-1/2-inch *(38 mm)* outlet (discharge) connection are both made to CSA Standard forestry thread specifications.

**Weight of pumping unit and major accessories**

| | | | |
|---|---|---|---|
| Dry pumping unit | 29 lbs. | 8 oz. | (13.38 kg) |
| Suction hose (10-foot) (3.0 m) | 12 lbs. | 4 oz. | (5.56 kg) |
| Foot valve and strainer | 1 lb. | 8 oz. | (0.68 kg) |
| 2-inch (51 mm) suction adapter | | 6 oz. | (0.17 kg) |
| Backpack pump harness | 2 lbs. | 1 oz. | (1.19 kg) |
| 4-gallon (18 litre) fuel tank (including fuel line and carry straps) | 8 lbs. | 4 oz. | (3.74 kg) |
| Protective U-bar and carrying handle | 1 lb. | 4 oz. | (0.57 kg) |
| Field tool kit | | 8 oz. | (0.23 kg) |

**Dimensions of pumping unit**

| | | |
|---|---|---|
| Height | 13-1/2 inches | (34.3 cm) |
| Width | 11 inches | (27.9 cm) |
| Length | 18-3/4 inches | (47.6 cm) |

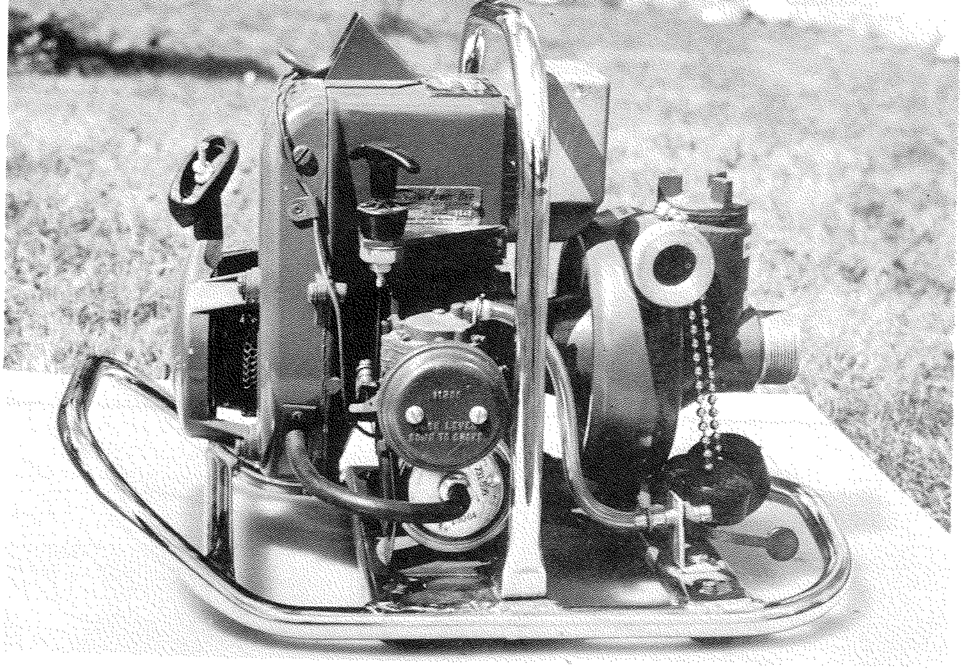


*Fig. 16. Fuel inlet and control side of Gorman-Rupp Backpack.*

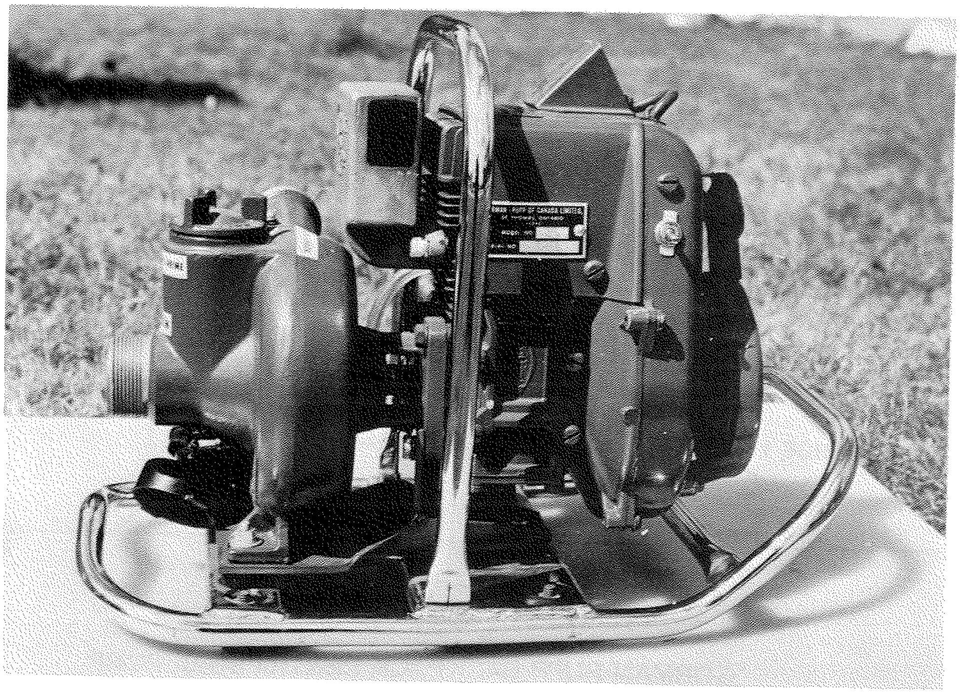


*Fig. 17. Exhaust side of Gorman-Rupp Backpack.*

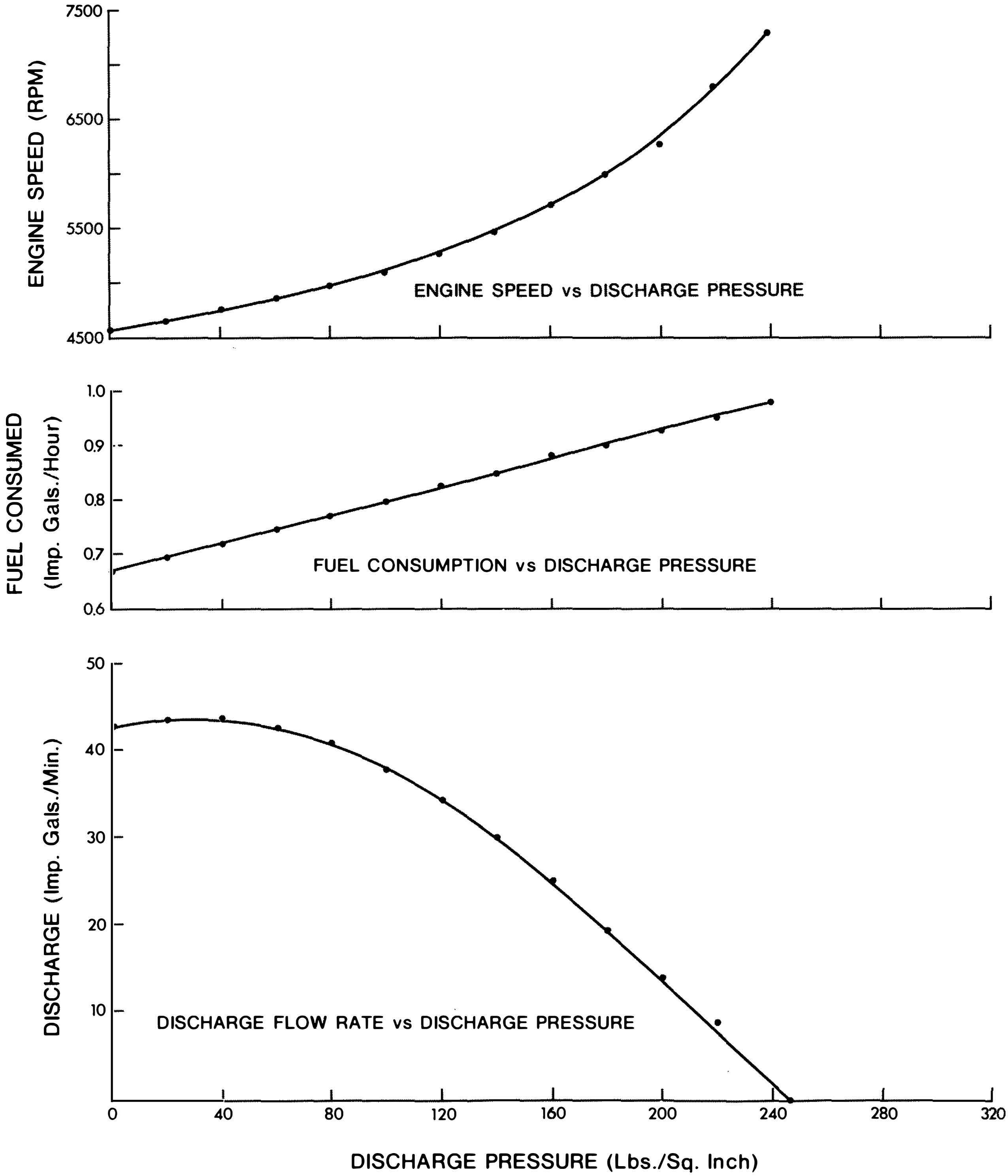



*Fig. 18. Performance curve of Gorman-Rupp Backpack.*

**Transportation**

The tubular base frame which arches up at each end of the pump acts as a natural handle for positioning and carrying the unit over short distances. The tubular U-bar, if attached, can also be used as a carrying handle. The U-bar will also protect cooling fins and spark plug should the unit be accidentally tipped over.

For backpacking the unit, a pump carrying harness constructed from heavy padded canvas duck is provided. The harness holds the pump in a vertical position by securing the base frame with four fasteners and a shallow pocket. The Gorman-Rupp Backpack will fit into a standard cargo drop container without removal of any engine or frame parts.

## *GORMAN-RUPP BUSHWHACKER*

The Bushwhacker is the most recent addition to the line of portable forestry fire pumps. The pump end is similar in design to that of the Gorman-Rupp Backpack, but of larger capacity in order to provide increased pumping pressure and flowrate. The unit is powered by a single-cylinder, air-cooled JLO Rockwell engine of approximately 14 horsepower. The engine is equipped with an automatic-rewind starter and a manual-starter-rope pulley. Controls provided for the engine are a choke-control lever, throttle lever, and an on-off ignition switch. The fuel mixture of 2/5 pint of oil to 1 gallon of gasoline (20:1) is supplied from a separate fuel tank through a Neoprene hose with a quick-connect coupling. Ignition is by a low-tension, flywheel-type magneto with external coil. The engine is protected from excessive speed by a diaphragm pressure switch similar to that of the Backpack pump.

Four rubber vibration mounts secure the engine base plate to the tubular-steel frame. The pump is coupled to the engine by means of an intermediate bracket, which is bolted to the engine crankcase. The pump casing is held to the intermediate bracket by a retaining ring. The 2-inch *(51 mm)* inlet (suction) connection and the 1-1/2-inch *(38 mm)* outlet (discharge) connection are both made to CSA Standard forestry thread specifications.

**Weight of pumping unit and major accessories**

| | | | |
|---|---|---|---|
| Dry pumping unit | 52 lbs. | 4 oz. | (23.7 kg) |
| Suction hose (10-foot) (3.0 m) | 16 lbs. | 7 oz. | (7.46 kg) |
| Foot valve and strainer | 2 lbs. | 1 oz. | (0.94 kg) |
| Fuel tank (including fuel line and carrying straps) | 8 lbs. | 4 oz. | (3.74 kg) |
| Field tool kit | 1 lb. | 1 oz. | (0.48 kg) |
| Fuel tank (bottom feed) | 7 lbs. | 7 oz. | (3.37 kg) |

**Dimensions of pumping unit**

| | | |
|---|---|---|
| Height | 17 inches | (43.2 cm) |
| Width | 16 inches | (40.6 cm) |
| Length | 19-1/4 inches | (48.9 cm) |

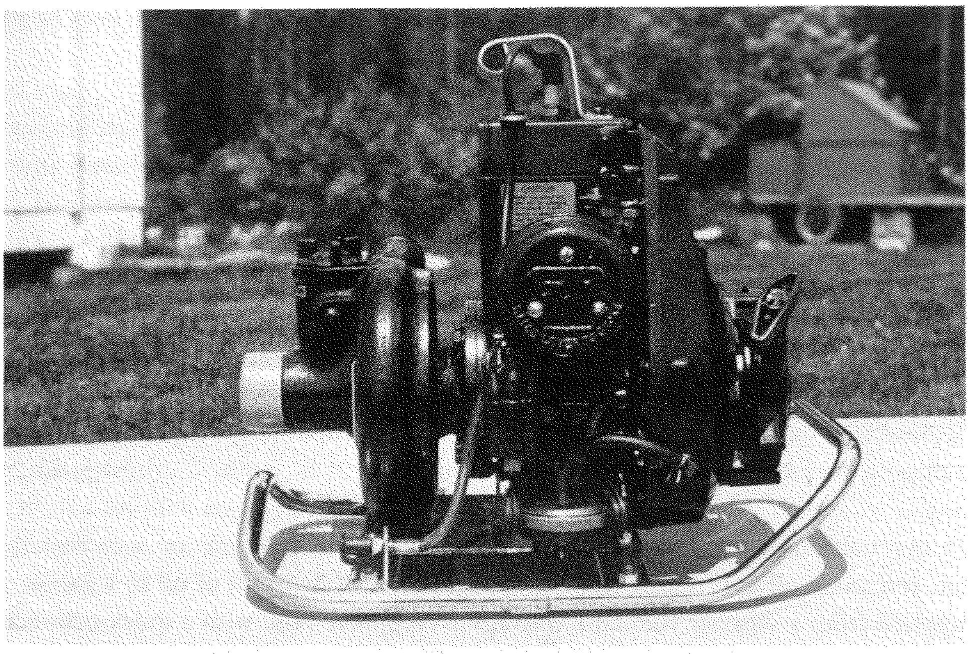


*Fig. 19. Fuel inlet and control side of Gorman-Rupp Bushwhacker.*

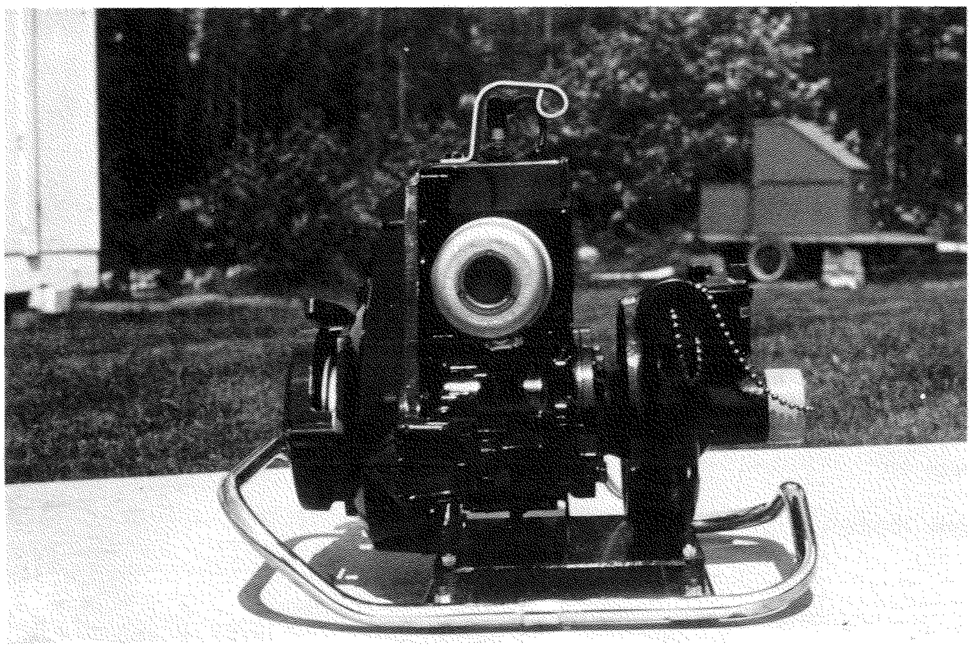


*Fig. 20. Exhaust side of Gorman Rupp Bushwhacker.*

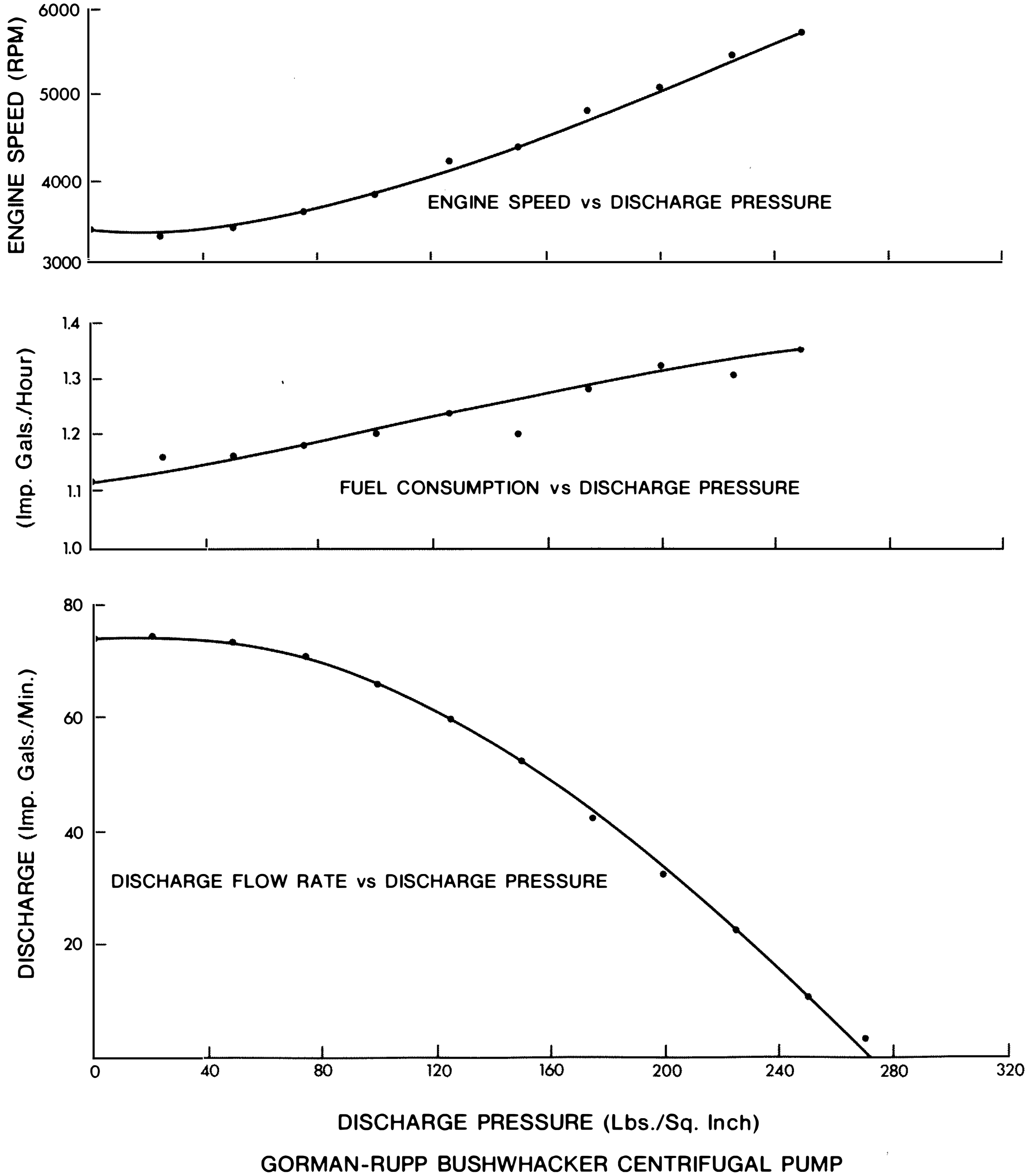



*Fig. 2 1. Performance curve of Gorman-Rupp Bushwhacker.*

## Transportation

A rolled-steel handle bolted to the cylinder head extends over the spark plug and will provide a degree of protection to the spark plug should the unit be accidentally tipped over. The tubular-steel frame which arches up at each end of the pump aids in handling and positioning the unit at the pumping site.

For backpacking the pump a padded canvas harness can be purchased from the manufacturer. It is similar to the Backpack harness but larger and stronger in design to hold the increased size and weight of the Bushwhacker.

Fitting the Bushwhacker into a standard cargo drop container will necessitate removal of the following parts: spark plug protector and handle, spark plug, muffler and base frame.

When reinstalling the muffler ensure that the muffler and gasket are right side up as the exhaust port is not quite symetrical. Mounting the muffler incorrectly will cause some interference with the exhaust flow.

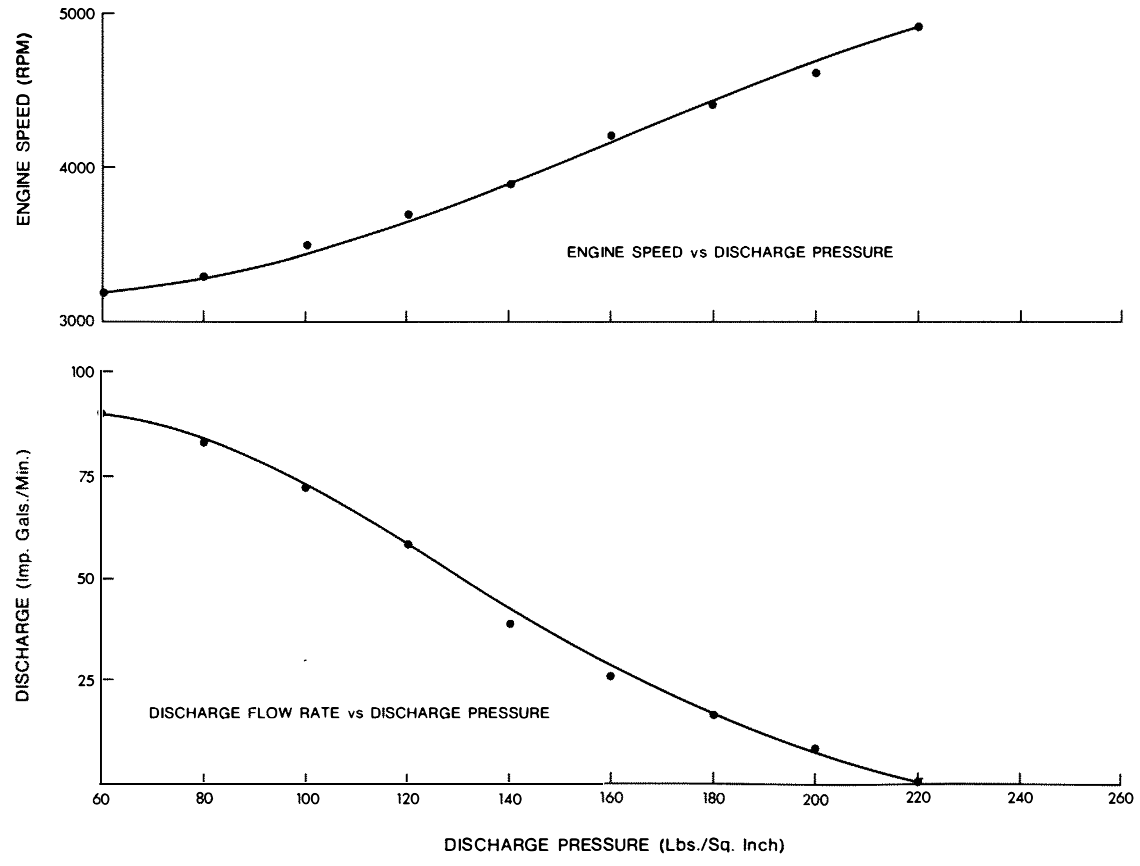



*Fig. 22. Performance curve of Paramount Cub.*

# EARLY MODELS OF PORTABLE FORESTRY FIRE PUMPS STILL IN USE

## *PARAMOUNT CUB*

The Paramount Cub was first introduced in 1939 and remained in production for a considerable period of time. It was the first pump designed to meet the specifications developed by *Hewson and Wright* (1939). Over the years changes were made to the cylinder head, engine cooling system, exhaust system, base frame and several other modifications of lesser importance.

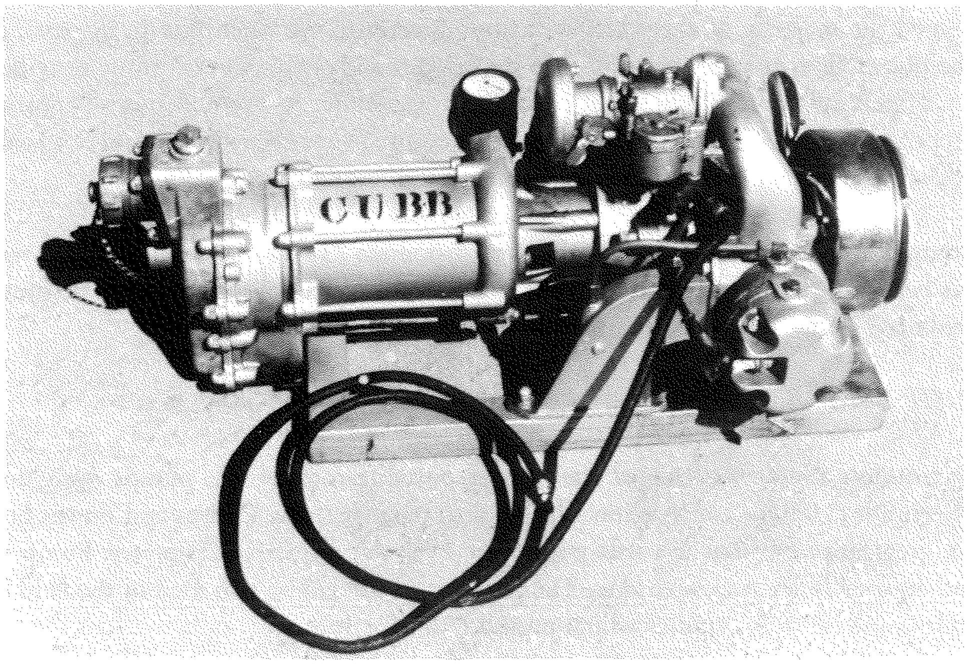



*Fig. 23. Paramount Cub.*

The pump is directly connected to a water-cooled, two-stroke, horizontally-opposed twin-cylinder engine.* Gasoline is supplied from a separate fuel supply tank to a Tillotson carburetor by means of a flexible rubber gas line. The carburetor is mounted on a double manifold supplying the air/fuel charge to each cylinder. Lubrication for engine parts is provided through the fuel mixture, 1 pint oil to 1 gallon of regular grade gasoline. Separate exhaust manifolds direct the gases to openings in the base frame. Water cooling for the engine is provided from the last stage of the centrifugal pump. The water passes through water jackets in the cylinder head and then is discharged into the exhaust manifold.

Earlier models of the Paramount Cub used Eisemann magnetos, however these were later replaced by Bendix-Scintilla high-tension flywheel-type magnetos. Both magnetos are similar in design and make use of a manual spark advance and retard lever mounted above the flywheel magneto. Starting the engine is accomplished through the use of a manual-starter-rope pulley mounted on the magneto flywheel.

The Paramount engine supplies rotation to a multistage centrifugal pump which is coupled to a positive-displacement priming pump. The vane pump is located on the end of the main pump shaft in front of the first stage of the centrifugal pump. As there is a small clearance between the vanes and pump wall, the vane pump must first be primed by a small amount of water. The vane pump is quite capable of priming the main pump with suction lifts of 15 feet *(4.6 m)* and more. When the centrifugal pump is primed the majority of the water will flow directly to the main pump, by-passing the vane pump. If the pumping unit is stopped and then restarted it will still retain its prime provided the unit has not been tipped upward to drain water from the pump body. As the pump is self priming, a foot valve is not necessary, however, the use of a strainer is required to prevent the entrance of large particles of sand, debris and stone which would cause damage to the vane pump walls.

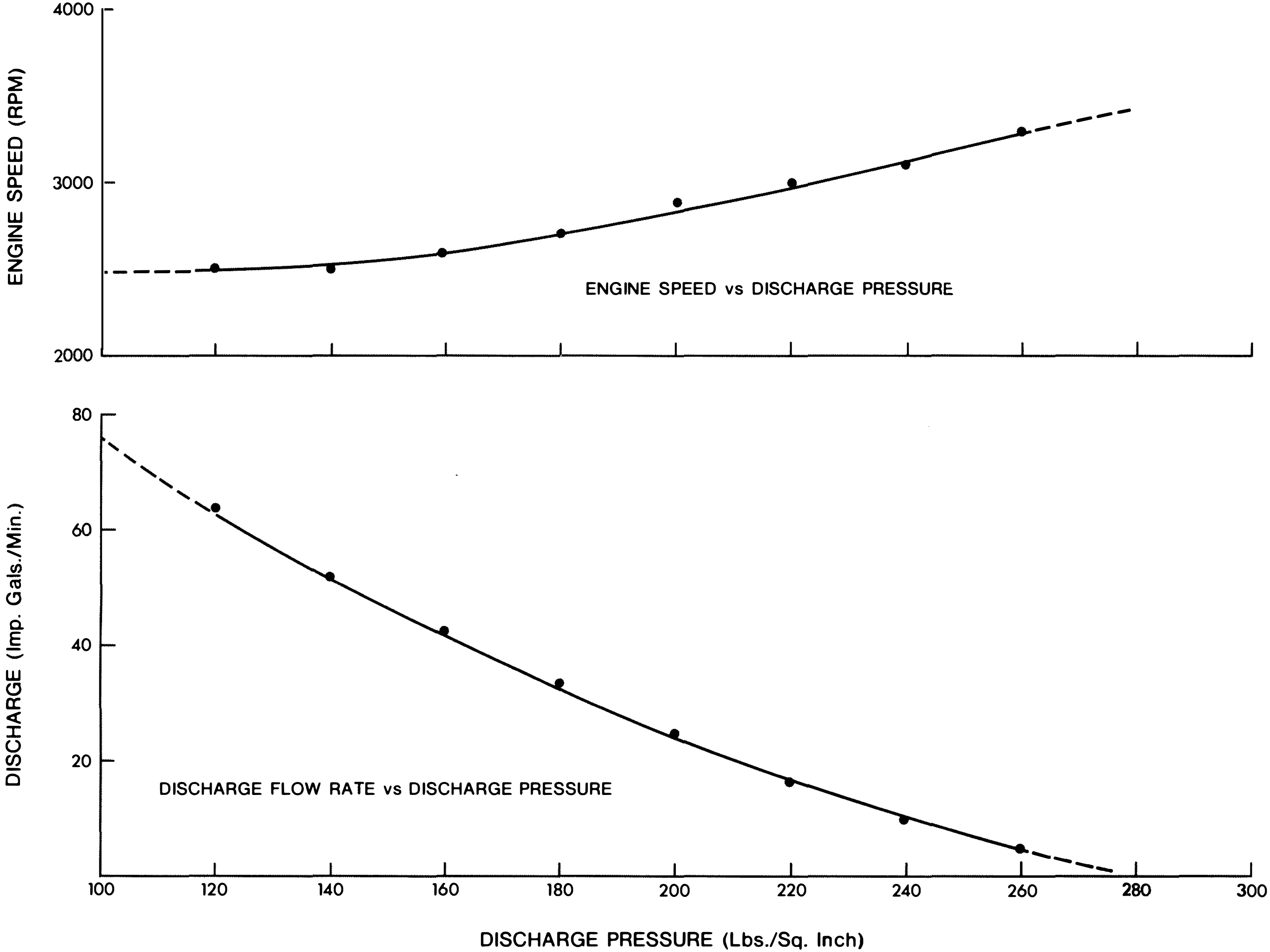
The complete unit, weighing approximately 75 pounds *(34 kg)* is mounted on a tubular-steel frame and is heavily chromium plated to avoid corrosion. The Paramount Cub can be mounted on a wooden packboard frame and easily transported to the fire site by one man.

### *PARAMOUNT SENIOR*

The Paramount Senior was one of the heavier portable forestry fire pumps, weighing approximately 225 pounds *(102 kg)* and was introduced onto the market by Pumps and Power Ltd. in 1937. There was a great improvement towards portability over the original Paramount Pump which was powered by a four-cylinder Austin engine. The unit can be carried by two men in the field by making use of the telescopic carrying handles which project from the frame.

The Paramount Senior's engine is gasoline-powered four-stroke twin-cylinder opposed. Engine cylinder head and exhaust manifold are water cooled by water provided from the last stage of the four-stage centrifugal pump. The Senior does not make use of a conventional flywheel-type magneto, in its place is a rotary induction-type magneto, gear driven from the engine crank shaft. Spark advance and retard are manually controlled by the operator. The unit can be started either by a crank geared to the crank shaft or by a manual starter rope pulley attached to the engine flywheel. The gasoline supply tank is mounted above the centrifugal pump with the fuel being gravity fed to the single barrel float-type carburetor. The carburetor is fitted with manual controls for throttle and choke. It is mounted

** A Neptune outboard, the same make of engine used on the American Edwards "Model 85" portable forestry pump which was built about the same time, and was the first pump designed to meet U.S. forestry standards.*




**PUMPS & POWER LIMITED PARAMOUNT SENIOR CENTRIFUGAL PUMP**

*Fig. 24. Performance curve of Paramount Senior*

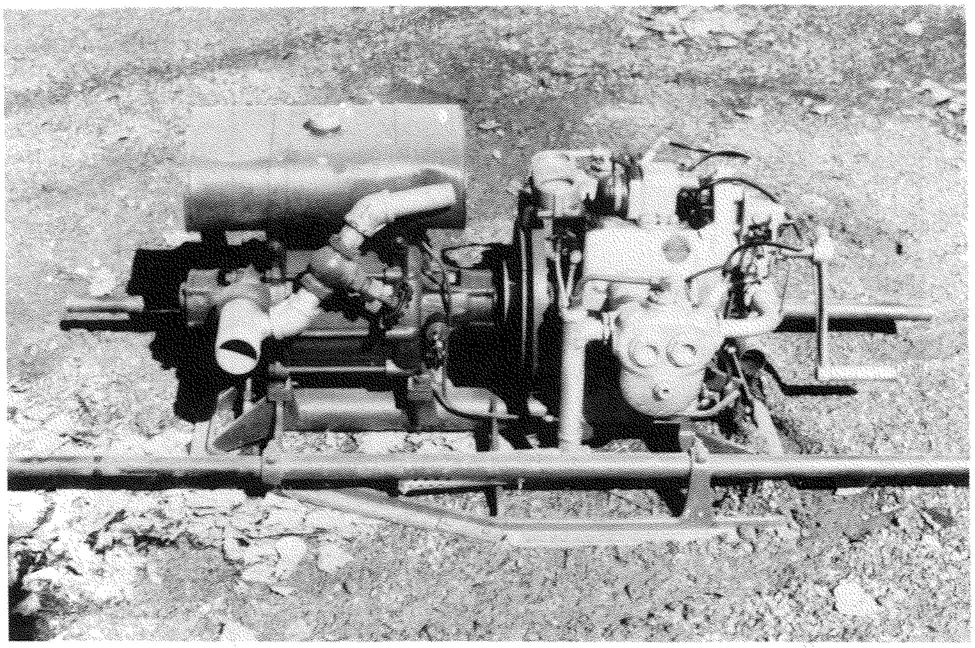


*Fig. 25. Paramount Senior.*

on a double manifold thereby supplying both cylinders. Lubrication of engine parts is obtained from the crankcase with no oil being added to the gasoline. Lubrication for the pump's packing glands is provided by grease cups mounted to the side of the pump body. A good grade of cup grease is recommended; however, a grease with a graphite base is not suitable as it will tend to wear packing gland surfaces.

The four-stage centrifugal pump uses corrosion resistant aluminum impellers and requires little maintenance. As the pump is centrifugal and not self-priming it requires the use of a foot valve and strainer. The pump's 2-inch *(51 mm)* suction and 1-1/2-inch *(38 mm)* discharge are standard hose connections compatible with CSA Standard B89.

## *WAJAX DDVA*

The Wajax DDVA was developed from the earlier model DDV's introduced by Watson-Jack Limited in the 1920's. The letter A of DDVA indicates the use of aluminum parts in its construction. The DDVA was manufactured by Wajax until 1954 and was then replaced in 1955 by the Wajax Mark 1. The DDVA is an internal rotor, positive-displacement pump connected to a two-cycle vertical-in-line twin-cylinder, water-cooled engine. Water cooling for the engine is provided from the discharge side of the pump, the water flowrate being controlled by an adjustable valve in the cooling line. The engine fuel supply tank is mounted above the pump body with a flexible fuel line running from the fuel tank filter to the single barrel float-type carburetor. The fuel mixture recommended for this unit is 2/3 pint of oil to 1 gallon of gasoline. Carburetor adjustments comprise a choke lever, throttle control lever and needle valves for adjustment of fuel flowrate. Ignition is provided by a high-tension flywheel-type magneto with manual spark advance and retard. The doubled-lobed cam on the crankshaft opens and closes the contact points twice per revolution, supplying a spark to both plugs simultaneously although only one cylinder at a time is in the correct cycle to fire. An ignition kill switch is mounted on the armature handle of the flywheel, however, there is no governor control or automatic cut-out switch to limit engine speed. Starting of the engine is accomplished through use of the manual-starter-rope pulley mounted on the flywheel rim.

Engine lubrication is supplied through the fuel mixture, and supplementary lubrication of engine bearings is supplied from oil kips mounted on the engine bearing housing. Grease cups, mounted on the pump body, supply lubrication to the aluminum alloy bearings. The pump's 2-inch *(51 mm)* inlet (suction) and 1-1/2-inch *(38 mm)* outlet (discharge) connections are both made to standard forestry thread specifications.

Through the use of aluminum parts in its construction the dry weight of the DDVA is approximately 75 pounds *(34 kg)*, a decrease of 25 pounds *(11.3 kg)* over the earlier model DDV's. Holes are provided in the frame for the insertion of handles if the unit is to be carried by two men. The DDVA may also be backpacked by one man if the unit is mounted on a special carrying frame supplied by the manufacturer.

The Wajax DDVA, like the other DDV's, has not been manufactured for a number of years and consequently spare parts are no longer obtainable. The interchange of many parts between the DDVO and DDVA should not present problems as the units are identical except for the use of aluminum alloy parts on the DDVA.

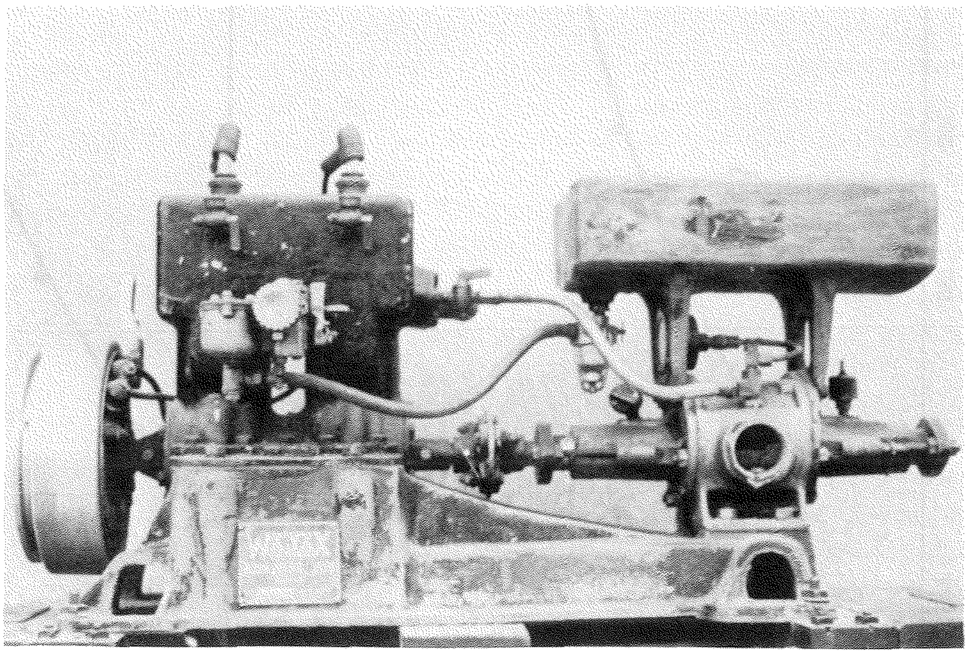
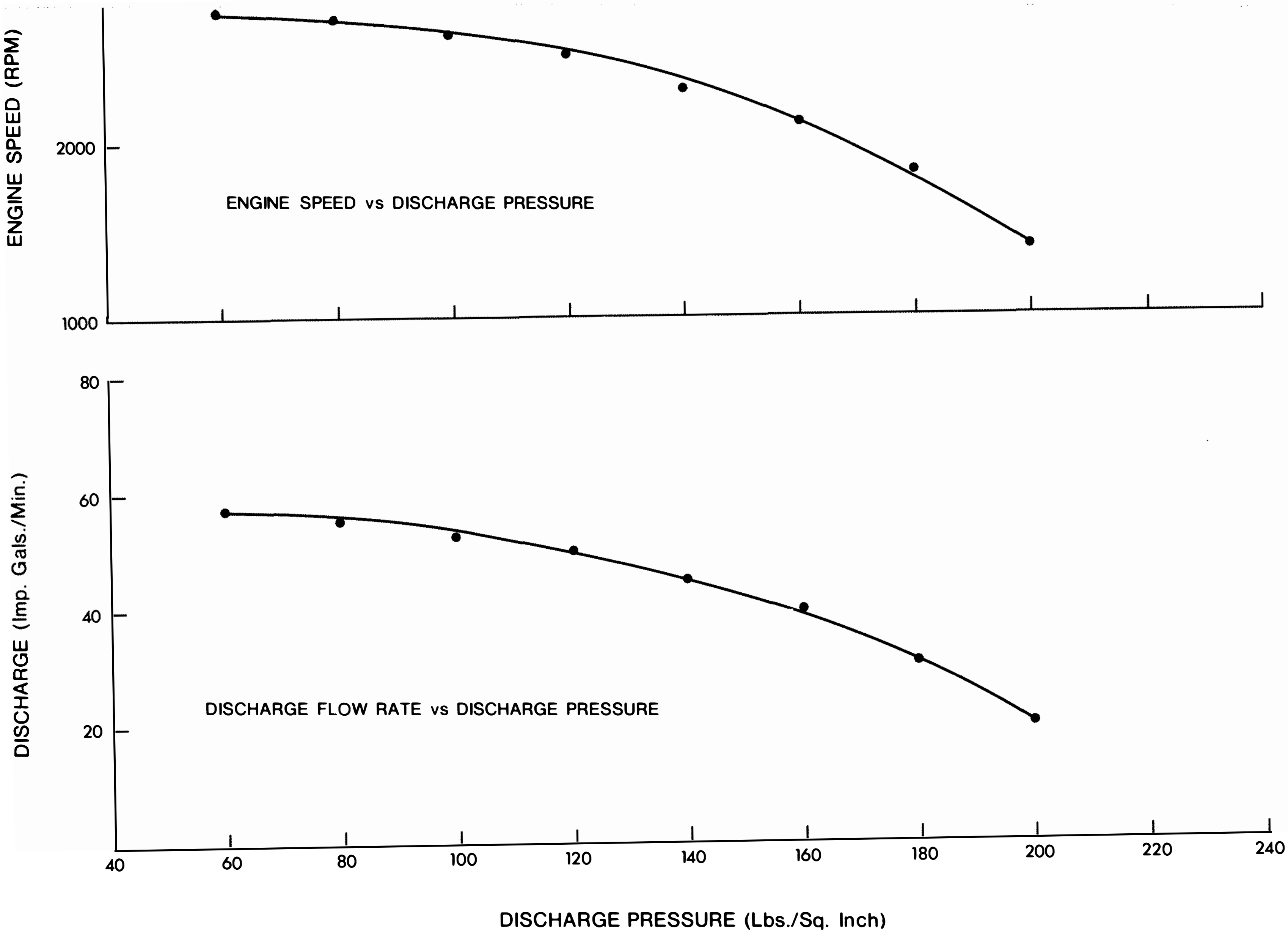


*Fig. 26. Wajax DDVA.*




WAJAX DDVO POSITIVE DISPLACEMENT PUMP

## OPERATING PRINCIPLES OF THE TWO-CYCLE ENGINE

The engines powering most current centrifugal pumps are two-cycle, single-cylinder, and air-cooled, with the exception being the twin-cylinder Wajax Mark 1. Two-cycle engines differ from four-cycle engines in that they have a power stroke with each revolution of the crankshaft and make use of piston porting to replace intake and exhaust valves. Lubrication for moving parts is supplied through the fuel mixture rather than the use of a crankcase oil sump. the cylinder is compressed, and a vacuum is created in the crankcase. In a two-cycle engine, as the piston moves upward in the cylinder, two events occur, the air/fuel charge in created in the crankcase. This vacuum is sensed at the carburetor and an air/fuel charge is drawn down into the crankcase. Just before the piston reaches the maximum upward position a spark ignites the compressed fuel charge. As the burning gas expands it forces the piston downwards causing a thrust on the crankshaft. The piston then exposes the exhaust port allowing the expanded gases to escape. The fresh air/fuel charge in the crankcase (that has been compressed by the piston) is now allowed to enter the cylinder with the uncovering of the intake port.

Most carburetors supplied with small gasoline engines are the all-position, diaphragm-type with integral fuel pump. The integral fuel pump of many carburetors is a rubber diaphragm pump operated by alternating vacuum and pressure impulses from the engine crankcase. Intake and discharge of fuel are controlled by check valves within the pump body. The purpose of the carburetor is to supply the correct air/fuel mixture under all engine operating conditions. The fuel is metered into a stream of air passing through the venturi of the carburetor. The proportion of fuel to air is controlled by a needle valve. During low speed operation the engine requires a richer fuel mixture than at normal operating speed. However, the vacuum created through the venturi at low speed is insufficient to draw the required fuel from the fuel jet. To make up the deficiency a second jet, called the low speed or idling jet, has been added at the throat of the carburetor. At low speed operation when the throttle plate is almost closed a high vacuum is created across the idling jet, drawing in a supplementary supply of fuel. As the throttle plate is opened and engine speed increases this vacuum decreases and fuel is no longer drawn in through this jet but passes through the main fuel jet. At high speed operation of the engine, a vacuum is again present across the carburetor throat and the idling jet once again supplies fuel to supplement the main jet's discharge.

A flywheel-type magneto supplies energy for the ignition system. The magneto is located on a fixed stator plate behind the flywheel and contains the ignition coil, condenser, and breaker point assembly. The flywheel is fitted with a magnet ring on it's inside rim. A revolving magnetic field is produced by the flywheel and this field induces a magnetic flux through the ignition coil. Current is allowed to reach a maximum at which point a cam located on the crankshaft opens the breaker points. As the points open the magnetic field collapses inducing a high tension voltage in the secondary winding of the coil. The purpose of the condenser is to absorb some of the current developed and help prevent the points from burning at the initial stage of opening. The high voltage induced in the secondary winding travels along the high-tension wire to the spark plug, jumps the gap and ignites the fuel mixture.

## *TERMS DEFINING ENGINE PERFORMANCE*

*Horsepower* - a specific rate of doing work. Work per unit of time. One horsepower is equal to 550 foot-pounds per second *(745.7 W)*.

*Torque* - is defined as the product of the force and the perpendicular distance from the line of action of the force to the axis of rotation. In a gasoline engine, torque is the product of the force created on the connecting rod multiplied by the perpendicular distance to the centre of the crankshaft.

*Frictional Horsepower* - the horsepower lost due to friction between moving parts of the engine.

*Brake Horsepower* - Brake horsepower is measured with the use of a pony brake attached to the engine crankshaft. A spring scale or balance will measure the turning force produced by the engine. Multiplying this force by the distance in feet to the centre of the crankshaft will determine the engine torque at a specific engine speed. The horsepower developed at that speed will be equal to the torque in foot-pounds multiplied by the engine rpm and divided by 5252.

Bhp = Torque X rpm/5252

Engine brake horsepower may also be measured with the use of a dynamometer. The dynamometer is an electric generator; for every 746 watts of electric power developed there is one brake horsepower present.

## *ENVIRONMENTAL FACTORS AFFECTING ENGINE PERFORMANCE*

There are three environmental factors which can have a noticeable affect upon engine performance.

(1) Ambient air temperature
(2) Barometric pressure
(3) Relative humidity

High ambient air temperatures at the pumping site can have a detrimental effect upon engine performance. Air temperatures may be high because of the heat generated by the fire or the normally high air temperatures associated with forest fire conditions. As temperatures increase, the density of the air decreases. This decrease in the density of the air lowers the amount of oxygen available for combustion.

The engine's ability to cool itself, that is, its rate of transferring heat to the atmosphere is dependent upon the temperature difference between the air temperature and cylinder temperature. With increasing ambient air temperature the rate at which heat can be transferred to the air will be decreased. The engine will therefore run hotter. The higher temperatures will place more strain on engine parts and decrease the oil's lubricating abilities.

High ambient air temperatures will also have an effect on carburetor performance. Gasoline is volatile by nature, has a boiling point between 40-100°C and is readily vaporized. Vapor locks can easily form in the fuel line and carburetor and result in the eventual stalling of the engine. The vapor can also take the form of a continuous stream of bubbles which will cause erratic carburetion with resulting poor engine performance. Shading the fuel supply tank and gas line from direct sunlight will help alleviate this problem. Painting the fuel supply tank and fuel line a white or metallic colour will help reflect some of the sun's radiant heat.

The humidity of the air can have a positive effect on engine performance. During the power stroke the water molecules in the air absorb heat and turn to steam, cooling the engine. As the relative humidity increases the water molecules tend to displace an increasing amount of oxygen. However, the per cent decrease of oxygen is negligible compared to the increased cooling ability of the engine.

While some humidity in the air may be good for engine performance, care should be taken that moisture in the humid air has not condensed inside the fuel tank. Since water is heavier than gasoline, it will sink to the bottom of the tank and collect there unnoticed. Fuel supply tanks that have been sitting in storage for long periods of time should be drained and flushed with fresh gasoline before use.

The density of the air varies in direct proportion to the barometric pressure. An increase in barometric pressure will increase the density of the air and a decrease in barometric pressure will rarefy the air. Barometric pressure can reflect a change in weather or an increase or decrease in altitude. With low barometric pressure, as with higher air temperatures, the amount of oxygen available for combustion will decrease. As the density of the air decreases, its ability to absorb heat from the engine's cooling fins will also decrease causing the engine to run slightly hotter.

As mentioned before, in a two-cycle engine, as the piston moves upward in the cylinder a slight vacuum is created in the crankcase. This vacuum is sensed at the carburetor and an air/fuel charge is drawn in and down into the crankcase. The pressure differential between crankcase pressure and barometric pressure governs the rate of air intake. Decreasing barometric pressure will decrease its ability to push air into the carburetor. As the air flow rate decreases there will be a smaller pressure drop across the venturi, drawing less fuel from the high-speed jet. Engines operating continuously at high altitudes are sometimes fitted with larger jets and wider needle valve settings to compensate for the rarified atmosphere.

## CALCULATION OF DECREASE IN HORSEPOWER DUE TO BAROMETRIC PRESSURE

The decrease or increase of horsepower due to barometric pressure is based upon the ratio of the actual barometric pressure to the standard barometric pressure of 14.7 psia (pounds per square inch absolute).

$$\text{Actual Hp} = \frac{\text{Bhp} \times \text{Actual Barometric Pressure}}{14.7 \text{ psia}}$$

*Example* 14 Bhp engine operating 2000 feet above sea level
Actual barometric pressure = 13.7 psia
14 Bhp X 13.7/14.7 =
13.04 actual horsepower

## ENGINE OIL

The proper choice of engine oil is a most important factor in engine performance. Only the engine oil recommended by the manufacturer should be used. Utility or chain-saw oils should be avoided. These oils are adequate when used in the engines they were specified for, but will breakdown under severe operating conditions.

A chain-saw oil would seem appropriate since both chain saw and pump use a light weight two-cycle air-cooled engine, however, chain saws are only operated intermittently at full throttle and are not subjected to the speed and continuous loads of a pumping engine. The use of a poor grade of lubricating oil will accelerate carbon formation on spark plugs, cylinder heads, pistons, and exhaust and intake ports. Carbon build-up cuts down engine performance as it will interrupt the efficient flow of gases through intake and exhaust ports. Carbon build-up on cylinder heads and pistons will tend to increase the compression ratio of the engine making it more prone to pre-ignition.

The use of a high detergency oil is not recommended for two-cycle engines. This type of oil has a beneficial effect on four-cycle engines by helping to reduce deposits on cylinder walls and prevent piston varnishing. In a four-cycle engine, the oil is not consumed during combustion to the extent it is by a two-cycle engine. The metallic additives found in the detergent oils such as molybdenum, graphite, phosphorous, and zinc may accelerate spark plug fouling and reduce spark plug life in a two-cycle engine. The incidence of pre-ignition is also increased by the use of metallic additive oils. The following table lists the appropriate grade of gasoline and oil as recommended by the manufacturer for use with their engines.

### *MANUFACTURER'S RECOMMENDED GASOLINE AND OIL*

| PUMP MODEL | FUEL RATIO | GASOLINE | OIL |
|---|---|---|---|
| Wajax Mark 1 | 16.1 | No. 2 Regular Automotive | SAE 30/40 Non-detergent Outboard Motor Oil |
| Wajax Mark 2 & 2M | 16.1 | No. 2 Regular Automotive | SAE 30/40 Outboard Motor Oil |
| Wajax Mark 3 | 16.1 | No. 2 Regular Automotive | SAE 30/40 Outboard Motor Oil |
| Wajax Mark 26 | 16.1 | No. 2 Regular Automotive | SAE 30/40 Outboard Motor Oil |
| Gorman-Rupp Backpack | 16.1 | No. 2 Regular Automotive or White gasoline | SAE 30 Outboard Motor Oil |
| Gorman-Rupp Bushwhacker | 20.1 | No. 2 Regular Automotive | SAE 30/40 Outboard Motor Oil |
| Terry T-7 | 16.3/4 | No. 2 Regular Automotive | Terry 2-cycle engine oil Outboard Motor Oil |

# IGNITION SYSTEM

Ignition systems for small gasoline engines are relatively simple in nature. The number of ignition-related problems involved in engine breakdowns are accordingly low. Operators have a greater tendency to play with carburetor adjustments as they are more accessible than the magneto's, and consequently more problems arise from improperly adjusted carburetors.

All of the modern fire pumping units, with the exception of the Gorman-Rupp Bushwhacker, are equipped with high-tension flywheel-type magnetos using an internal coil. No problems have come to our attention attributable to the use of the external coil provided on the Bushwhacker as it seems quite durable and resistant to moisture. As all flywheel magnetos are of the same basic principle, the following points on ignition maintenance will be applicable to all models.

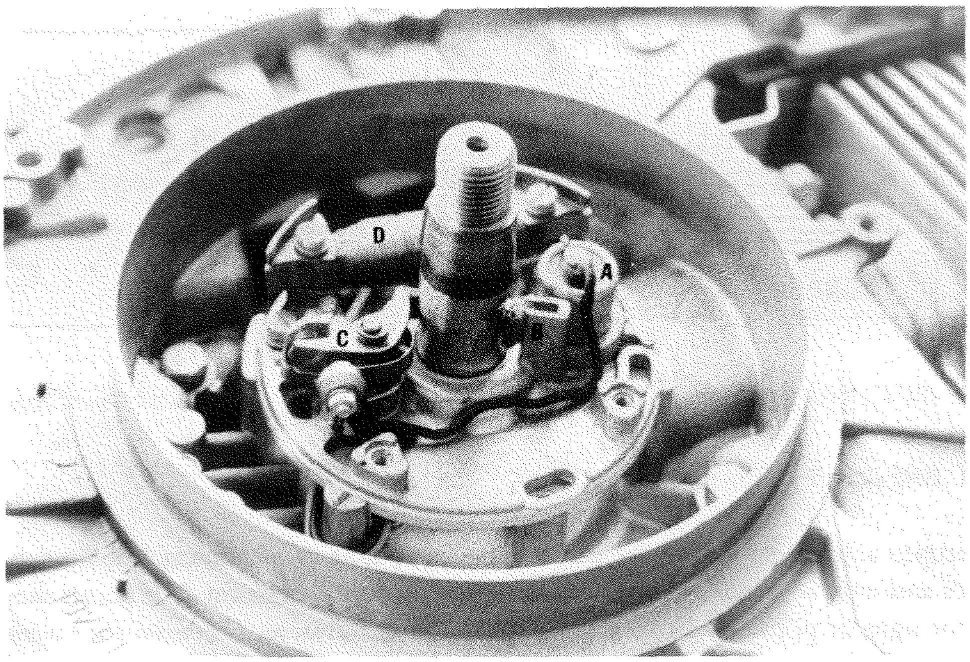



*Fig. 28. Gorman-Rupp ignition system.*

*a. Condensor, b. Oiler, c. Breaker Points, d. Coil*

## *CONDENSERS*

The purpose of the condenser is to store the electrical charge developed in the coil and thus prevent the contact breaker points from burning during the early stage of opening. If there was no condenser present, or the coil was in faulty condition, the electrical energy would arc across the points as they begin to open and cause their rapid deterioration.

Condensers are constructed by alternating layers of metal-foil plates between dielectric insulators. The metal-foil plates are alternately connected to the positive and negative poles of the condenser. The metal foil and insulating plates are coiled and placed inside an aluminum can. The metal can is then hermetically sealed to prevent the entrance of moisture which could conduct electricity across the plates.

When replacing a condenser it is important to choose a replacement of similar capacity. A condenser is rated according to its ability to store an electric charge*. One of insufficient capacity will not store the necessary amount of charge and will allow the remaining charge to arc across the contact points. There will be a weaker arc across the spark plug gap due to the smaller charge held by the condenser. The use of a condenser of excessive capacity will also have a detrimental effect on point life and spark plug performance. Condensers of a larger capacity require more time to charge and discharge. With an increased charging time and greater capacity, larger voltages will build-up and create excessive voltage across the points causing them to burn. Also, increased arcing time and the possibility of refiring across the spark plug gap will decrease the service life of a plug.

When examining the condenser for faults check for loose or corroded wires and ensure a good ground for the condenser base. The absence of a good electrical connection will increase the series resistance to the condenser which, in turn, will increase the charging time.

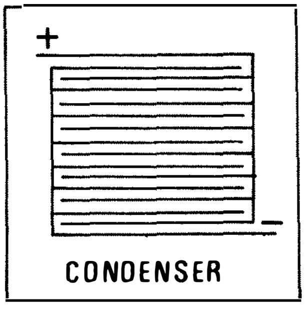



*Fig. 29. Construction of condenser.*

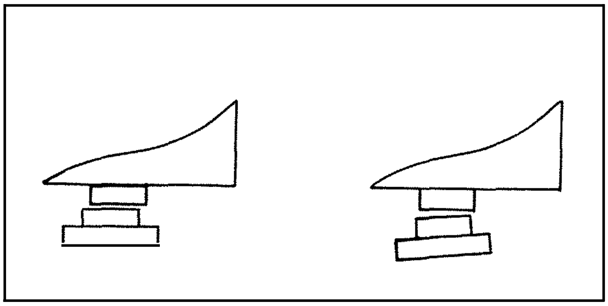


*Fig. 30. Contact point misalignment.*

## *CONTACT BREAKER POINTS*

The proper adjustment setting of contact breaker points is of utmost importance to engine performance and with a little attention it is a fairly simple task to perform. The points should first be examined for signs of pitting and corrosion as well as proper clearance between the bushing and the contact swing arm. Excessive clearance between the arm and the bushing will frustrate any attempt to align and set the points. Figure No. 30 shows two types of contact point misalignment which could exist between the contact points on the arm and stationary plate. These types of misalignment can be caused by improper adjustment of the stationary plate or bending of the contact breaker point assembly during installation.

Contact breaker point pitting or corrosion could be caused by several factors: a condenser of incorrect capacity, crank case oil vapor leaking past the oil seals, improper adjustment of breaker point opening and misalignment of breaker points. Mildly corroded or pitted contact points can be resurfaced by the use of a contact point file. The point file should be held parallel to the point surfaces to avoid cutting a bevel. Allow the contact points to close on the file, this will provide sufficient cutting force and remove equal amounts of metal from both surfaces. Never use an emery cloth or sandpaper to dress contact point surfaces. Small particles of sand or dust may remain on the contact point surfaces preventing the points from closing completely. The electric charge will then arc across the gap and burn the contact point surfaces.

* *Condensers are rated in microfarads. A capacitor or condenser has a capacitance of 1 farad if 1 coulomb of charge is deposited on the plates by a potential difference of 1 volt across the plates.*

The condition of the breaker arm rubbing block should be examined, and if the rubbing block is worn excessively, loose or broken, install a new contact breaker point assembly. Snap back the breaker point swing arm to check the tension of the leaf spring. Lack of a good tension will allow the points to float or remain open at high rpm.

## *SPARK PLUGS*

All spark plugs have a characteristic known as the heat range. The heat range of the plug is an indication of the plug's ability to transmit heat energy through the body of the spark plug to the surrounding cylinder head. A plug with a high heat range will have a longer insulator nose-length than that of a plug with a low heat range. The heat travelling through a "hot" plug will have a longer path through the insulator nose before it reaches the metal shell of the spark plug. Therefore, the mean temperature developed at the insulator nose will be higher for a "hot" plug as the heat cannot be dissipated at the same rate as from a "cold" plug. Whether a hot or cold plug is used is dependent upon engine operating conditions. An engine which is used mainly for low power or low speed operation is normally fitted with a hot plug. By using a hot plug the temperature of the insulator nose and centre electrode is kept sufficiently high to burn off any carbon deposits which tend to form under low power operation.

Engines which are utilized for high speed or high power operation will develop considerable heat. When temperatures of over 1400°F *(760°C)* occur in the combustion chamber, serious chemical corrosion of the spark plug electrode may develop and significantly shorten spark plug life. If the temperature in the combustion chamber reaches 1750°F *(950°C)*, pre ignition may occur due to localized hot spots on the cylinder head or piston crown.

The engines powering centrifugal pumps are operated in their middle and higher rpm ranges and require spark plugs with a good ability to dissipate heat. A cold plug, having a shorter insulator nose than that of a hot plug, will dissipate combustion chamber heat at a greater rate. When engines utilizing cold plugs are idling or used for low power operation, the spark plug will have a greater tendency to foul, as cold plugs will dissipate too much heat from the insulator nose. When the insulator temperature is lowered below 750°F *(400°C)*, carbon particles will start to accumulate, and may result in carbon fouling of the plug. As a precaution against spark plug fouling the engine should not be idled for sustained periods of time.

*Fig. 31. Carbon fouled spark plug.*

*Fig. 32. Lead fouled spark plug.*

Following is a list of manufacturer-recommended spark plugs to be used with their respective portable forestry fire pumps. If the recommended plugs are used, along with the correct gap setting, a minimum amount of trouble should develop with this component of the ignition system.

For the adjustment of the electrode gap, a wire spark plug gauge will be required. These gauges are designed specifically for spark plugs and are equipped with an electrode bender for use in setting the side electrode. Wire gauges are preferable to the flat feeler gauges as they give a more accurate indication of the electrode gap. As the steel wire of the gauge is of constant diameter, it can be held at any angle to the electrode gap and will still give a true reading of the gap spacing. This is not possible with a flat feeler gauge which must be held perpendicular to the spark plug body at all times. Holding the feeler gauge at an angle to the electrode gap may spring the side electrode away and will not give a true indication of the gap setting. Another reason for not using a flat feeler gauge is that it will ride over the top of electrode pitting or corrosion and give only an indication of the smallest gap present.

## *RECOMMENDED SPARK PLUGS*

| PUMP MODEL | POINT GAP | PLUG GAP | SPARK PLUG |
|---|---|---|---|
| Wajax Mark 1 | 0.015" | 0.025" | Champion J-67 |
| Wajax Mark 2 & 2M | 0.016"-0.018" | 0.016"-0.022" | Bosch M240-T1 |
| Wajax Mark 3 | 0.014"-0.018" | 0.016"-0.020" | Bosch M240-T1 |
| Wajax Mark 26 | 0.014"-0.018" | 0.016"-0.018" | Bosch W225-T1 |
| Gorman-Rupp Backpack | 0.015" | 0.038" | Champion L4J, I4 |
| Gorman-Rupp Bushwhacker | 9.014"-0.018" | 0.016"-0.020" | Champion K-7<br>Bosch M260-T1 |
| Terry T-7 | 0.025" | 0.025" | Champion H-3 |

# CARBURETOR

With the exception of the Wajax Mark 2, all recent portable pumps have been fitted with Tillotson carburetors. The Tillotson carburetor was designed specifically for use with two-cycle engines to take advantage of the crankcase pressure pulses to operate the diaphragm fuel pump. Adjustments and controls on the carburetor are limited to throttle and choke shutters along with high speed and idle adjustment screws. The high speed and idle adjusting screws are spring loaded to prevent movement due to engine vibrations and require few adjustments after the initial settings have been made. Erratic behaviour of the carburetor is often the result of field conditions rather than incorrect setting of the carburetor adjustment screws. A commonly occurring problem is that of vapour lock, which is an accumulation of gasoline vapour bubbles in the fuel supply line and fuel pump body. Vapour bubbles form when the vapour pressure of the gasoline exceeds the pressure in the fuel line. The vapour bubbles displace the liquid gasoline, limiting the amount of fuel available for combustion, resulting in loss of power, missing and under extreme conditions, engine stalling. Heat conducted from the engine block to the carburetor body and fuel line is the main factor in creating vapour locks. Another cause of vapour locks can be attributed to the use of winter grade gasoline. Fuel companies switch to a gasoline with a higher vapour pressure during the winter months to allow easier vaporization of the gasoline in the carburetor. The high vapour pressure of the winter grade gasoline will cause serious vapour lock problems if used on days with high ambient temperatures. The switch from winter grade to summer grade gasoline normally takes place around May 1.

Another temperature related carburetor problem is that of carburetor icing. Carburetor icing is the accumulation of ice particles on the throttle plate, blocking off the flow of air through the carburetor. Carburetor icing will occur only under certain conditions: an ambient air temperature between 28°F *(2°C)* and 55°F *(13°C)* combined with a relative humidity between 65 and 100% and will only occur under starting conditions where the carburetor body has not yet been warmed up by heat from the engine block.

When gasoline is vaporized by mechanical means it will absorb an equivalent amount of heat that would have been necessary to vaporize it by heat alone. The rapid vaporization of the gasoline will lower the temperature of the throttle plate and venturi by as much as 25°F *(14°C)*. With a high relative humidity present, the water vapor in the air will collect on the throttle plate and form ice. The air passage will be blocked, and will result in the stalling of the engine.

To prevent carburetor icing under cold, humid conditions, run the engine at a faster idle than normal during engine warm-up. There will be a larger gap between the throttle plate and carburetor throat which will make it more difficult for the formation of ice to take place.

## *COMMON CARBURETOR PROBLEMS*

The following is a list of possible causes for erratic carburetor performance:

(1) Carburetor mounting loose. If not bolted securely to the intake manifold, air will leak past the gasket causing the air/fuel mixture to become leaner.

(2) High speed needle improperly adjusted.

(3) Low speed needle improperly adjusted.

(4) Loose jets.

(5) Worn needle valve and seat.

(6) Dirt in carburetor and passages.

(7) Dirty fuel strainer screen.

(8) Cracked diaphragm in fuel pump.

(9) Sticking float needle valve.

(10) Blown or leaking carburetor gaskets.

(11) Welch plugs not sealing.

(12) Fuel tank pressure build-up.

## ENGINE PROBLEMS

### *FREQUENT PROBLEMS RELATED TO HARD STARTING OR NON-STARTING ENGINES*

**Causes related to carburetor or fuel supply**

(1) Gas tank is empty.

(2) Gas tank shut-off valve is closed.

(3) Air vent on gas tank is closed.

(4) Water in gasoline.

(5) Oil has been poured into gas tank before gasoline was added and not properly mixed, resulting in clogged carburetor.

(6) Carburetor mixture too lean.

**Causes related to ignition**

(1) Contact breaker points remain open.

(2) Coil has shorted out because of contamination by water.

(3) Leaking condenser.

(4) High-tension lead to spark plug disconnected, grounded or leaking.

(5) High-tension lead to armature disconnected, grounded or leaking.

(6) Break between high-tension lead and spark plug cap.

(7) Points not properly spaced.

(8) Points contaminated by oil from leaking oil seal between camshaft and main bearings.

(9) Contact breaker points out of alignment.

(10) Breaker point camshaft worn.

(11) Spark plug porcelain cracked.

(12) Spark plug improperly gapped.

(13) Centre electrode of spark plug not secure.

(14) Engine had been idled down too long on previous run resulting in spark plug carbon fouling.

(15) Automatic cut-out switch activated and not reset.

(16) On-off switch grounded through loose or frayed wire.

**Engine flooding**

Engine flooding could be the result of a mechanical fault.

(1) The gas tank cap or vent could be closed or plugged allowing excessive pressure to build up.

(2) The fuel pump diaphragm may be incorrectly installed or damaged allowing fuel to flow past the inlet control valve.

(3) The inlet control valve fulcrum may be loose or damaged allowing fuel to flow directly to carburetor jets.

(4) The inlet control lever might not be sitting flush with the metering chamber floor.

(5) An incorrectly adjusted choke stop or broken release spring. The choke will remain partially closed when it is thought to be open.

## *ERRATIC PERFORMANCE WHILE ENGINE UNDER LOAD*

**Causes related to carburetor or fuel supply**

(1) High speed needle adjustment.

(2) Sticky float needle valve.

(3) Cracked diaphragm in fuel pump.

(4) Fuel tank vent clogged.

**Causes related to ignition**

(1) Lead and carbon fouling of spark plug.

(2) Spark plug porcelain cracked.

(3) Spark plug improperly gapped.

(4) Centre electrode of spark plug not secure.

(5) Leaking or corroded condenser.

(6) Breaker points pitted.

**Other causes**

(1) Reed valves fouled.

(2) Crankcase seal leaks.

## *VIBRATION*

Engine vibration is a destructive force. Single-cylinder engines are subject to more vibration than multi-cylinder engines. The power strokes of multi-cylinder engines are smoothed by the larger reciprocating masses and the power strokes of opposing cylinders. The single-cylinder engine is solely dependent upon the balancing factor of the flywheel. To help dampen vibration, the base frame of portable fire pumps incorporate springs or rubber bushings which absorb much of the shock.

If excessive engine vibration is present, it may have been caused by either a mechanical fault of the engine or frame. Excessive engine vibration could be the result of an out-of-balance flywheel, bent crankshaft, rod, or misalignment of the pump drive shaft. It may also be due to mounting the engine incorrectly to the frame, broken rubber bushings or springs.

Avoid bolting the base frame directly to slip-on tanker platforms as this will prevent adequate dampening of engine vibration. Special pump unit spring-mounted bases are commercially available and are designed to absorb shock and to minimize vibration of the pumping unit.

## *OVER-HEATING*

Engine over-heating can be an aggravating and costly problem. Over-heating can be difficult to spot before damage is done to pistons, rings and cylinder walls. High speed and over-loading are the common causes of engine over-heating. In two-cycle engines, however, the most important cause is lack of proper lubrication. The pump's lubrication is controlled by the oil-to-fuel ratio and the quality of the oil used. Insufficient or poor quality oil will increase the friction between the piston and cylinder wall, and other moving parts of the engine. The horsepower lost through friction will generate large amounts of heat. The normal amount of heat generated by combustion, combined with friction heat may expand the moving parts, such as the piston, to the point where they may seize.

Over-heating caused by a mechanical failure or incorrect adjustment is also possible. One or a combination of the following can result in engine over-heating.

(1) *Operating engine without air shroud attached.* There will be an insufficient volume of air blown across the engine cooling fins to absorb the heat generated.

(2) *Broken or bent flywheel fan blades.* The remaining fan blades will be incapable of blowing a sufficient amount of air across the cooling fins.

(3) *Clogged cooling fins.* Dirt, oil, or other debris clogging the cooling fins will act as insulation to keep the heat from escaping to the atmosphere.

(4) *Incorrect cylinder head gasket.* A gasket which is too thin will raise the compression ratio of the engine. A higher compression ratio will raise the engine operating temperature. A thicker than recommended gasket will hinder heat transfer to cylinder-head cooling fins.

(5) *Head bolts improperly torqued.* If the head bolts are not tightened to the recommended value, exhaust gas may leak past the head gasket to the outer cooling fins. This will create hot spots on the cylinder head which may lead to cracking of the head.

(6) *Cracked cylinder head.* Localized hot spots may develop in the region of the crack because of the lessened ability to transfer heat across the fracture.

(7) *Carburetor adjusted too lean.* If the carburetor is running lean, not enough oil will be provided to properly lubricate the moving parts of the engine. A leaner mixture will also burn slower and may continue to burn after the exhaust stroke. During the intake of the new air/fuel charge, backfiring through the carburetor may occur.

(8) *Clogged muffler creating high back-pressure.* A clogged muffler will disrupt the efficient flow of exhaust gas from the engine. Exhaust gas contains approximately 30 per cent of the heat generated by the engine and it is therefore very important that it be expelled promptly at the end of each power stroke of the engine.

# CENTRIFUGAL PUMPS

A centrifugal pump is a dynamic fluid machine depending upon the centrifugal action, or variation of pressure due to the rotation of the impeller, to move water through the pump unit. Centrifugal pumps can be of the volute, diffuser, or circular casing type. In the volute and circular casing type, the water is discharged directly from the impeller to channels in the pump casing. From these channels the water is then directed either to the discharge outlet or to a further impeller stage.

Figure No. 33 shows a cross section of a single stage Gorman-Rupp pump volute and impeller. Note the straight vane-type impeller which replaces the normally curved vanes found in most centrifugal impellers. In the diffuser type, the impeller is smaller in size than that of the volute or circular casing type, and is set inside of a diffuser distributor. The diffuser consists of a set of curved guide vanes set between two metal plates. These vanes direct the flow of the water and reduce its velocity. The diffuser tends to equalize the pressure on all sides of the pump body and reduce side thrust on the impeller shaft. Due to the reduced size of the impeller in diffuser type pumps, two or more stages of impellers and diffusers are required to bring the pumping capacity up to an acceptable level.

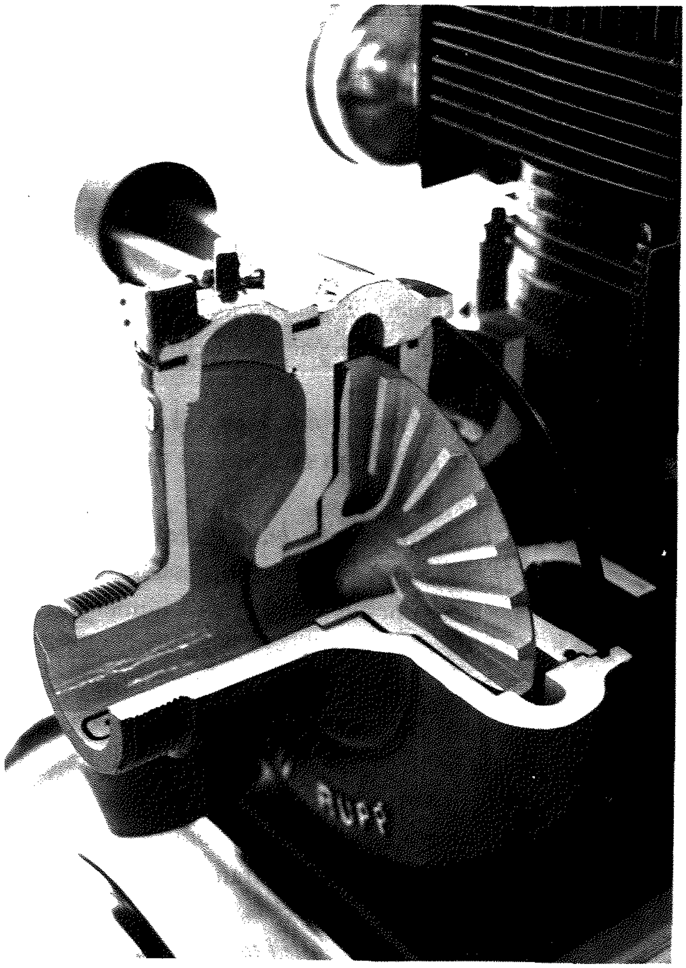



*Fig. 33. Cross section of Gorman-Rupp single stage pump.*

The guide vanes shown in Figure No. 34 are important to the efficiency of the diffuser type of pump. As the water flows axially towards the impeller, it has a tendency to rotate. The rotation interferes with the pick-up of the water by the impeller blades and decreases the efficiency. The guide vanes help to control or eliminate this pre-rotation of the water. Guide vanes are normally placed in the intake (suction) nozzle of the pump, with a blind bushing located at the centre of the guide vanes to hold the end of the pump driveshaft, preventing deflection of the driveshaft during rotation.

Between the stages of a multi-stage pump there is a pressure differential. To prevent the higher pressure water from returning to a lower stage, stationary diffusers are pressed into the pump body, "O" rings on the diffuser rims insure a water tight seal between the pumping stages. Volute and circular

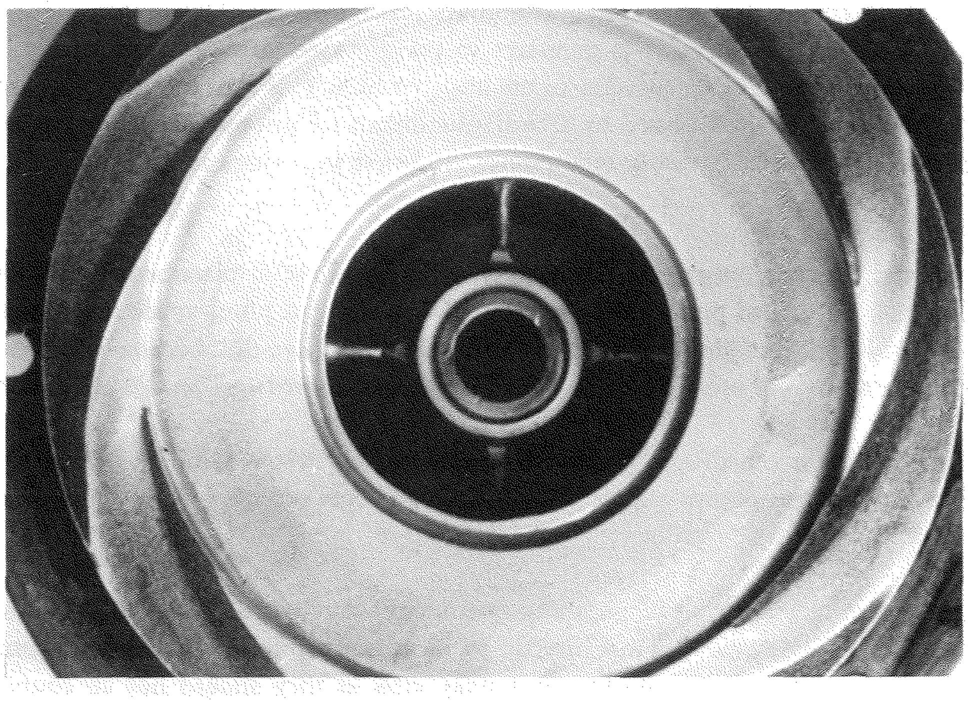


*Fig. 34. Guide vanes.*

casing types of pumps normally do not make use of fixed guide-vanes. A wear ring or clearance ring, as shown in Fig. 35, is used to contain the pump driveshaft and control leakage from the pump casing to the suction intake. The leakage would take place because of the pressure differential between the water discharged from impeller vanes and the water drawn in through the impeller eye. Wear rings are made of a bronze alloy and are always softer than the metal of the impeller. This will insure that the wear ring will absorb the abrasion and wear encountered due to impeller hub deflection and pumping

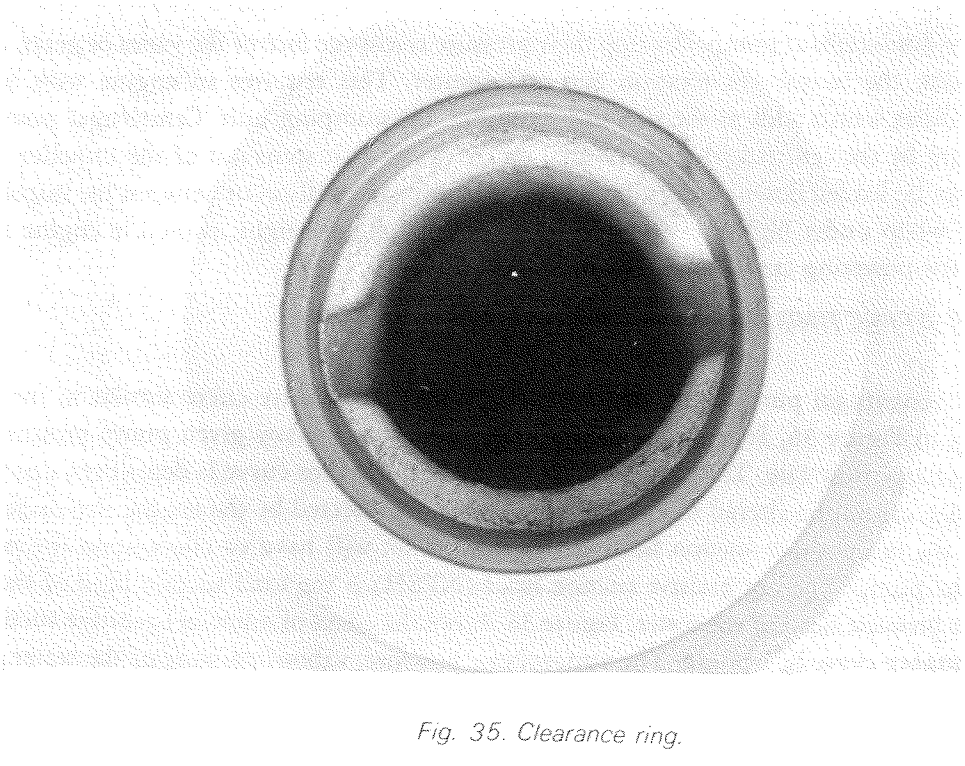


*Fig. 35. Clearance ring.*

muddy water. There is a clearance of 0.006 inches to 0.009 inches between the impeller hub and the wear ring. This clearance will allow a certain amount of leakage to occur between the pump casing and suction inlet, however, the clearance is necessary to prevent sand particles from becoming trapped between the two surfaces, causing abrasion to the impeller hub. This clearance will also allow for the deflection of the impeller shaft caused by a hydraulic imbalance at opposite points on the impeller. Multi-stage volute and circular casing type pumps are fitted with rings at the impeller hub of each stage.

Many of the original forestry fire pumps were of the positive displacement type. However, the advantages of the centrifugal pump over the positive displacement pump made it the most practical and adaptable pump for firefighting service. Centrifugal pumps have thus become widely accepted for use on portable forestry fire units. Some of the advantages of centrifugal pumps are as follows:

(1) The ability of most centrifugal pumps to handle muddy water without damage to impellers. Positive displacement pumps require a water tight seal between the vanes or gears and the pump wall. Sand particles will soon destroy this seal and greatly reduce pumping efficiency.

(2) Centrifugal pumps are capable of pumping in tandem by connecting the discharge hose from the discharge outlet of the first pump directly to the suction inlet of the second pump. Positive displacement pumps require the use of a relay tank as they should not be coupled directly together.

(3) The addition of extra hose lengths to a hose-lay will require the water flow to be temporarily shut-off. A hose strangler or siamese valve may be used to shut-off flow when a centrifugal pump is supplying water to the line without stopping the pump, whereas, a positive displacement pump will stall under no-flow conditions. A positive displacement pump will have to be either shut-down temporarily or, equipped with a relief valve, or a siamese valve and overflow line will have to be incorporated into the hose-lay.

(4) Positive displacement pumps develop their pressure across the face of the vanes or gears. As pressure increases, the torque for rotation becomes greater. This requires an engine with high torque capabilities which adds to the size and weight of the pumping unit. Centrifugal pumps develop pressure by the centrifugal force created on the water as it spins out of the impeller. The pump will not be loaded down under a high torque, as slippage will occur between the impeller and the water when under high pressure operation. A small light-weight, two-cycle engine is therefore ideal for powering centrifugal pumps.

## *FACTORS AFFECTING PUMP PERFORMANCE*

Every centrifugal pump has a characteristic pump performance curve similar to the one shown graphically in Figure 36. It can be seen from the curve that for any given pump pressure there is a known discharge flow rate. The general shape of the performance curve is dependent upon the pump design which cannot be altered by the operator and is not affected by the engine size or performance. However, the net positive suction head at the pump inlet will have an effect upon the performance curve of the pump. The net positive suction head (NPSH) is the total suction head of the water less the vapour pressure head of the water. Figure 36 shows the effect of a low net positive suction head on the performance curve of a pump. The atmospheric pressure, vapour pressure of the water, and height of the pump above the water level will determine the net positive suction head and the subsequent performance of the pump.

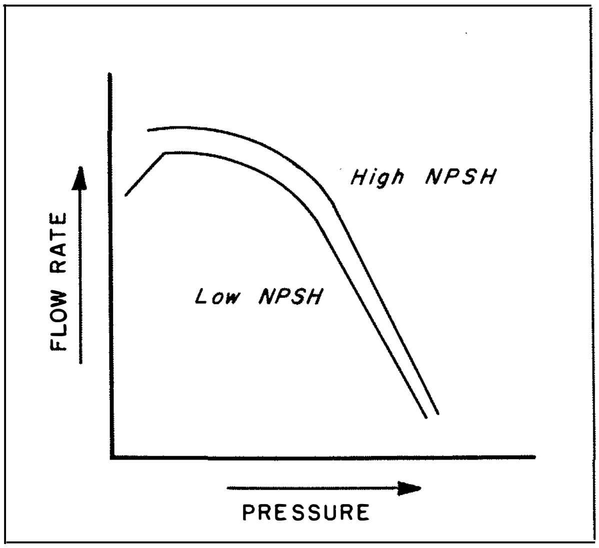



*Fig. 36. Effect of net positive suction head on performance.*

**VAPOUR PRESSURE OF WATER**

| Temperature | | Absolute Pressure | |
|---|---|---|---|
| F° | C° | psi | kPa |
| 32 | 0.0 | 0.0886 | 0.6109 |
| 40 | 4.4 | 0.1217 | 0.8391 |
| 50 | 10.0 | 0.1730 | 1.1928 |
| 60 | 15.6 | 0.2563 | 1.7671 |
| 70 | 21.1 | 0.3631 | 2.5035 |
| 80 | 26.7 | 0.5069 | 3.4949 |
| 90 | 32.2 | 0.6982 | 4.8139 |
| 100 | 37.8 | 0.9492 | 6.5444 |

The vapor pressure of water below approximately 85°F *(29°C)* will not have a significant effect on pump performance. However, under certain conditions, such as pumping from a stagnant pond or from a slip-on tanker, the water temperature can rise to 100°F *(38°C)* or more. With increased vapor pressure the drafting or "lifting" ability of the pump is decreased, and the possibility of cavitation increases. Cavitation occurs when the absolute pressure in the pump suction intake drops below the vapor pressure of the water. Vapor bubbles form in the suction intake and travel into the impeller. Through impeller action the water pressure increases greatly, collapsing the vapor bubbles. The violent collapse of these bubbles can tear away minute particles from the impeller vanes. Prolonged running of the pump under these conditions can cause deterioration of the impeller vanes. Cavitation can also be caused by several other factors such as: the use of too small a suction hose; an obstruction in the suction hose and strainer; or a suction lift that is too high for the volume of water being discharged.

Low atmospheric pressure will have the same effect on pumping performance as a high water temperature. Through the centrifugal action on the water by the impeller vanes, the water is forced into the pump discharge outlet. A partial vacuum is then created in the pump suction inlet because of the absence of water. The absolute pressure within the pump suction inlet is therefore lower than the atmospheric pressure. The unbalanced force created by this pressure differential pushes more water into the pump inlet. As the atmospheric pressure decreases the pressure differential becomes smaller, and accordingly, the force available for lifting and replacing the water that has been discharged also decreases. As a result the absolute pressure in the suction nozzle may fall below the vapor pressure of the water and bubbles form in the intake area. Cavitation at the impeller vanes will occur with the sudden collapse of the vapor bubbles as the water pressure increases.

**Static suction lift**

The static suction lift is the vertical distance between the pump suction inlet and the water supply level. The static suction head may be either positive or negative. Positive suction heads occur when the water supply level is higher than that of the suction inlet. Slip-on tankers and relay tanks are examples of where positive suction head heads will be encountered. The most common suction head is the negative suction lift of between zero and 10 feet *(3.0 m).* It has been found by experimentation that suction lift heads between zero and 15 feet *(4.6 m)* will have very little effect upon the performance of most models of pumps (Higgins, *D.G.,* 1972-74).

Between 15 feet *(4.6 m)* and the maximum theoretical negative suction lift of 33 feet *(10 m)* pump performance may be affected drastically, with the possibility of pump cavitation always present. The force available for pushing water into the pump suction inlet is the difference between the barometric pressure head and the static suction lift head. Barometric pressure will normally provide a head of between 30 and 33.3 feet *(9.1 and 10.1 m)* of water.

The available pressure for suction lift is equal to the static suction lift height minus the barometric pressure in feet of water. Therefore, at 15 feet *(4.6 m)* suction lift there will be approximately one half the maximum force available to push the water through the suction hose. The pump impeller when operating will demand the same amount of water as it has just displaced. It will become harder to meet the pump's demands as suction lift height increases. If the operator wishes to avoid severe cavitation damage to the impeller and pump housing, a change to a smaller diameter nozzle will decrease the pump's demand for water.

**To avoid cavitation**

(1) Set pump up at site of minimum suction lift.

(2) Avoid pumping water that is over approximately 85°F *(29°C).*

(3) Change to smaller diameter nozzle tip.

(4) Throttle engine down if a smaller replacement tip is unavailable.

(5) Avoid the use of suction hose of a smaller diameter than specified by manufacturer.

## PERFORMANCE TESTING

Before pumps are brought out to the fire site it is a good idea to know the pumping capacity of the unit. A performance test carried out during the spring, and at regular intervals during the summer, will keep the fire boss informed of the capabilities of his pumping units and enable him to better plan their allocation during a fire situation.

To set a control for the reasonable comparison of the pumping unit's efficiency from test to test, it is imperative that the engine's carburetor and ignition be set according to manufacturer's specifications at the start of each test. Suction lift height, length of discharge hose, and type of siamese valve must also remain the same to insure a fair comparison of the engine and pump condition and to limit the influence of the pump operator upon the test.

Pump test kits are commercially available from several manufacturers and usually consist of a 1-1/2-inch pressure gauge adaptor fitting, pressure hose, a pressure gauge (0-400 psi), a set of calibrated nozzle tips (1/8-, 1/4-, 5/16-, 3/8-, 7/16-, and 1/2-inch barrel) and one or two 10-foot lengths of latex-lined hose. A siamese valve connected to the discharge outlet of the pump will allow the operator to change nozzle tips without interfering with engine operation. If a tachometer is available it should be used to record the rpm for each nozzle pressure. When nozzle pressures have been recorded for each tip, a performance curve of gallons per minute discharged versus pressure can then be plotted using the standard nozzle discharge curves shown in Figure 37, or a set of curves supplied by the manufacturer of the calibrated nozzle tips. A procedure for carrying out the test will be found in Research Note 13 (Macleod, 1947).

A comparison of this curve with a previously-developed standard curve for the particular pump model will enable the operator to determine the condition of his equipment. A check of engine rpm versus discharge flowrate may give the operator some help in deciding the cause of poor pumping performance. If during the test the engine rpm has remained fairly high, but the pump has not produced the desired flowrate, the operator can conclude that the problem originates in the pump end. If, however, engine rpm has remained low during the test with a corresponding low discharge flowrate, the reason is more likely to be a faulty engine.

By comparing the actual discharge flowrate to the previously-developed standard an efficiency rating for the pump unit can be derived. If the unit is presently delivering 40 gpm *(180 l/m)* at 100 psi *(690 kPa)* compared to the pump standard of 50 gpm *(230 l/m)*, the unit's efficiency can be seen to be 80 per cent. An alternative method of rating can be accomplished on the basis of high pressure discharge. The efficiency is calculated from the difference between a previous standard and the pressure obtained at a pump discharge flowrate of 10 gpm *(45 l/m)*. This method, suggested by J.G. Wright is outlined in *Macleod*, 1947.

The fire control supervisor will have to arrive at a cut-off point in the efficiency rating. Units performing above the cut-off point will be deemed adequate for fire control use, while those below the cut-off point will be sent for repair and servicing. The cut-off point will primarily be determined from economic considerations.

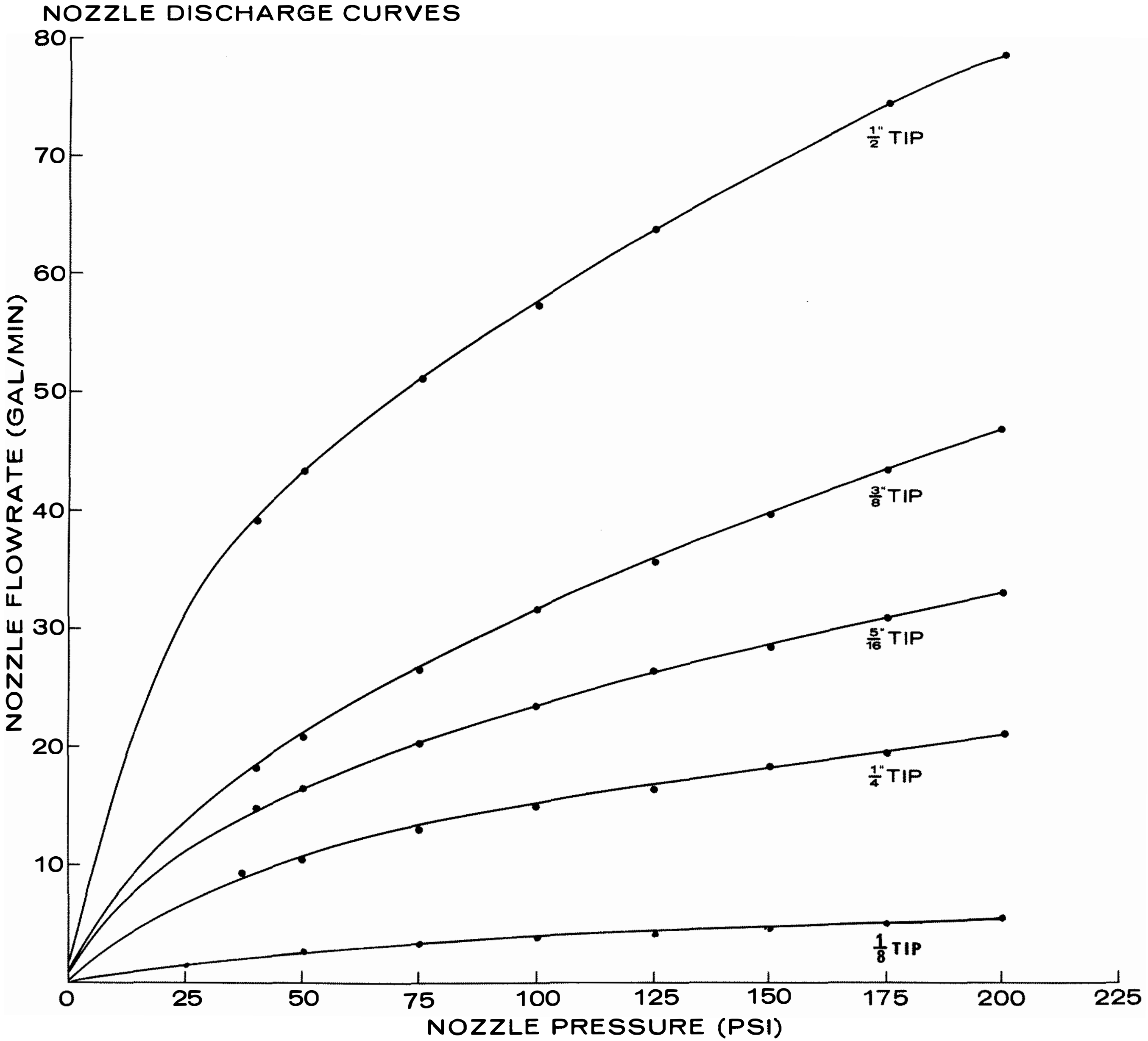



*Fig. 37. Standard nozzle discharge curves.*

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