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AN INVESTIGATION OF THE POSSIBILITIES OF SMALL INTERNAL COMBUSTION ENGINES IN INDUSTRIAL ARTS SHOPS

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By

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ABSTRACT

The role of the small internal combustion engine is fast becoming of importance to many home owners. The possession of one or more of these engines either in the form of an outboard motor, motor scooter, power lawn mower, etc., is almost taken for granted in our homes today. Along with this comes the problem of keeping the engine in good running order. This study was developed to determine the possibilities of teaching a unit or area covering these engines in our industrial arts shops.

The questionnaire method was used to gather subjective data. The returns revealed that some schools were already teaching such work in their industrial arts programs, as well as points of view on such matters as equipment requirements, grade level considerations, course materials, etc. Other data were gathered from books, periodicals, and engine manuals.

The returns indicated that such a course would be profitable for the students, and that "boy interest" would be high. The general opinion seemed to be that these engines should be included as a unit or area in either auto mechanics or the general shop. Most automobile mechanics teachers indicated they would be able to teach such a course, and that in order to do so they would need to purchase only a few additional tools.

It was concluded that auto mechanics is not becoming too complicated for secondary schools but, if auto mechanics was

not available, then definitely a unit of small gas engines should be taught. Twenty-five percent of the respondents thought small gas engines would be a satisfactory substitute, while 47.2 percent refrained from answering this question. This might imply larger and more important uses of these engines in shops in the future.

CHAPTER I

INTRODUCTION

Introduction to the Problem

The duties and obligations of every Industrial Arts instructor behoove him to be constantly on the lookout for new trends and areas in his field. The overcrowded class-rooms and shops of our schools today constantly keep the problem of instructional methods and subject matter looming before the instructor. He must constantly strive to keep abreast of new trends in his field as well as achieve the most with his present shop and equipment. As new areas develop, can and should the instructor include these in his shop courses, thus eliminating perhaps some less practical or desirous course? Such decisions will have to be made by the individual instructor with perhaps the help of fellow teachers in the field, supervisors and administrators, people in the community, and student opinions.

Statement of the Problem

This study is primarily an investigation to obtain the opinions of Industrial Arts teachers and supervisors as to the opportunities for small internal combustion engines in today's school shops. Does the era of the "putt, putt" warrant a unit or area in Industrial Arts shops? Where floor space and equipment prohibit auto mechanics, could a small internal combustion engine shop be used? Would a small internal combustion engine shop be satisfactory as a basic mechanics course? If so, what should be included in the course content? In what type of school would these shops be most satisfactory?

Need for the Study

> The time is ripe for establishing a unit of instruction in school shops covering the maintenance and overhaul of small air-cooled gasoline engines. Power lawn mowers, outboard motors, sprayers, chain saws, garden tractors, pumps, and myriad other uses of small engines has made them almost universal equipment. But the era of the "putt, putt," which makes it possible for more and more Americans to do jobs themselves with less effort, has brought with it the problem of keeping the engine in good running order.
>
> In Indianapolis alone, according to the Chamber of Commerce, residents owned 33,650 power mowers in 1953. This figure increased to 43,900 in 1954. Figure this on a national average and you'll see the real need for a unit of instruction in school shops which covers small air-cooled engines.[1]

There are some 5,000,000 outboard motors now in use in the United States. In 1956, the industry sold approximately 600,000 motors. In 1957, the industry expects to sell approximately 700,000 motors for a dollar volume of $230,000,000. These figures were compiled by Mr. Howard F. Larson, Director of Sales and Marketing, Evinrude Motors,

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[1]Warren F. Haas, "The 'Putt-Putt' Era," <u>School Shop</u>, XV, No. 4 (December, 1955), 77.

Milwaukee, Wisconsin.[2]

> Evinrude, the oldest and largest producer of outboard motors in the country, recorded an increase of 35 percent in sales at the end of its fiscal year, September 30. This is the largest single increase in the 47 year history. Evinrude's entire 1956 production was sold out by June 1. According to Mr. Larson, the company should again show an increase close to 35 percent in dollar volume in 1957.[3]

During the writer's few years of teaching Industrial Arts, he has observed students running paper routes with motor scooters and mowing lawns with power mowers. Many times these machines would fail to operate, thus causing the students to have them repaired at some garage. Through instruction in a small engine class in school, these boys could have prevented some of their operational trouble, perhaps even doing better preventive maintenance, and some of the repair work themselves in the school shop.

From the above data, it is the opinion of the writer that a definite need for small internal combustion engine units or areas in Industrial Arts shops exists.

Sources of Data

Subjective and objective data were used in this study. The subjective data were received from questionnaires sent to Industrial Education supervisors and Auto Mechanics instructors in a five state area.

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[2]Howard F. Larson, "Small Boat Industry in 1956 and a Prophecy for 1957," The Boating Industry, XIX, No. 7 (October 15, 1956), 55.

[3]Ibid., 55.

The objective data used were engine manuals and repair manuals from many different manufacturing companies of these small gas engines. Other books, pamphlets, and magazine articles were used.

Limitations of the Study

This study is limited to small gasoline engines of a portable type less than approximately nine horsepower. In the case of outboard engines the h orsepower rating would not affect, to a great extent, the type of engines used in Industrial Arts shops.

Engines falling into these classifications are small enough in size and weight to be handled by school age students without extra equipment.

The questionnaires were mailed to Industrial Education supervisors and Auto Mechanics instructors in the states of: Kansas, Oklahoma, Missouri, Iowa, and Arkansas.

CHAPTER II

HISTORY AND DEVELOPMENT OF SMALL INTERNAL COMBUSTION ENGINES

History of Internal Combustion Engines

An engine is: "Any mechanism or machine designed to convert energy into mechanical work; a steam engine, internal combustion engine, etc. . . ."[1] "A steam engine is an external combustion engine as the fuel is burned outside of the engine proper."[2] A steam engine cannot run without a boiler and firebox. The fuel used may be solid, liquid, gas, or atomic.

> An internal combustion engine is one in which energy is directly translated into mechanical power by causing an explosion to take place behine a piston. Professor Andrade has epigrammatically described this as "puting the furnace into the cylinder.[3]

The easiest way to acquire a knowledge of the operating principle of an internal combustion engine is to consider a close relative, the rifle. Gunpowder, burned in the breech of the gun, forms a gas which drives the bullet out of the gun with great velocity. If we could harness the bullet, we could obtain mechanical power.

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[1]Jud Purvis, All About Small Gas Engines. (Chicago: The Goodheart-Wilcox Company, Inc., 1956), p. 9.

[2]Ibid.

[3]Encyclopaedia Britannica, Inc. (Chicago, Illinois, 1956), XII, 496.

Christiaan Huygens in 1680, a Dutchman, attempted to use gunpowder to obtain motive power. Denis Papin and Abbe' Hautefeuille both, later experimented with Huygens' proposal but were unsuccessful. Gunpowder is not a suitable substance to be used in an internal combustion engine.

> R. Street, in 1794, proposed an engine driven by a flame-ignited explosive mixture of vapourized spirits of turpentine and air, and Sir Dugald Clerk regards this as the first real gas engine described in Britain. In 1820, W. Cecil of Cambridge described to the Cambridge Philosophical Society his engine operated by the explosions of a hydrogen-air mixture used to create a partial vacuum below a piston, the atmospheric pressure then producing the working stroke, much as in the earliest steam engines; he describes such an engine and states that at 60 revolutions per minute the explosions were perfectly regular; this is considered to have been the first actually working gas engine in the world.[4]

The gas engine's commercial career began with Samuel Brown in 1823. Brown's engines operated on the atmospheric-vacuum principle. Many of these engines were in regular service in 1832. "Brown engines were also fitted in a road vehicle in 1826, and in a 36-foot boat in 1827."[5] William Barnett in 1838, was the first to realize the importance of compressing the explosive charge before ignition. He also invented the well known Barnett igniting cock.[6]

The next big contribution was the "free-piston" engine invented by Barsanti and Matteucci in 1859. The cylinder

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[4] Ibid.

[5] Ibid., pp. 496-497.

[6] Ibid., p. 497.

was vertical, and open at the top. The explosive charge was electrically fired, driving the heavy piston up as high as the pressure would force it. The piston fell to its former position by its own weight. This engine was very noisy in operation.

Lenoir, a Frenchman, in 1860, was building gas engines which worked and looked like a double-acting steam engine of normal horizontal pattern. These engines worked with great regularity, smoothness, and quietness. A great many of these engines were built, but as they were very wasteful they were superseded later by the Otto and Langen "free piston" engine.

In 1862, M. Beau de Rochas, a French engineer, patented the theory for the best working conditions for an internal combustion engine.

> His cycle of operations was in all respects the same as that in use at the present day in the so-called Otto cycle engines. The following four propositions were embodied in his patents: (1) The largest cylinder capacity with the smallest possible cooling surface. (2) Maximum possible piston speed. (3) The greatest possible pressure at the beginning of the working stroke. (4) The greatest possible expansion.[7]

Beau de Rochas further stated these conditions could be accomplished by the following sequence of operations:

> (1) Suction during the first out-stroke of the piston. (2) Compression of the mixture during the following instroke. (3) Ignition of the compressed charge at the dead point, and

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[7]The United States Naval Institute, Annapolis, Maryland, Internal Combustion Engines. 1931, Historical Sketch.

> subsequent expansion of the exploded gas during the next out-stroke, this is the "working stroke". (4) Expulsion of the burnt and expanded gasses during the next in-stroke.[8]

This famous cycle sequence is currently employed in all four cycle engines.

Dr. Otto, the famous German engineer, in 1876 patented the famous "Otto silent engine", using the suggestions of Beau de Rochas. He showed the engine at the Paris Exposition in 1878, revolutionizing the construction of gas engines. The "Otto engine" practically superseded all other engines, launching the internal combustion engine upon its amazing commercial career.

The Otto engine combined the four operations stated by Beau de Rochas into four piston strokes covering two revolutions. In this cycle, only one working impulse or power stroke occurs.

Two years later, 1878, Sir Dugald Clerk produced a two-stroke cycle engine. The two cycle engine today is often called the "Clerk cycle" engine. He showed an improved example of this engine at the Paris Electrical Exhibition in 1881. The two cycle engine has a working impulse every other stroke, twice as many as the four cycle, combining the same four operations but in one revolution.

Today we recognize Otto and Clerk as being the inventors of their respective engines, although we must realize,

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[8] Encyclopaedia Britannica, op. cit., p. 497.

without the aid of many previous engineers and inventors, they would not have succeeded.

Four Essential Systems of Every Engine

There are four essential systems to every engine: (1) fuel system; (2) ignition system; (3) cooling system; and (4) lubrication system.

The fuel system usually consists of a fuel tank, strainer, fuel pump, carburetor, and the exhaust, usually terminating in a muffler.

Liquid fuels must be volatilized and mixed with air before they can be ignited in the cylinder. "'The Mixture' is the term commonly employed to designate the product of the carburetor when ready for combustion."[9] "For normal operating conditions the best economy is obtained by a mixture of one part by weight of gasoline to between 16 to 17 parts of air."[10] For idling or quick acceleration a somewhat richer mixture is needed, one part of gasoline to about 12 or 13 parts of air.

> Some of the earlier types of carburetors were so designed that the air drawn in by the engine would first pass over the surface of some gasoline. In that way enough gasoline vapor was carried on to the engine as a combustible mixture. Another type used a wick, the lower end of which was submerged in

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[9] F. W. Sterling, *Internal Combustion Engine Manual* (Washington, D. C., Beresford, Printer, 1917), p. 44.

[10] Purvis, *op. cit.*, p. 139.

> gasoline, while air passed over the exposed end and then into the engine cylinder. A third type was known as a mixing valve. In the mixing valve air is drawn in through the valve which is opened by the suction of the engine. The air passing the opening to the gasoline supply draws fuel with it and the mixture of air and fuel is drawn into the cylinder. The amount of fuel is controlled by a needle valve.[11]

These early type carburetors were very erratic and unsatisfactory. Maybach designed a carburetor which used a float to maintain the level of the fuel within the carburetor at approximately the same level. This was a great improvement over the old type carburetors even though the float in the carburetor had to remain approximately horizontal. Today with many added improvements in carburetion, especially the diaphragm carburetor, engines may be operated at almost any angle.

The strainer or sediment bowl as it is commonly called, is usually placed under the fuel tank. The location of the fuel tank will determine whether or not a fuel pump is needed. If the tank is above the carburetor it is called a "gravity" fuel system, if the tank is located below the carburetor level, a fuel pump is needed, usually referred to as a "pressure" fuel system.

"Next to carburetion, the most important feature in internal combustion engine operation is proper ignition."[12]

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[11] Ibid., p. 137.

[12] Sterling, op. cit., p. 54.

Electric ignition is the most commonly used system.

> In general the electric-ignition system consists of a source of electric current; an electrical circuit of wire, or a combination of wire and a ground (the metal of the motor); a spark-plug gap inside the cylinder; an induction coil for transforming the low-tension current to a high-tension current; a distributor (a revolving contact-maker) for distributing the high tension current to the spark plug at the correct instant; and a condenser to reduce arcing and the loss of current. The sources of electric current may be dry cells, a storage battery, a generator, or a magneto.[13]

The general systems used for cooling internal combustion engines are: (1) Liquid cooling, generally water but occasionally oil, and (2) Air cooling.

Without some means of temperature regulation, some parts of the internal combustion engine would melt from the intense heat of the burning gas. The lubricating oild would burn up and the piston and rings would expand and grip or "freeze" to the cylinder wall. The temperature of the gases is very high, sometimes 3,000 degrees F. at the time of ignition.

> As the fuel is burned in the combustion chamber, about one-third of the heat energy in the fuel is converted into power. Another third goes out the exhaust pipe unused and the remaining third must be handled by the cooling system.[14]

Liquid cooling is the more flexible and more common of the two systems.

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[13] United States Naval Institute, op. cit., Chapter VIII, p. 2.

[14] Purvis, op. cit., p. 97.

> When water is used for cooling, the cylinder is made with a double wall, the space between the two walls being called the water jacket. The water jacket should cover the entire length of the stroke, to avoid unequal expansion in the cylinder bore and burning of the lubricating oil.[15]

There are two methods used to circulate the water through the water jacket. One method employs a positive circulating pump, usually a centrifugal pump driven by the engine. The second method is called the thermo-syphon system of cooling. It utilizes the principle that heated water is lighter than cold water, thus the heated water rises to the top of the radiator, is cooled, and reenters the engine from the bottom of the radiator in a continuous circulating process.

Engines to be air cooled have provisions made to create a draft of air around the cylinder, either natural draft or forced draft. Air cooled engines have ribs or cooling fins either cast or machined into the cylinder surface, depending upon the metal used for construction. The hottest part of the cylinder, exclusive of the exhaust valve and seat, is the center of the head. Therefore, aluminum is usually used because of its high thermal conductivity. The cooling fins have two functions: (1) Expose more surface to the cooling air, and (2) Serve as guides to break the air into thin streams to obtain the maximum cooling effect.

> The cylinder walls of air cooled engines operate at a temperature considerably above 200 degrees F. in many cases. This is hot to

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[15]United States Naval Institute, _op_. _cit_., Chapter X, p. 1.

> touch but cool in comparison with the heat generated in the combustion chamber of the engine.[16]

Air cooled engines are apt to overheat and lose power if they are run at full load for long periods of time, especially in enclosed spaces during hot weather. The two causes contributing to this loss of power are: (1) Loss of volume of fuel mixture entering combustion chamber due to heat generated, and (2) Friction caused by piston expanding more than cylinder wall, often increased by the failure of the lubricating oil at high temperature.

> Air cooling possesses several advantages, giving a light-weight and simple engine and one which can be operated in regions where water is very scarce or heavily laden with impurities. It is also impossible to damage an air-cooled engine by frost.[17]

Air cooled engines possess several disadvantages. They are slightly more noisy due to the absence of the insulating cooling water and even cooling is more difficult. A difficulty with air-cooled single-cylinder engines is that the rear of the cylinder is not directly exposed to the cooling stream of air and, therefore, has a higher temperature than the front.

The lubrication systems of internal combustion engines will be discussed following the description of four and two stroke cycle engines.

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[16] Purvis, op. cit., p. 97.

[17] C. F. Hirshfield and T. C. Ulbricht, Gas Engines For the Farm (New York, John Wiley & Sons, Inc., 1914), pp. 47-48.

Engine Design

The cylinder arrangement determines the different types of motors. The cylinders may be arranged vertically, horizontally, angularly or opposed. Each of these types are illustrated in a diagrammatical form in Plate A, Figures A-3, A-4, A-5, and A-6.

Cylinder shape is determined by the location of the valves. "There are four general designs known as: T-Head, L-Head, F-Head and I-Head."[18]

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[18] Purvis, op. cit., p. 16.

Engine Designs[19]

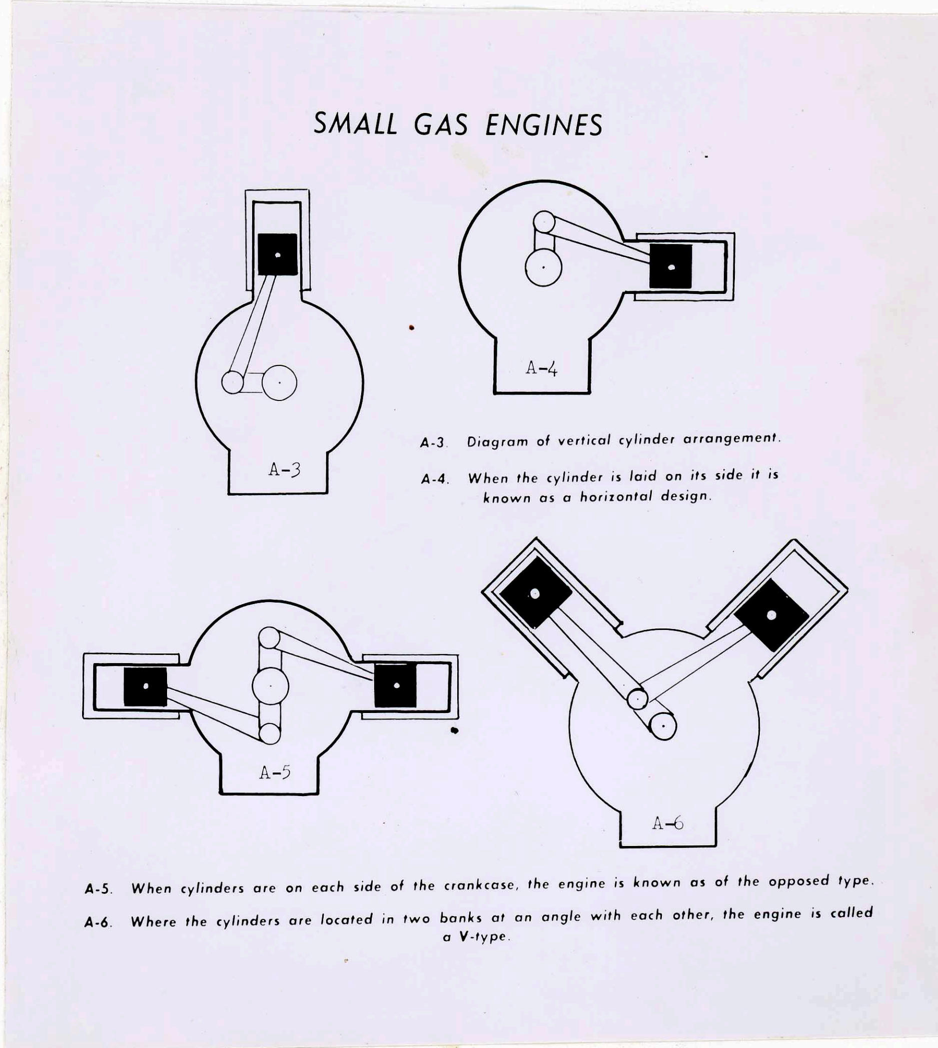

Plate A

The T-Head, Plate B, Figure 1, has the inlet valve on one side of the cylinder and the exhaust valve on the opposite side. In early days when cylinders were individual or cast

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[19]Jud Purvis, All About Small Gas Engines (Chicago: The Goodheart-Wilcox Company, Inc., 1956), p. 11.

in pairs, this design was widely used.

Valve Location in Engines[20]

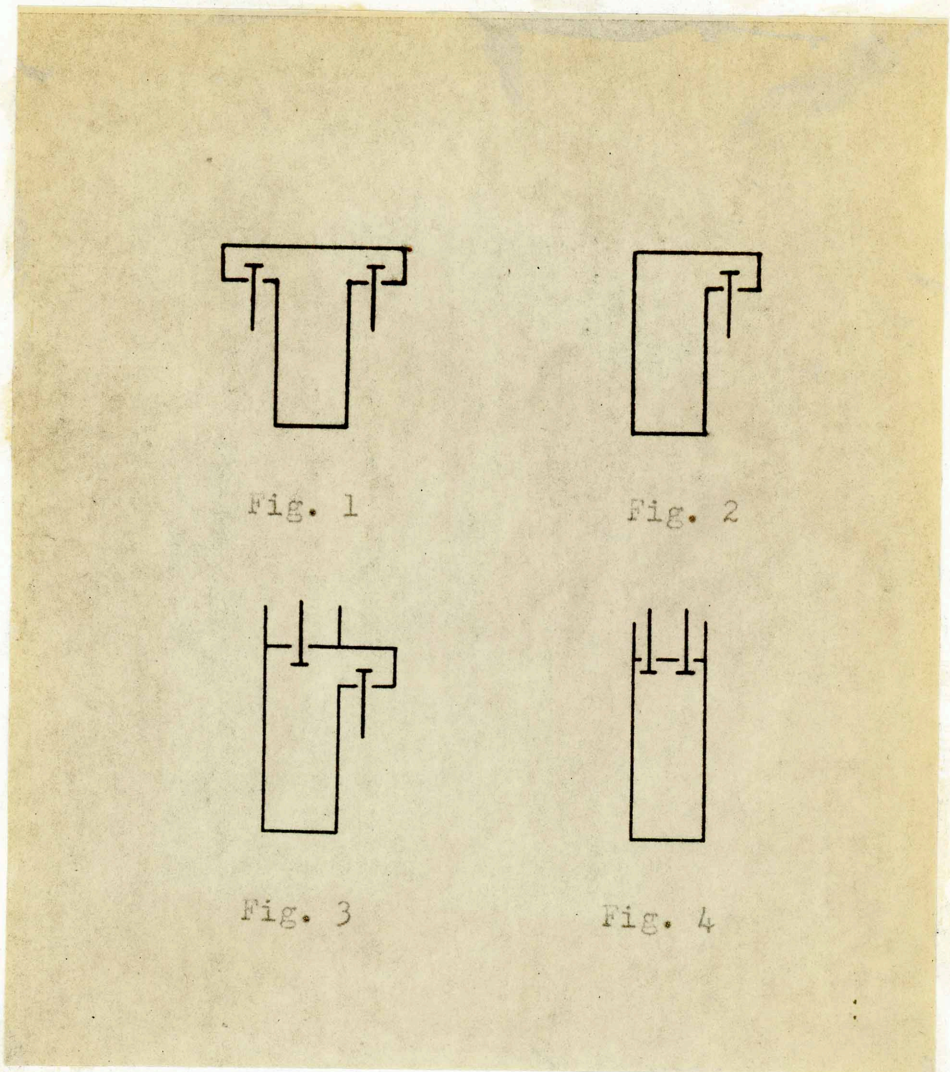

Plate B

The L-Head, Plate B, Figure 2, has both inlet and exhaust valves on the same side of the cylinder. Since cylinders have been cast in block form with detachable cylinder heads, this

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[20] *Ibid.*, p. 17.

has been the predominant design.

The F-Head, Plate B, Figure 3, has the inlet valve in the head of the block and the exhaust valve at the side of the cylinder. This design has never been used extensively, it is a combination of the L-Head and I-Head design.

The I-Head or valve-in-head or overhead valve engine is currently the most popular engine. This design has both inlet and exhaust valves located in the head over the piston as shown in Plate B, Figure 4.

Four Stroke Cycle Engine

The four stroke cycle internal combustion engine operates by going through the following cycle operations: (1) intake stroke, (2) compression stroke, (3) power stroke, and (4) exhaust stroke. There is only one operation performed for each upstroke and downstroke of the piston.

Two and Four Stroke Cycle of Operation[21]

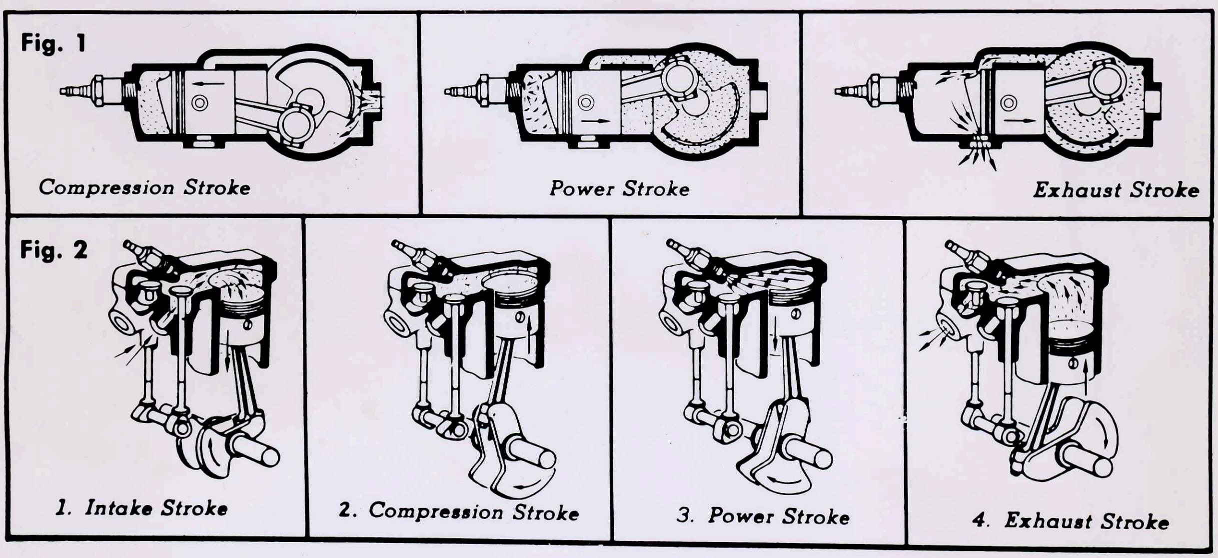

Plate C

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[21] Clinton's Cooperative School Program Handbook (Maquoketa, Iowa, Clinton Machine Company), Sec. VI, Div. A, p. 14.

Starting with the piston at the top of the cylinder (See Plate C, Figure 2, Step 1), the piston descends, opening the intake valve. Withdrawal of the piston creates a partial vacuum in the cylinder. Outside air pressure forces a mixture of vaporized gasoline and air into the cylinder.

As the crankshaft turns over, the piston rises compressing the gas in the cylinder. The intake valve closes as the piston reaches the bottom of its stroke. As the piston arrives at the top of the cylinder, the gas is fully compressed. The timing mechanism actuates the ignition system, which causes the spark plug to spark, igniting the gas in the cylinder.

The piston is driven downward with great force, delivering power on the power stroke to the crankshaft.

As the piston rises again, the exhaust valve opens and the burned gases are forced out through the exhaust. The exhaust valve closes as the piston reaches the top of its stroke. The intake valve opens as the piston starts down, and the cycle repeats itself.[22]

The intake and exhaust valves are operated by a mechanical means, thus controlling the admission of gaseous mixture from the carburetor into the cylinder and the expulsion of burned gases from the cylinder. There are two valves in each cylinder.

The actions of the valves are controlled by cams on a shaft driven from the crankshaft through gears, known as the valve timing gears. The cam shaft is geared to revolve at one-half the speed of the crankshaft and carries a separate cam for each inlet and each exhaust valve.[23]

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[22] *Ibid.*

[23] U. S. Naval Institute, *op. cit.*, Chapter V, p. 4.

Since power is delivered to the crankshaft on every other stroke, a larger cubic piston displacement is required, so that a greater amount of gas can be fired at each ignition period. When less than three power strokes are delivered each revolution, the torque is not continuous. The momentum of a heavy flywheel is employed to furnish continuous flow of power from the engine. In a 1-cylinder, 4-stroke cycle engine, this flywheel stores sufficient energy to cause the piston to make the other three strokes, as well as furnish a continuous flow of power.

In the air-cooled engines, the 4-stroke cycle engine is a cooler running engine than the 2-stroke cycle, owing to the longer period between consecutive firing stages.

Lubrication Systems of Four Stroke Cycle Engines

The need for a lubrication system in an engine is to eliminate as much friction as possible. Friction can never be entirely eliminated although it can be reduced to a minimum. The results of friction are the conversion of useful energy into useless heat.

"The fundamental theory of lubrication is that there should be a continuous film of oil between the rubbing surfaces of a properly lubricated bearing."[24]

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[24] *Ibid.*, Chapter IX, p. 1.

When the moving parts are separated by a film of oil the friction takes place within the liquid itself, and between its particles and the surfaces in contact with it.

The oil in internal combustion engines has the following tasks to perform: (1) reduce the friction between the moving parts of the engine, (2) act as a seal to prevent leakage of gasoline vapors between the piston rings and cylinder wall, (3) carry away much of the heat by flowing between friction generating parts, and (4) wash away the abrasive metal worn from friction surfaces.

The moving parts of the engine may be supplied with oil either by the splashing system or by pump pressure. Some engines use a combination of both types.

The four stroke cycle engines have a reservoir of oil in the crankcase. In the splashing system the dippers on the connecting rod end strike the oil as the engine turns, splashing it in all directions. In the pump pressure system, frequently called "forced oiling system", the oil is forced, under pressure, through tubes or ducts to camshaft bearings, main bearings, connecting rod bearings, and wrist pins. After having passed through the various bearings, the oil returns to the crankcase where the oil pump again picks it up and forces it through the system.

Early Types in the United States

The early four stroke cycle engines were used for various jobs but agricultural uses probably were the most numerous. Plate D, is a typical air cooled four stroke cycle engine. International Harvester Company manufactured it under the trade name of the Tom Thumb Engine. It had a rating of one horsepower. The flywheel diameter is 15½ inches.

An Early Air Cooled Engine[25]

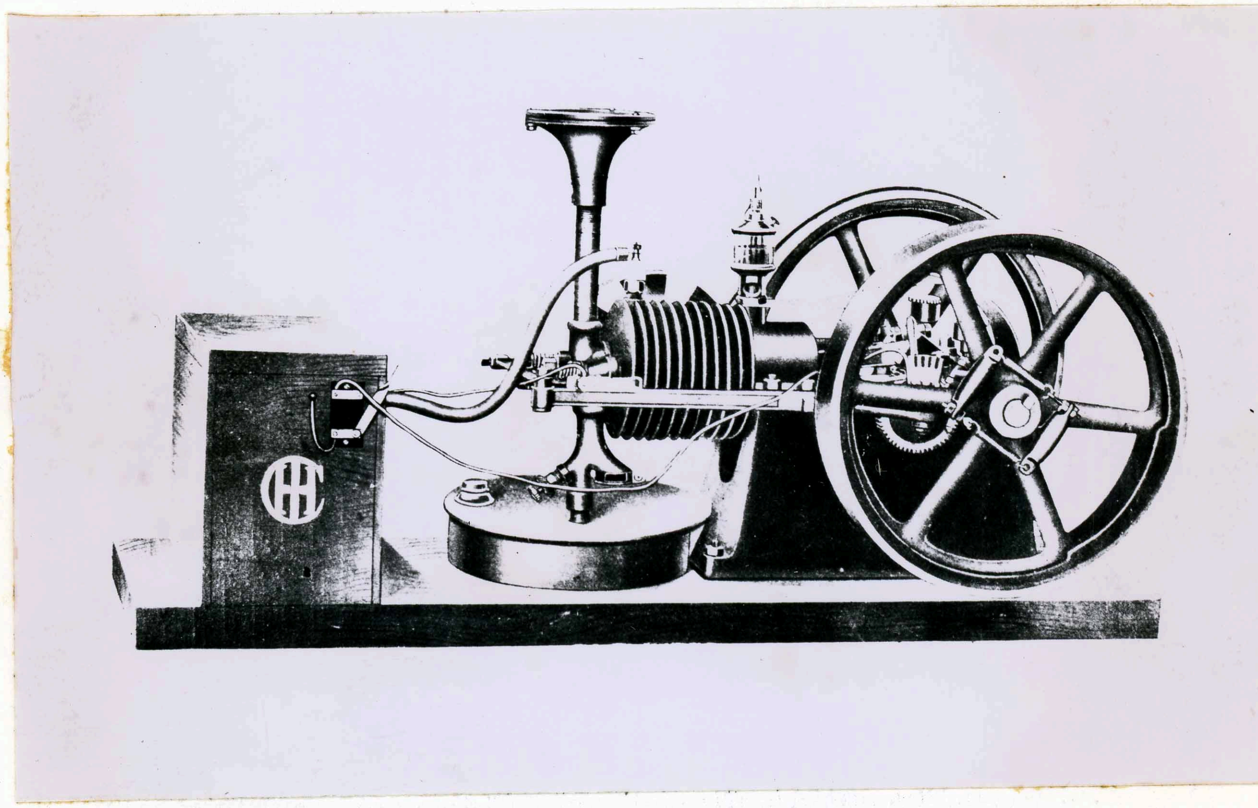

Plate D

Plate E, is a modern air cooled four stroke cycle engine ranging from 1½ to 9 horsepower depending upon the model.

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[25]Hirshfield and Ulbricht, op. cit., pp. 47-48.

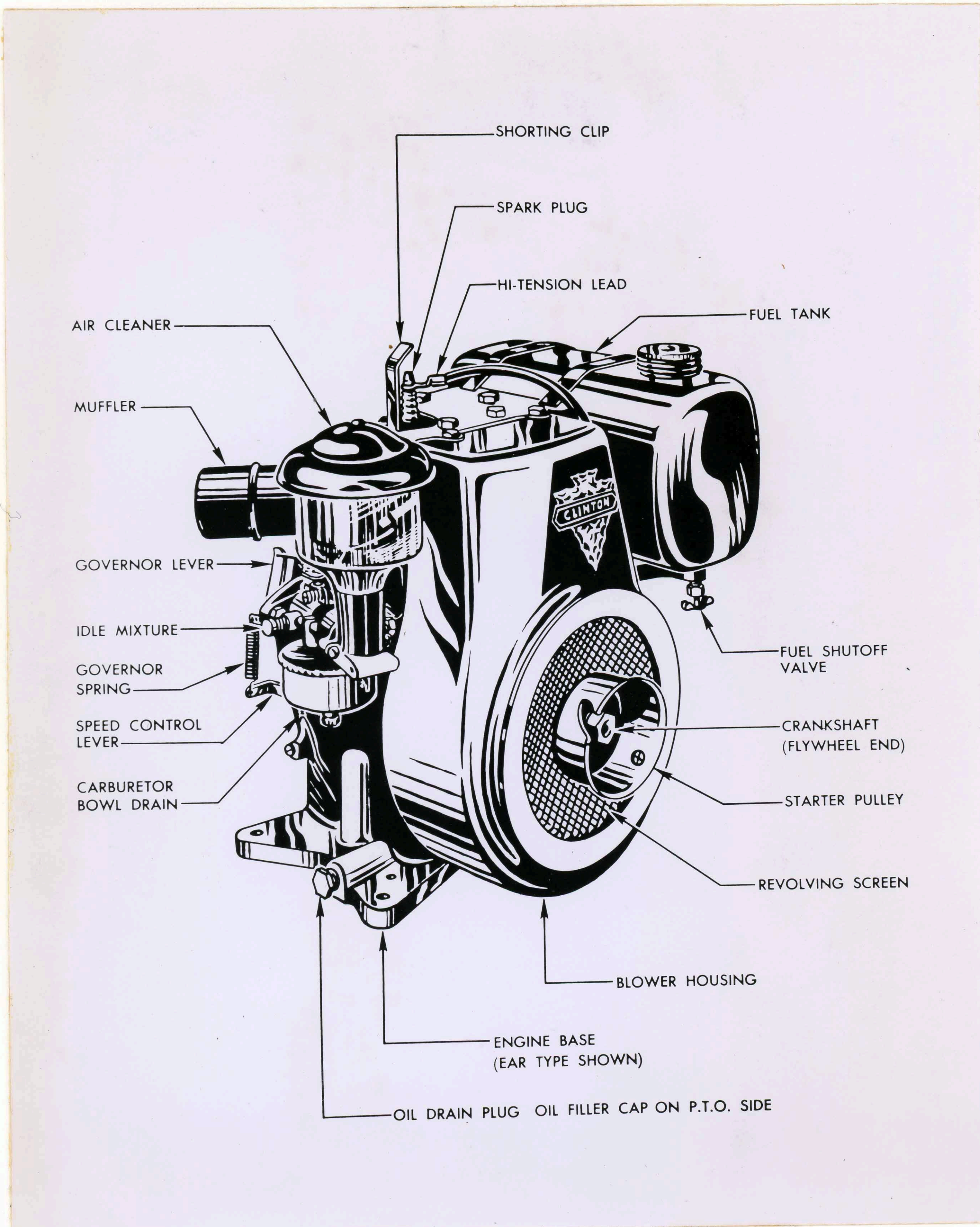

Plate E[26]

[26] Clinton's Cooperative School Program Handbook (Maquoketa, Iowa, Clinton Machine Company), Sec. VI, Div. A, p. 15.

These engines have many more uses than its forerunner due to its compactness, durability, better design, etc.

Two Stroke Cycle Engine

The two stroke cycle engine has only three moving parts: the piston, the connecting rod, and the crankshaft. The two stroke cycle engine requires only two strokes to complete the cycle, receiving a power stroke with every crankshaft revolution.

> On the upward stroke of the piston a partial vacuum is created in the crankcase (See Plate C, Figure 1, Step 1). First, the vacuum and outside air pressure cause the reed valve between the crankcase and the carburetor to open. The air-fuel mixture from the carburetor flows into the engine crankcase. Then, the downward movement of the piston compresses the fuel charge in the crankcase. Near the bottom of its stroke the piston uncovers the intake by-pass port, which connects the combustion chamber and the crankcase.
>
> As the piston moves upward on its stroke, it passes the intake port, closing the port openings. Its continued upward movement causes the fuel mixture in the cylinder to be compressed. At the same time a new fuel charge is drawn into the crankcase. As the piston nears the top of the compression stroke, the fuel mixture in the combustion chamber is ignited by the spark. The burning and expansion of gases forces the piston down on its power stroke. Power is not delivered for the full length of the stroke. Some time is required to rid the cylinder of burned gases, so that it may receive a fresh fuel charge from the crankcase.
>
> As the piston nears the bottom of its stroke, it uncovers the exhaust port opening slightly ahead of the intake port. This permits taking advantage of the pressure of the exhaust gases in

> the cylinder, which are still comparatively high, and allows them to start escaping. Further downward travel of the piston uncovers the intake by-pass port. The incoming charge assists in forcing the exhaust gases out of the cylinder, to complete the cycle.[27]

The two stroke cycle engine is sometimes referred to as the "valveless engine". To be completely valveless, a three or four port engine, such as the Navy Type Engine, must be constructed (See Plate F). The other ports eliminate the valve between the carburetor and crankcase.

Three Port Two Stroke Cycle Engine[28]

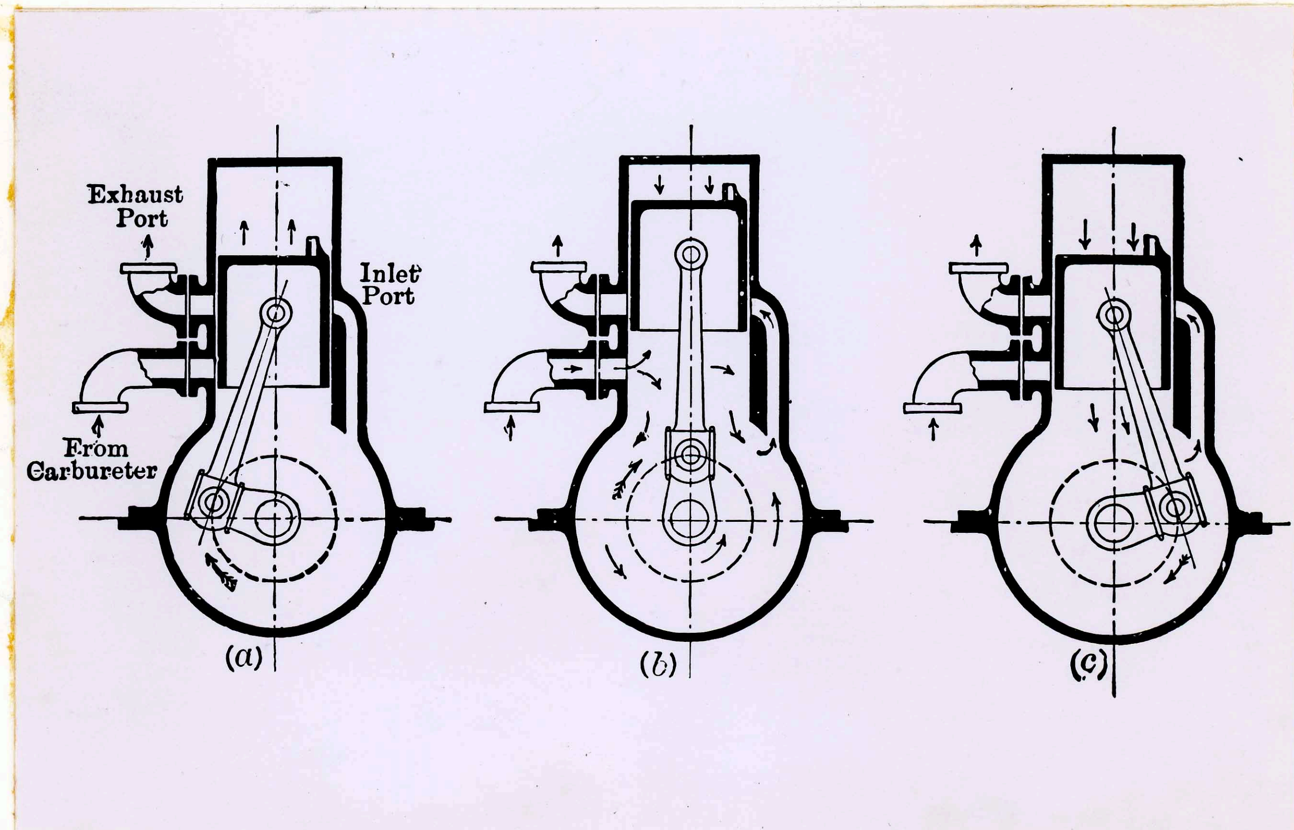

Plate F

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[27] Ibid., Sec. VI, Div. A, p. 14.

[28] Hirshfield and Ulbricht, op. cit., p. 26.

It would appear that the two stroke cycle would develop twice the horsepower of a four stroke cycle of the same bore and stroke. The factors prohibiting this are: (1) shorter intake stroke, (2) heat decreases volume of fresh fuel mixture entering cylinder, and (3) loss of small amount of fresh fuel mixture helping to force out exhaust gases.

The crankcase compartment of two stroke cycle engines is small and fits closely around the moving parts. It must be air tight as the gas is compressed in the crankcase to force it into the cylinder ports. The crankcase is made as small as possible to obtain maximum pumping efficiency.

Lubrication System of Two Stroke Cycle Engine

Two stroke cycle engines have no oil reservoir and no specific oiling system. The engine oil is mixed with the gasoline. The fuel enters the crankcase in a finely atomized mixture in which the gasoline is largely vaporized while the oil is carried to the working parts in the form of an oily mist. The oil condenses and collects on the metal parts, thus providing lubrication. Any excess oily mist is carried into the combustion chamber where it is burned along with the fuel.

> Since nearly all the oil is subjected to high operating and combustion temperatures, it is obvious that the oil selected for use in such engines must have characteristics

> which will enable it to provide satisfactory lubrication under the conditions encountered, with a minimum tendency to form deposits in the combustion chamber.[29]

Correct fuel preparation is one of the most important points in the correct operation of the two stroke cycle engine.

Numerous tests have been made using detergent oil mixed with the gasoline to see if detergent oil would actually harm the engines. The engines tested were not harmed in any way from using detergent oils, although the spark plug life was shortened. For this reason a detergent oil or one containing additives, is not advised.[30]

Early Types in the United States

"In the United States, one of the first commercial applications of the two-cycle engine was on an outboard motor."[31] Its development was caused by a woman wanting a dish of ice cream.

> While on a picnic, Ole Evinrude, a young Milwaukee machinist, was asked by his fiance' to row across the lake for some ice cream. By the time he returned (with a somewhat soggy supply of ice cream), he was firmly convinced that there should be an easier, quicker way to satisfy the wishes of his fiance'. He applied himself to solving the problem, and in 1910

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[29] Ernest Venk, Irving Frazee, William Landon, Outboard Motors and Other Two-Cycle Engines (Chicago: American Technical Society, 1953), p. 49.

[30] Lawn-Boy Service Manual (Lamar, Missouri, 1956), Section I, p. 5.

[31] Sheldon D. Pollow, Chief Engineer, Power Products Corporation. Speech delivered December 8, 1953 at the meeting of the Society of Automotive Engineers, Chicago, Illinois.

was granted a patent which was the forerunner of the present-day outboard motor.[32]

Evinrude's First Production Engine[33]

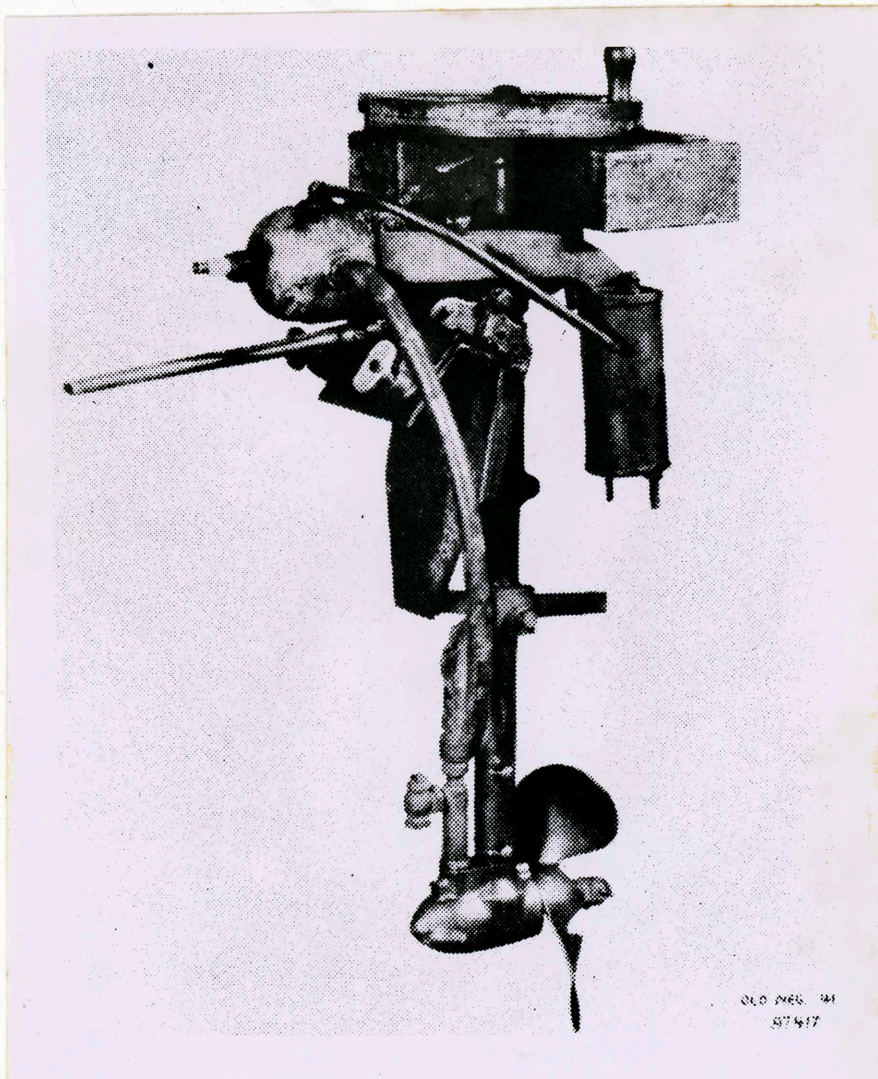

Plate G

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[32]Venk, Frazee, Landon, *op. cit.*, pp. 3-4.

[33]Hank W. Bowman, *The Encyclopedia of Outboard Motoring* (New York: A. S. Barnes & Company, Inc., 1955), p. 7.

Ole built his first ten motors entirely by hand. They weighed sixty-two pounds each and Ole came up with a price of one dollar a pound so the motors sold for sixty-two dollars each.

Two stroke cycle engines are the overwhelming choice for outboard motors because of their extreme light weight and compactness. They are made in all sizes up to sixty horsepower. They may have one, two, four or six cylinders and late models have electric starters and other accessories.

Another important invention helped taked the drudgery out of washdays. An important manufacturer built a washing machine and a two stroke cycle engine to power it. Even today, many of these washing machines and engines are still running.

Small two stroke cycle engines as we know them today are relatively new. Outboard motors originated commercially in 1910. The Clinton Machine Company produced and shipped its first engines in 1946. In 1952 they introduced their two stroke cycle engines. Almost all of these small gas engines are air cooled with the exception of the outboard motors.

Uses of Small Internal Combustion Engines

The writer realizes his incapability to list all the uses of these engines, consequently he has chosen to limit them to three categories. Under these categories he lists numerous uses of both 2- and 4-stroke cycle engines.

<u>Agricultural Uses</u>:

1. Small individual power plants for generating electricity
2. Grain augers
3. Garden tractors
4. Lawn mowers and weed cutters
5. Pump jacks
6. Washing machines
7. Starting motors on diesel tractors
8. Chainsaws
9. Bale elevators
10. Operate pumps

<u>Commercial Uses</u>:

1. Refrigeration units on large trucks
2. Elevate and pump cement
3. Cement mixers
4. Fuel pumps on tank wagons
5. Generators f or lights on oil rigs, etc.
6. Air generator for paint guns
7. Various loading machines in plants
8. Motor scooters
9. Chainsaws

10. Lawn mowers[34]
11. Inhalators
12. Fishing industry
13. Logging industry
14. United States Army, Air Force, Navy and Coast Guard

Recreational Uses:

1. Outboard motors
2. Motor scooters
3. Caddie wagons on golf courses

Summary

The steam engine, an external combustion engine, burns its fuel outside the engine. The internal combustion engine, of which there are many kinds, burns its fuel inside the engine. The energy is transformed into mechanical power by explosions taking place behind a piston.

A German engineer, Dr. Otto, in 1876 patented his famous gasoline engine. He used M. Beau de Rochas' sequence of operations: (1) suction, (2) compression, (3) ignition, and (4) expulsion. This cycle was completed in two revolutions of the crankshaft, involving four strokes, hence the name four-stroke cycle. This engine revolutionized the construction of gas engines and practically superseded all earlier types of this engine. The four-stroke cycle engine of today is sometimes referred to as the "Otto engine".

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[34] Tom Riley, "Use the Engine on Your Power Mower for Other Jobs," Popular Mechanics, CV, No. 4 (April, 1945), 194-196.

Sir Dugald Clerk in 1878 produced his famous engine which still bears his name. Clerk used the same sequence of operations, but his engine completed the cycle in two strokes or one revolution of the crankshaft. He did not use any valves in his engine, hence it is sometimes called the "valveless engine".

Every engine has four essential systems: (1) fuel system, (2) ignition system, (3) cooling system, and (4) lubricating system.

Small gas engines usually have gravity fuel systems, magneto ignition systems, and air cooling systems. Outboard motors are exceptions, sometimes employing pressure or suction fuel systems and practically all of them are water cooled.

Four-stroke cycle engines use both forced and splash lubricating systems. The two stroke cycle uses neither but gets its lubrication from mixing oil in the gasoline. The mixture goes through the air tight crankcase enroute to the combustion chamber and the oily mist tends to lubricate the engine.

Today these engines may be purchased in four different engine designs: (1) vertical, (2) horizontal, (3) angular, and (4) opposed.

In view of the fact that small gas engines operate on the same sequence of operations as large internal combustion engines, it would seem feasible to operate shops of this type in schools. With this idea in mind a survey of Industrial Education supervisors and Auto Mechanics instructors was made, and the results will be reported in the next chapter.

CHAPTER III

REPRESENTATIVE VIEWS OF INDUSTRIAL EDUCATION SUPERVISORS AND INSTRUCTORS

In order to secure data on such questions as the extent to which small engines were being used in school shop programs, the attitudes toward the use of these engines, the types of shops to which they would be suited, equipment requirements, etc., forty-six questionnaires were sent to selected supervisors and automobile mechanics instructors in this region. This questionnaire is given in Appendix A. Replies were received from thirty-six of the forty-six questionnaires sent, a total of 80 percent. The distribution of questionnaires is shown in Table I.

TABLE I

DISTRIBUTION OF QUESTIONNAIRES

Questionnaires Sent to	Number Sent	Number Returned	Percent
Heads of Departments in Colleges	5	4	80.0
Supervisors of Industrial Education	18	16	88.9
Automobile Mechanics Instructors	23	16	70.0

Question 1. Do you think small gas engines could be used as a section or unit in Industrial Arts Shops? (yes) (no)

Thirty-five or 97 percent of the respondents answered this question in the affirmative, while one individual did not answer the question.

Question 2. Do you think such a course covering maintenance and overhaul would be profitable for the students? (yes) (no)

Thirty-three or 91.6 percent of the thirty-six respondents answered this question in the affirmative. One individual answered in the negative while two failed to answer the question.

Question 3. What type of school should, in your opinion, the small gas engine shop be placed? (Jr. High) (Senior High) (Both)

Thirty-five replies to this question were received and 55.6 percent of them indicated the shop should be placed in Senior High. The breakdown of the opinions is as follows:

TABLE II

SCHOOL MOST DESIRABLE
FOR SMALL GAS ENGINE SHOP

Type of School	Response	Percent
Junior High	6	16.6
Senior High	20	55.6
Both	9	25.0
No answer	1	2.8
Totals	36	100.0

Question 4. Do you know of any shops where small gas engine work is taught?

Forty-seven percent of the respondents knew of shops teaching small gas engine work. Seventeen answered in the negative while two failed to answer the question. The following schools were named as teaching small gas engine work:

Coffeyville Vocational School, Coffeyville, Kansas
Des Moines Technical School, Des Moines, Iowa
Des Moines East High and Lincoln High, Des Moines, Iowa
Franklin Trade School, Joplin, Missouri
Highland Park High School, Topeka, Kansas
Larned High School, Larned, Kansas
McPherson College, McPherson, Kansas
Oklahoma City Public Schools, Oklahoma City, Oklahoma
Ottawa High School, Ottawa, Kansas
Pittsburg Senior High School, Pittsburg, Kansas
Salina High School, Salina, Kansas
Shawnee Mission High School, Merriam, Kansas
Springfield High School, Springfield, Missouri
Tulsa Public High Schools, Tulsa, Oklahoma
Winfield High School, Winfield, Kansas

Question 5. Would you think that boys' interest would be generally high in work with small internal combustion engines? (yes) (no)

Eighty-six percent of the replies were in the affirmative. Three negative answers were received while two failed to answer the question.

Question 6. Would you teach the principles of engine operation first or teach care and maintenance first, or should these be taught together? (Principles of engine operation first) (Care and Maintenance) (Together)

The breakdown of answers are as indicated:

TABLE III

INFORMATION TO BE TAUGHT

Items	Response	Percent
Principles of engine operation	12	33.3
Care and Maintenance	0	00.0
Together	24	66.7
Totals	36	100.0

Approximately 67 percent of the respondents favored teaching principles of engine operation and care and maintenance together, a significant point of view on this question.

Question 7. Do you think Auto Mechanics is becoming too complicated for secondary school shops? (yes) (no) If so, would small gas engines be a satisfactory beginning substitute? (yes) (no)

Eighty-one percent of the replies to the first question were in the negative while 19 percent were in the affirmative. According to the answers received, auto mechanics is not becoming too complicated for secondary school shops in the opinion of a large majority of the respondents.

Ten negative answers were received for the second question. The breakdown of answers is as follows:

TABLE IV

USE OF SMALL GAS ENGINES
AS SUBSTITUTE FOR AUTOMOBILE MECHANICS

Opinions		Response	Percent
Yes		9	25.0
No		10	27.8
No answer		17	47.2
	Totals	36	100.0

Comments received regarding the increasing of complexity of Auto Mechanics:

a. "Auto Mechanics is becoming too complicated for secondary school shops unless it is taught as a day trade class, 15 hours per week."

Comments received in favor of small gas engines for beginning substitute:

a. "Used together, small engines to teach principles. Industrial Arts Auto Mechanics for general education only. Vocational Auto Mechanics for a vocation."

b. "Auto Mechanics requires many special tools of very high cost to make satisfactory operation."

Question 8. Would Auto Mechanics instructors be qualified for teaching small gas engine work? (yes) (no) If not, should instructors receive special training for this work? (yes) (no) (Comments)

Thirty-two answered in the affirmative, in other words, 88.9 percent of the respondents felt qualified to teach small gas engine work. Three answers were negative and one was blank.

Only three affirmative answers were received for the second question, 8 percent felt they would need special training. Some of the comments were:

a. "Companies often offer short courses that are valuable to instructors."

b. "If not they should quit."

c. "Most Auto Mechanics instructors can qualify with very little extra preparation."

d. "A competent instructor should know the basic principles of all gasoline engines."

Question 9. How do you think small gas engines would compare with Auto Mechanics as a shop course for Junior-Senior High School age boys in Mechanics? (Better) (Just as good) (Not as good) (Comments)

Twenty-five or 69.4 per cent replied that small gas engines would not be as good as Auto Mechanics. The break-down and comments are listed below.

TABLE V

SMALL GAS ENGINES VS AUTOMOBILE
MECHANICS FOR JUNIOR-SENIOR HIGH SCHOOL BOYS

Opinions	Response	Percent
Better	3	8.3
Just as good	5	13.9
Not as good	25	69.4
No answer	3	8.3
Totals	36	100.0

Comments opposing small gas engines:

a. "Too much interest in the boy working on his own car."

b. "It would provide only a portion of the work that should be covered."

Comments favoring small gas engines:

a. "Requires much less room for same size class."

b. "Gas engine work could e asily lead into further work in auto mechanics."

c. "It would help to understand the operation and construction of gas motors."

d. "Good course where the other is not possible."

Question 10. Would you need to purchase new tools in your present shop, to maintain and overhaul small gas engines? (Complete set) (Partial set) (None)

Here is the breakdown of replies:

TABLE VI

EXTRA TOOLS REQUIRED
FOR OPERATION OF SMALL GAS ENGINE SHOP

Tools Needed	Response	Percent
Complete set	3	8.3
Partial set	22	61.1
None	10	27.8
No answer	1	2.8
Totals	36	100.0

Over one-fourth of the schools as indicated by these replies, are presently equipped to maintain and overhaul small gas engines. With a very small investment by 61.1 percent of the schools for a partial set of tools, 88.9 percent could perform this type of work.

Question 11. Do you know of any books, manuals, or course material on small gas engines? (yes) (no) (Comments)

TABLE VII

KNOWLEDGE OF AVAILABLE COURSE MATERIAL

Answers		Response	Percent
Yes		18	50.0
No		10	27.8
No answer		8	22.2
	Totals	36	100.0

Eighteen or 50 percent of the respondents knew of books, manuals, or course materials on small gas engines. Several suggestions are listed below.

a. "Factory manuals are very good in this field."

b. "Briggs & Stratton Corp., Clinton Corp., furnished us with intensive manuals, etc."

c. "All About Small Gas Engines - Goodheart-Wilcox."

Question 12. List some small gas engines you are familiar with.

Some respondents listed more than one engine. The tabulation listed on next page indicates the most familiar engines to the men questioned.

TABLE VIII

FAMILIAR SMALL GAS ENGINES

Name of Engine	Listed by
Briggs & Stratton	24
Busy Bee	1
Clinton	19
Continental	2
Cushman	3
Delta	1
Evinrude	4
Fairbanks-Morris	2
Franklin	1
Jacobsen	1
Johnson	4
Kohler	2
Lauson	7
Maytag	5
Mercury	2
Power Products	2
Sea King	1
Service Cycle	1
Toro	1
Waukesha	1
Wisconsin	9

Question 13. Would there be a possibility of constructing projects involving small gas engines? (yes) (no) (Comments)

Seventy per cent of the respondents thought projects could be constructed involving small gas engines. Only four negative answers were received, nine neglected to answer the question. Some of the comments and suggested projects are listed below.

Comments opposed to constructing projects:

a. "Would take a machine shop and foundry in my opinion."

b. "Perhaps somewhat limited because class time is too limited, for most projects."

Comments in favor of constructing projects:

a. "Have student overhaul these engines as projects."

b. "Toys, scooters, motor bikes, farm elevators, grain augers, post hole diggers, wood saws, battery chargers, light plants, pumps, lawn mowers, motor boats."

Question 14. Check the following items you would like to include in a course of study. Please feel free to add additional items.

The items are listed below in numerical order of preference given by the respondents.

TABLE IX

ITEMS TO BE INCLUDED IN A COURSE OF STUDY

Item	Listed by
Theory of 2- and 4-stroke cycle engines	34
Fuel systems (both gravity and pressure type)	34
Carburetion	34
Instruction on engine overhaul	34
Trouble shooting, care and maintenance	34
Ignition systems	33
Engine tune-up	33
Instruction on lubrication	32
Carbon monoxide poisoning	30
Lawn mower safety	28
Overloading and over speeding	27
Engine storage	26
Outboard maintenance and boat safety	25
Power output testing	1
Governor	1
Tools and equipment used in servicing engines	1

Question 15. What do you think would be the greatest difficulties in setting up and operating a small engine shop?

Fifty percent of the men thought the biggest difficulty would be to get sufficient repair jobs in the shop. The breakdown on the answers received is listed below.

TABLE X

DIFFICULTIES IN OPERATING SMALL ENGINE SHOP

Difficulties	Listed by
Getting sufficient repair jobs in shop	18
Securing text and reference books	12
Supply of engine parts	12
Getting a qualified instructor	11
Securing equipment	9
Organizing a course	8
Getting boys interested in this new field	7
Providing sufficient variation to maintain enthusiasm	1
Keep course interesting, avoid mere assembly and disassembly	1
Cost of equipment	1
Selling idea to administration	1

The questionnaire contained space for further comments and some of the more pertinent ones are listed below.

a. "Will concede to you that this project is very important to the field of Ind. Ed. However, I feel the biggest job in the Ind. Arts Field is to sell the administration on the idea that shops are an important part of Education and not just a place to put students that class room teachers don't feel that they want to put up with them or not capable of handling."

b. "Idea is good--would be a good preliminary to Auto Mechanics or a consumer course."

c. "Todays classrooms are overcrowded, very little room for large stationary engines. This in my opinion makes way for a more practical small engine, which theoretically performs and functions alike."

d. "These small engines should be a part of one course on internal combustion engines. If facilities are not met that automobiles could not be handled, by all means add a unit in small 2-4 cycle engines."

e. "I am highly in favor of such a division of work in the General Shop."

f. "Since more and more of these engines are in use I think a unit of this work would be justified from the standpoint of Practical Ind. Arts and gas engine work where space was not available for larger engines."

g. "Even though I have checked the above and have probably left the impression I favor such a course, it does seem to me that much that is more important is being omitted from our present offerings. Electricity is one that comes to mind."

h. "A power output testing device of some kind would be helpful for:
   1. Providing load for run in and tuning.
   2. Giving an idea of the technique involved in power measurement.
   3. Permitting a variable load."

   "Such a device may be home made:
   Hydraulic - use oil or water pump - measure pressure.
   Electric - use generator - measure power output. (A torque measurement device could be added to either system.)"

i. "Judging from my own experience, I would say that the chances for real success of the Unit shop in small engines, is rather slim. The possibilities as an area in the general shop appear rather bright to me. I have used small engines, to a limited degree, in my auto mechanics class for some time. They lend themselves well to teaching nomenclature, procedures, engine principles and the care and use of tools."

Summary

It appears from the foregoing facts that the Industrial Education supervisors and Auto Mechanics instructors in the five state area mentioned, think that small gas engines could be used as a section or unit in industrial arts shops. The survey indicated such a course would be profitable primarily in senior high school.

Approximately 50 percent of the respondents knew of schools teaching small gas engine work although not all of them were teaching it. There was an indication that boys' interest would be generally high in small internal combustion engine work.

There was an indication that principles of engine operation and care and maintenance should be taught together.

Apparently auto mechancis is not becoming too complicated for secondary school shops. It is interesting to note that 19 percent of the men did think auto mechanics was becoming too complicated and that 25 percent of them thought small gas engines would be a satisfactory beginning substitute. From this it may be inferred that small gas engines might be desirable for beginning mechanics classes. The Auto Mechanics instructors felt that they would be qualified to teach small gas engine work.

In comparing small gas engines with auto mechanics for Junior and Senior High School boys, 69 percent of the respondents thought that small gas engines were not as good.

Most of the men stated that they would need to purchase a few additional tools to operate such a shop.

The engines familiar to most of the men were: Briggs &

Stratton, Clinton, Lauson, and Wisconsin. Motor manuals from these companies were suggested for textbooks and reference materials. Many thought projects could be constructed with these engines.

Items suggested for a course of study were: (1) principles of operation of 2- and 4-stroke cycle engines, (2) four essential systems of internal combustion engines, (3) instruction on tune-up, trouble shooting, and overhaul, (4) engine overloading, over speeding, and storage, (5) carbon monoxide poisoning and various other related topics of information.

The greatest difficulty in setting up and operating a small engine shop was thought to be getting sufficient repair jobs in the shop.

In view of the favorable reception for small engine work in the schools, the problem of a course of study will be examined in the next chapter.

CHAPTER IV

COURSE OF STUDY FOR INTERNAL COMBUSTION ENGINE SHOP INSTRUCTION

The course of study developed in this chapter is based merely upon the suggestions and comments developed in the preceding chapter and upon manufacturer's manuals and published material in this area. As the small gas engine shop is relatively new and in the exploratory stage, instructors will have to develop a course suitable to their own shop conditions.

Textbooks

Small gas engine shops can use very effectively manufacturer's manuals for good reference materials, as do auto mechanics classes. Almost every manufacturer publishes a manual covering the proper operation and care of his engines. Many manuals contain information on: (1) operation of engine, (2) recommended maintenance, (3) trouble shooting hints and remedies, and (4) parts replacement and overhaul procedures.

A book that would be suitable for a textbook in a small gas engine shop is <u>All About Small Gas Engines</u>, written by Jud Purvis. This book is published by The Goodheart-Wilcox Company, Inc., Chicago, Illinois, and was issued in 1956. It appears to be one of the best in the field.

> ALL ABOUT SMALL GAS ENGINES tells and shows how small two-cycle, and four-cycle gas engines are constructed; how they operate, what goes wrong; how to service and repair them.[1]

This book can be used as a basic text for those who desire to learn about automobile engines. "Much of the basic information given here is applicable to automobile engines."[2]

Another book that would make a good text is: Small Engines Service Manual, published by Implement and Tractor Publications, Inc., Kansas City 5, Missouri.

The Encyclopedia of Outboard Motoring by Hank W. Bowman, published by A. S. Barnes & Company, Inc., New York, would be a good reference book. It gives the history of outboard motorboating; information on choosing proper outboard motors; trouble shooting ailing motors; routine motor maintenance, repairs and overhaul. This book also deals with the pleasures of boating, safety, racing and many other topics of information.

Practical Work

From the opinions of the men questioned in the survey the following major units of work are suggested for a practical course of study:

1. Theory of 4- and 2-stroke cycle engines
2. The four essential systems of internal combustion engines:
   a. Fuel system
   b. Ignition system
   c. Cooling system
   d. Lubricating system

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[1]Jud Purvis, All About Small Gas Engines (Chicago: Goodheart-Willcox Company, Inc., 1956), p. 3.

[2]Ibid.

3. Instruction on engine overhaul
4. Engine tune-up
5. Trouble shooting, care and maintenance
6. Carbon monoxide
7. Overloading and over speeding
8. Power output testing
9. Lawn mower and boat safety
10. Engine storage

Related Jobs

Listed below are common jobs performed in most auto mechanics shops and would also be performed in Small Gas Engine shops.

1. Engine tune-up including checks on:
   a. Compression
   b. Points and condenser
   c. Plugs
   d. Timing
   e. Carburetion
2. Grinding valves
3. Removal of carbon from pistons, head, etc.
4. Install new piston rings
5. Rebore engine
6. Install new rod and main bearings
7. Replacing and adjusting breaker points and condenser
8. Cleaning and adjusting carburetor

Trouble Shooting

Trouble shooting sequences should have a definite procedure. Instructors may develop their own or use methods already established. The trouble shooting sequence usually deals with failure to start, usually implying malfunction of either carburetion or ignition. The difficulty rarely occurs in both systems simultaneously.

Preliminary steps

1. Clean the engine.

2. With spark plug tightly installed, rotate the flywheel. This will usually disclose any broken parts such as: crankshaft, connecting rod, wrist pin, piston, etc. This will give a preliminary check upon the condition of rod and main bearings, compression, magneto roto-stator clearance, and tightness of flywheel.

Ignition

1. Check the spark plug.

2. Preliminary magneto check, see if there is any spark.

3. Complete magneto check
   a. Check for loose connections
   b. Check for grounded wires
   c. Check breaker points
   d. Check condenser
   e. Check high tension coil
   f. Check cam lobe position
   g. Check magneto timing

Carburetor

1. Check fuel flow to carburetor.

2. Check mixture and adjustments.

3. Make an external check of gaskets and seals.

4. Check air filter.

5. Check reed valve.

6. Disassemble carburetor: Inspect and clean with solvent and air blast.[3]

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[3]Power Products Maintenance Manual.

Tests

Small gas engine work tends to be easily tested by several types of tests. Perhaps the biggest and best test is satisfactory engine operation after the student has finished working on it. It is certainly the most rewarding to the student and builds his confidence in his knowledge and skills.

The instructor may use advantageously any of the following tests:

1. Objective recall
2. Objective recognition
   a. Multiple-response
   b. True-false
   c. Matching
   d. Rearrangement exercises
3. Objective performance
   a. Quality
   b. Technique
   c. Speed

Objectives

The objectives should be determined by the instructor before beginning the small gas engine shop. The community environment and size of shop will influence the course objectives. The writer would like to suggest at least the following objectives:

General

1. Develop the ability to intelligently select, use, and care for small gas engines.
2. Develop planning procedure, form habits of orderly step by step ways of performing a job.

3. Provide fundamental experiences valuable to all students either in advanced mechanics courses or life situations.

Specific

1. To provide an opportunity for the student to understand the principles of operation of both two and four stroke cycle engines.
2. To provide an opportunity for the student to understand the four essential systems of an internal combustion engine.
3. To provide an opportunity for the student to repair, tune-up, maintain, and perform trouble shooting operations on small gas engines.

Summary

As this type of shop work is new, a tentative course of study is suggested. Jud Purvis' book, All About Small Gas Engines, as a suitable text, is suggested by the writer. Another good textbook is, Small Engines Service Manual. Any of the motor manuals published by the manufacturers would be desirable.

The practical work suggested involves teaching: (1) theory of 4- and 2- cycle internal combustion engines, (2) the four essential systems, and (3) care and maintenance, trouble shooting, overhaul, etc. The jobs involved in teaching a small gas engine shop correspond very close to those found in an auto mechanics shop.

A trouble shooting sequence should follow a definite procedure, usually seeking mechanical difficulties in carburetion, ignition, etc.

Small gas engine work easily lends itself to objective informational type tests: (1) recall, (2) recognition, and (3) performance.

The objectives for the course will vary, depending upon the locality and instructor. The following objectives are fundamental for the course to be a success: (1) develop ability to intelligently select, use and care for small gas engines, (2) develop planning procedures, (3) understand the principles of 4- and 2- stroke cycle engines, and (4) provide opportunity for the student to maintain and repair small gas engines.

CHAPTER V

TOOLS AND EQUIPMENT
FOR THE SMALL INTERNAL COMBUSTION ENGINE SHOP

The writer has compiled a list of standard tools from recommendations made by different engine manufacturers. The list is for a small shop class and is only a minimum, more tools and special equipment may be desirable.

<u>Minimum List of Standard Tools</u>

1 - 2 oz. Ball Pein Hammer

1 - 8 oz. Ball Pein Hammer

1 - 1 lb. Ball Pein Hammer

1 - 8 oz. Cellulose Tip Hammer

1 - Heavy Rawhide Mallet

1 - 6" Long Needle Nose Pliers with Wire Cutters

1 - 6" Heavy Duty Diagonal Cutters

1 - 7" Standard Pliers

1 - 8" Vice Grip Pliers

1 - 8" Adjustable Wrench

1 - Set Sockets, ¼" up to 1 1/8"

1 - Set Box End and Open End Wrenches, ¼" up to 1"

1 - 7/16" 45° x 90° Open End Wrench

1 - Set Allen Wrenches (Small) .050, 1/16, 5/64, 3/32, 1/8, 5/32, 3/16, 7/32, ¼, 5/16, and 3/8.

1 - Meter Torque Wrench (Ft. lbs.)

1 - Screwdrivers 7/32 x 6", ¼ x 9", 5/16 x 10½"

1 - Small Screw Holding Screwdriver

2 - Philips Screwdrivers, No. 1, No. 2

1 - Set Feeler Gauges .004 to .025

1 - Carborundum Stone for Points

1 - 10" Flat File

1 - 6" Round File

1 - Scriber

1 - Pencil Flashlight

1 - Center Punch, ¼ x 3½"

1 - ½" Cold Chisel

1 - 1/8" Nail Set

1 - Burr Knife

1 - Carbon Scraper

1 - Ring Expander

1 - Ring Compressor

1 - 1" to 2" Micrometer

1 - 1" to 2" Telescope Gauge

1 - 7/16" Die and Holder

1 - ¼" Die and Holder

1 - 7/16" Tap

1 - ¼" Tap

1 - Hack Saw

Special Equipment

1 - Drill Press

1 - Set Drills

1 - Vise, metal

1 - Grinder Wire Brush

1 - Condenser Tester

1 - Coil Tester

1 - Valve Grinding Set

1 - Compression Tester

1 - Test Tank for Outboard Motors

This equipment would be suitable for a small gas engine unit in the comprehensive general shop or in the automotive mechanics shop. For a unit gas engine shop, additional equipment, such as a lathe, would be necessary.

CHAPTER VI

SUMMARY AND RECOMMENDATIONS

Summary

Christiaan Huygens as early as 1660 was searching for a source of continuous rotary motive power by means of the explosive force of gunpowder. Denis Papin and Abbe Hautefeuille later endeavored to develop Huygens proposal of using gunpowder but were not successful.

The commercial career of gas engines began with Samuel Brown's engine in 1823. These engines were put in road vehicles by 1826 and in boats by 1827.

The next important development in gas engines was the invention of the "free piston" engine by Barsanti and Matteuici in 1859. This engine was extremely noisy. A year later, Lenoir was building gas engines resembling the horizontal, double-acting steam engines, a much quieter engine although not very efficient.

M. Beau de Rochas patented the theory for the four-stroke cycle internal combustion engine in 1862. These cycles in brief were: (1) intake, (2) compression, (3) ignition, and (4) expulsion or exhaust, all performed in two revolutions of the crankshaft.

Dr. Otto in 1876 developed a gas engine using Beau de Rochas' sequence of strokes. These cycles were completed in two revolutions of the crankshaft, involving four strokes, hence the name four-stroke cycle. This engine revolutionized the construction of gas engines. It practically superseded all other engines and launched the internal combustion engine upon its amazing commercial career.

Sir Dugald Clerk in 1878 produced his notable two-stroke cycle engine. Clerk used the same sequence of operations, but his engine completed the cycle in two strokes or one revolution of the crankshaft.

Every engine has four essential systems: (1) fuel system, (2) ignition system, (3) cooling system, and (4) lubricating system.

Small gas engines usually have gravity fuel systems, magneto ignition systems, and air cooling systems. Outboard motors are exceptions, sometimes employing pressure or suction fuel systems and practically all are water cooled.

Four stroke cycle engines use both forced and splash lubricating systems. The two stroke cycle uses neither, but gets its lubrication from mixing oil in the gasoline. The mixture goes through the airtight crankcase enroute to the combustion chamber and the oily mist tends to lubricate the engine.

Today these engines may be purchased in four different engine designs: (1) vertical, (2) horizontal, (3) angular, and (4) opposed.

Due to the fact these small gas engines operate by the same sequence of operations that automobile engines do, it is felt that these engines could be used in industrial arts shops. The opinions of auto mechanics teachers and industrial education supervisors indicated these small gas engines could be used as units in industrial arts shops. Such a unit, it was indicated, would be most profitable in the senior high school.

There seemed to be a general opinion that boys would be interested in this type of work. Approximately one half of the respondents knew of schools teaching some small gas engine work.

Apparently auto mechanics is not becoming too complicated for secondary school shops, a lthough 25 percent of those who answered the questionnaire thought that small gas engines would be a satisfactory beginning substitute. Sixty-nine per cent of them implied small gas engines would not be as good as auto mechanics. The auto mechanics teachers indicated that they would be able to teach this type of work and would need to purchase only a few additional tools.

Most of the men were familiar with many of these small engines, the following seemed to be most common: (1) Briggs & Stratton, (2) Clinton, (3) Lauson, and (4) Wisconsin.

The following items were suggested for a course of study:

1. Theory of 2- and 4-Stroke cycle engines.
2. Instruction on lubrication.
3. Fuel systems (both gravity and pressure type).
4. Carburetion.
5. Ignition systems.
6. Instruction on engine overhaul.
7. Engine tune-up.
8. Trouble shooting, care and maintenance.
9. Engine storage.
10. Overloading and over speeding.
11. Outboard maintenance and boat safety.
12. Lawn mower safety.
13. Carbon monoxide poisoning.
14. Power output testing.
15. Governor.
16. Tools and equipment used in servicing engines.

The greatest difficulty in setting up and operating a small engine shop was thought to be that of getting sufficient repair jobs in the shop.

Two satisfactory textbooks have been written in this area: (1) All About Small Gas Engines, and (2) Small Engines Service Manual. Engine manuals from the many different companies would make suitable reference or supplementary reading material.

The practical items of work have been listed (See Chapter IV, page 37). Upon close comparison, many of these jobs are seen to coincide with auto mechanics jobs and instruction. This type of work tends to be easily tested by various objective tests.

The objectives for the course will vary, depending upon the locality and instructor. The following objectives are fundamental for the course to be a success: (1) develop ability to intelligently select, use and care for small gas engines, (2) develop planning procedures, (3) understand the principles of 4- and 2-stroke cycle engines, and (4) provide opportunity for the student to maintain and repair small gas engines.

Recommendations

The following facts are listed to help justify the recommendation that small gas engine work be taught either as: (1) a unit in auto mechanics class, (2) an area in a composite general shop, or (3) a unit shop.

1. The principles of operation are the same as automobile engines, with minor variations such as in the ignition and cooling systems. Both 2- and 4-stroke cycle engines operate on the same sequence of operations. Carburetion, timing, and lubrication are all quite similar. These engines lend themselves well to teaching nomenclature.

2. Small gas engine work could be used as prerequisite or beginning substitute for auto mechanics. As mentioned in Number 1, these engines operate on the same principles. Overhauling procedure, trouble shooting sequences, care and maintenance, tune-up, carburetion, and numerous other jobs, basically coincide with auto mechanics.

3. Small floor area required by small gas engines. These engines are small, consequently they may be placed on benches to be overhauled. Storage space for these engines while being overhauled could very definitely be small, shelves could be used on top of each other. In a small school or shop, this might be one of the most important factors.

4. Expensive tools and machines are unnecessary. A minimum of standard hand tools would be sufficient to maintain a small gas engine shop. All timing and tune-up machines, wheel balancers, lathes, welding equipment, and numerous small tools could be eliminated.

5. Smaller and more numerous projects could be constructed. The following suggestions were received in the survey: scooters, motorbikes, grain augers, post hole diggers, light plant, pumps, lawn mowers, farm elevators, etc. The list is limited only by the imagination and skills of the students and instructors.

6. There are wide and numerous uses of small engines. These different uses are almost innumerable (See Chapter II, pages 23-24).

7. Boy interest in small engines is high. Almost every boy has been exposed to these engines in some fashion. Many own scooters, power mowers, outboard motors, etc. Many of their parents will own such engines, thus helping create the boys' interest in these engines.

8. Small gas engines are maneuverable, can be lifted by hand, and are easy to work on. Accessibility would be a prime factor of importance. These engines would be safer by eliminating hoists and having to move heavy engines. Repair jobs and tune-up jobs would be easier and faster due to simplicity.

9. Students need consumer, maintenance, and safety knowledge about these engines. The use of the engine will determine: size, design, and 2- or 4-cycle engine. Students should learn how to choose the engine that will perform the job satisfactorily at the lowest cost. Any engine will run longer and perform better if properly maintained. To do this, students must learn certain procedures and likewise be able to apply them to different motors. With the many uses of these engines, safety becomes very important. For example: boat safety, lawn mower safety, overheating, carbon monoxide poisoning, road safety, etc.

10. Some companies will furnish engines free to school shops. Some companies will furnish different types of engines, even cutaway engines. These are especially good for teaching the principles of operation and nomenclature. This service is

good public relations for the company besides being very beneficial to the school.

11. Companies will furnish free engine manuals. It is to the best interests of the companies to perform this service. If their engines are properly cared for, they will operate better, and satisfied customers are good salesmen.

In view of the favorable reception of the idea of small engines shops or areas in schools, a new area of activity, it would seem that the future of this new school endeavor is promising.

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APPENDIX

Pittsburg, Kansas
December 27, 1956

Dear Mr.

Since small gas engines have become important to most home owners and in wide use over the country, I am making a study of the "Possibilities of Small Gas Engines in Specific Industrial Arts Shops or As Areas in Composite Shops".

Since you are in the field teaching Industrial Arts, I would like your opinion concerning the possibilities of using these engines for units of instruction covering; maintenance, overhaul, and as a basis for studying the principles of internal combustion engine operation.

Enclosed is a brief questionnaire with a self addressed envelope which I would like for you to complete at your earliest convenience. Thank you for your promptness and considerate cooperation.

Sincerely,

Carl J. Hohmann

THE POSSIBILITIES OF SMALL GAS ENGINES IN SPECIFIC
INDUSTRIAL ARTS SHOPS OR AS AREAS IN COMPOSITE SHOPS

1. Do you think small gas engines could be used as a section or unit in Industrial Arts Shops? Yes ____ No ____

2. Do you think such a course covering maintenance and overhaul would be profitable for the students? Yes ____ No ____

3. What type of school should, in your opinion, the small gas engine shop be placed? Jr. High ____ Senior High ____ Both ____

4. Do you know of any shops where small gas engine work is taught? ____________
____
____

5. Would you think that boys interest would be generally high in work with small internal combustion engines? Yes ____ No ____

6. Would you teach the principles of engine operation first or teach care and maintenance first, or should these be taught together? Principles of engine operation first. ____ Care and maintenance. ____ Together. ____

7. Do you think Auto Mechanics is becoming too complicated for secondary school shops? Yes ____ No ____. If so, would small gas engines be a satisfactory beginning substitute? Yes ____ No ____

8. Would Auto Mechanics instructors be qualified for teaching small gas engine work? Yes ____ No ____. If not, should instructors receive special training for this work? Yes ____ No ____. Comments. ____________
____

9. How do you think small gas engines would compare with Auto Mechanics as a shop course for Jr-Sr. High School age boys in Mechanics? Better. ____ Just as good. ____ Not as good. ____ Comments. ____________
____

10. Would you need to purchase new tools in your present shops, to maintain and overhaul small gas engines? Complete set. ____ Partial set. ____ None. ____

11. Do you know of any books, manuals, or course materials on small gas engines? Yes ____ No ____. Comments. ____________
____

12. List some small gas engines you are familiar with. ____________
____

13. Would there be a possibility of constructing projects involving small gas engines? Yes ____ No ____. Comments. ____________
____

14. Check the following items you would like to include in a course of study. Please feel free to add additional items.

____ Theory of 2-and 4 stroke cycle engines.
____ Instruction on lubrication.
____ Fuel systems (both gravity & pressure type).
____ Carburetion.
____ Ignition systems.
____ Instruction on engine overhaul.
____ Engine tune-up.
____ Trouble shooting, care & maintenance.
____ Engine storage.
____ Overloading and over speeding.
____ Outboard maintenance and boat safety.
____ Lawn mower safety.
____ Carbon monoxide poisoning.
-Others-

15. What do you think would be the greatest difficulties in setting up and operating a small engine shop?

____ Getting a qualified instructor?
____ Organizing a course?
____ Securing text and reference books?
____ Securing equipment?
____ Getting boys interested in this new field?
____ Getting sufficient repair jobs in shop?
____ Supply of engine parts?
-Others-

Further comments, please use back of this sheet if necessary.