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Electronic Ignitions

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Electronic Ignitions

Abstract

It is the purpose of this study to (1) review all available literature on electronic ignitions; (2) study the function and application of electronic ignitions; (3) determine the advantages of a capacitive-discharge ignition system over a conventional system; (4) develop an instructional unit around the function and application of electronic ignitions; and (5) prepare a written and oral report on electronic ignitions.

Approved by:

Graduate Committee, Chairman

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Date

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Master of Arts

by

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Chapter 1

THE PROBLEM

Statement of the Problem

The area of electronic ignitions has recently come to the fore due primarily to the need for improved automotive engine emission control. The advent of these sophisticated systems presents a new and interesting challenge to the industrial arts teacher in the automotives area. The problem of becoming informed about these systems and preparing an effective method of communicating this information to students in auto mechanics must be met by those teachers wishing to stay informed of current technological developments in the field of automotives.

Purpose of the Study

It is the purpose of this study to (1) review all available literature on electronic ignitions; (2) study the function and application of electronic ignitions; (3) determine the advantages of a capacitive-discharge ignition system over a conventional system; (4) develop an instructional unit around the function and application of electronic ignitions; and (5) prepare a written and oral report on electronic ignitions.

Importance of the Study

In this time of dwindling fuel supplies, it is becoming increasingly important to explore methods of diminishing the consumption of natural sources of energy. It is equally important to educate the consumer in order that he may take advantage of the methods available to him which would help conserve energy. Improving gas mileage is one such method. Explaining the advantages of electronic ignitions and demonstrating the improvement in fuel economy using electronic ignitions allows the student to become aware of recent innovations and how they affect his daily life. The importance of energy conservation cannot be overemphasized. Incorporating an instructional unit on electronic ignitions in auto mechanics courses will keep students informed of technological advances in automotives and also provide them with an insight to a means of conserving energy.

Limitations of the Study

The study will be limited to library research of four ignition systems; conventional, transistorized, capacitive-discharge, and magnetic induction. It is felt by the writer that these ignition systems comprise the most important of the various systems utilized by spark ignition, internal combustion engines in automobiles. The project activity will be limited to the testing and comparison of a conventional ignition system to a capacitive-discharge system. Due to the cost and time limitations, no attempt will be made to compare conventional systems to transistorized or magnetic induction systems. An instructional unit, including all four systems, will be written for students at the senior high level.

Definition of Terms

Bottom Dead Center: The lower limit of the piston's stroke before its motion is reversed (Obert, 1973, p. 3).

Brake Horsepower: The power available after frictional losses have been overcome. Usable horsepower available to do work (Obert, 1973, p. 43).

Capacitor or Condensor: An electronic device which stores current until it becomes fully charged (Judge, 1971, p. 134).

Electrode Gap: The space between the center electrode and the ground electrode of a spark plug (Larew, 1968, p. 115).

Engine Displacement: The displacement is the volume swept by the piston in one stroke multiplied by the number of cylinders in the engine (Obert, 1973, p. 2).

Magnetic Pulse: A control signal generated by an iron timer core rotating inside a magnetic pick-up coil (Cantonwine, 1972, p. 29).

Point Dwell: This is the percentage of time the contact points are closed, expressed in degrees and called the dwell or dwell angle (Cantonwine, 1972, p. 9).

Top Dead Center: The upper limit of the piston's stroke before its motion is reversed (Obert, 1973, p. 3).

Chapter 2

RELATED INFORMATION

Historical Background

In the first experimental gasoline engines, various methods of igniting the air-fuel mixture were used. The method of introducing an open flame into the cylinder through a small hole to produce combustion was the forerunner of the modern automobile ignition system. This system was crude and difficult to control. An improvement of this design was a hot metallic surface in the form of a tube or ball inserted into the combustion chamber. These early systems led to the development of the device we now know as the glow plug. Glow plugs are commonly used in small model airplane engines. Heat from the burning fuel causes the glow plug element to become red hot. This red hot element ignites each incoming air-fuel charge, initiating combustion and maintaining engine operation. Although these methods worked, they were far from efficient. Varying speed and load condition requirements demand a more precise method of igniting the air-fuel mixture. It was found that an electrical spark introduced into the combustion chamber at the correct time provided a means of igniting the air-fuel mixture for more efficient engine operation.

The first spark ignition systems were very basic in their construction and operation. The Model-T Ford automobile employed a magneto as a means to provide electrical current to fire the spark plug. This magneto multicoil ignition system (Figure 1) used a separate ignition coil, switch, and capacitor for each spark plug. Current flowing to the primary (L_p) is controlled by the timer which is rotating at one half the engine crankshaft speed. The timer completes the circuit through each of the primary windings to ground at the instant the corresponding spark plug should fire. A manual control, mounted on the steering column, gave the operator the ability to vary the spark timing as engine requirements changed. The flywheel magneto also provided electrical power for the lighting system.

The next phase in the evolution of automobile engine ignition systems came in the early 1900's.

> It was not until 1910, approximately seventeen years after the Duryea brothers had first assembled an American car using the gasoline engine, that a workable battery ignition system made its debut. This system, shown in the original patent drawing of Charles F. Kettering, its inventor, was introduced by Cadillac in 1911 (Graf, 1971, p. 7).

The Kettering system (Figure 2) became the tried and true ignition system and has remained the primary type used by all spark ignition engines to date. The main components of the Kettering or conventional system as it is more commonly referred to are; a battery, an ignition switch, an ignition coil, a distributor containing contact points and a condensor, and spark plugs. Mr. Kettering was also instrumental in the development of the electric starter for automobile

Magneto Ignition Systems

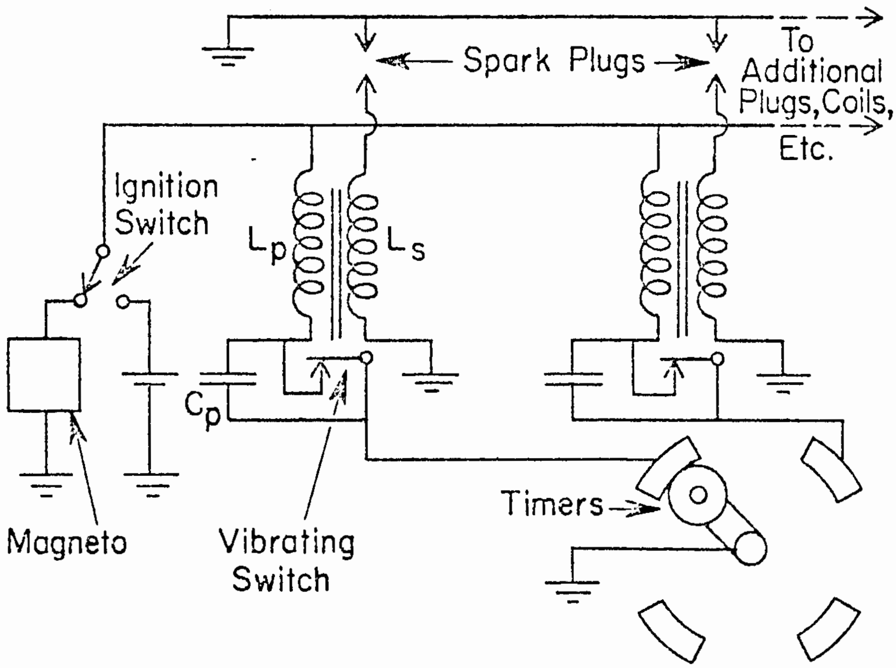
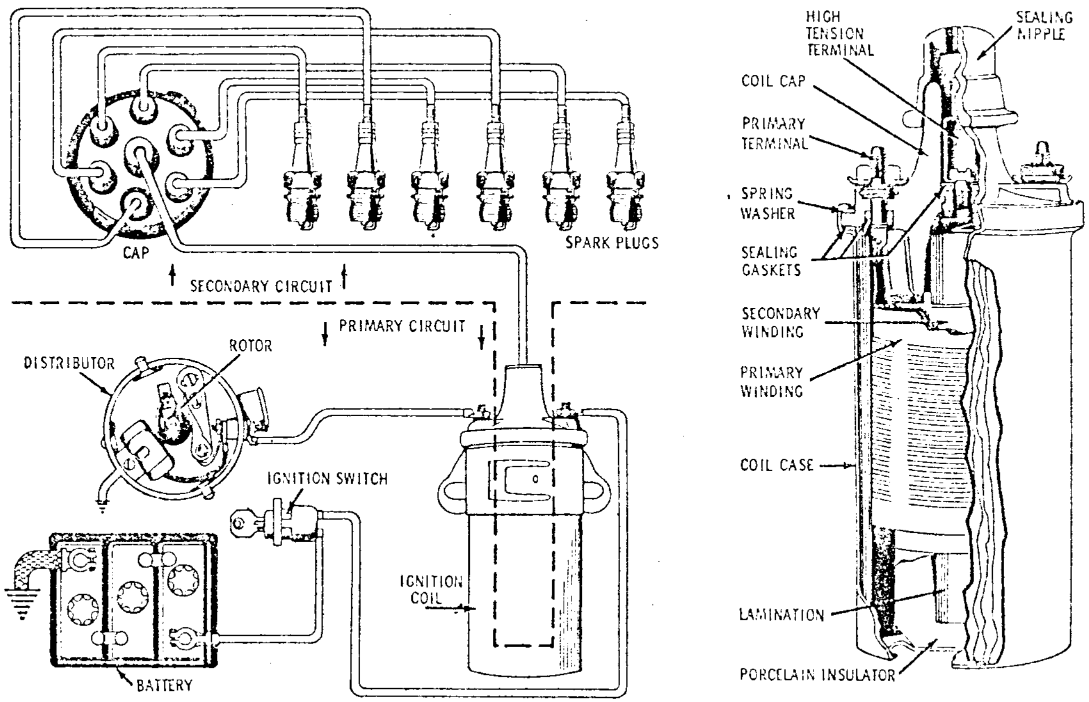


Fig. 41 Magneto multicoil ignition system.

FIGURE 1

(Larew, 1968, p. 146).

Fig. 2-1. The Kettering ignition system.



(A) Wiring layout. *(B) Details of the coil.*

FIGURE 2

(Ward, 1965, p. 18).

engines and the automobile lighting system. Only recently have such technological advances as transistor, capacitive-discharge, and magnetic induction ignition systems made their appearance on the automotive scene. Prior to this time, high cost of components and low reliability have served to preclude their acceptance by automobile manufacturers.

Industrial-Geographical

Manufacturers and distributors of electronic ignitions are located throughout the United States. These companies are engaged primarily in the design, production, and distribution of electronic ignitions as conversion kits for cars produced with conventional ignition systems. In addition to these companies, there are the automobile manufacturers who have recently begun to mass produce automobiles with solid state ignition systems. Chrysler Corporation now equips all of its production cars with electronic ignitions. Ford Motor Company has electronic ignitions as standard equipment on its two largest engines and on all Ford engines over 200 cubic inch displacement produced for sale in California.

> Beginning with the 1974 model year, this new type ignition system was made standard equipment on all California vehicles that have a 200 C.I.D. or larger engine. In all other 49 states the Solid State Ignition System will be standard equipment on only the 400 and 460 cubic inch V-8 engines (Tech Talk, Nov./Dec., 1973, p. 2).

General Motors offers, as optional equipment, electronic breakerless ignition systems on their production V-8 engines.

By 1975, most, if not all, of the major automobile manufacturers will be producing cars with solid state ignition systems as standard equipment.

A list of some of these manufacturers and a map (Figure 3) with the approximate geographical location indicated have been provided. This is by no means a complete tabulation of those companies involved in the production of electronic ignition systems.

1. Accel Ignitions
   P. O. Box 142
   Brandford, Connecticut 06405

2. Delta Products, Inc.
   P. O. Box 1147
   Grand Junction, Colorado 81501

3. Gaylord Electronics Inc.
   2314 Fourth Street
   Berkeley, California 94710

4. Heath Company
   Benton Harbor, Michigan 49022

5. General Nuceonics/Tyco
   2811 Metropolitan Place
   Pomona, California 91767

6. Allied Radio Corporation
   100 North Western Avenue
   Chicago, Illinois

7. Automotive Electronics Company
   387 Park Avenue South
   New York, New York 10016

8. Delco-Remy
   Division of General Motors
   Anderson, Indiana

9. Electronic Ignition Corporation
   4120 East Washington Street
   Phoenix, Arizona

10. Mallory Electric Corporation
    12416 Cloverdale Avenue
    Detroit, Michigan

11. Motorola Incorporated
    Automotive Division
    9401 West Grand Avenue
    Franklin Park, Illinois

12. Prestolite, Division of Eltra Corp.
    P. O. Box 931
    Toledo, Ohio

13. American Motors
    14250 Plymouth Road
    Detroit, Michigan 48232

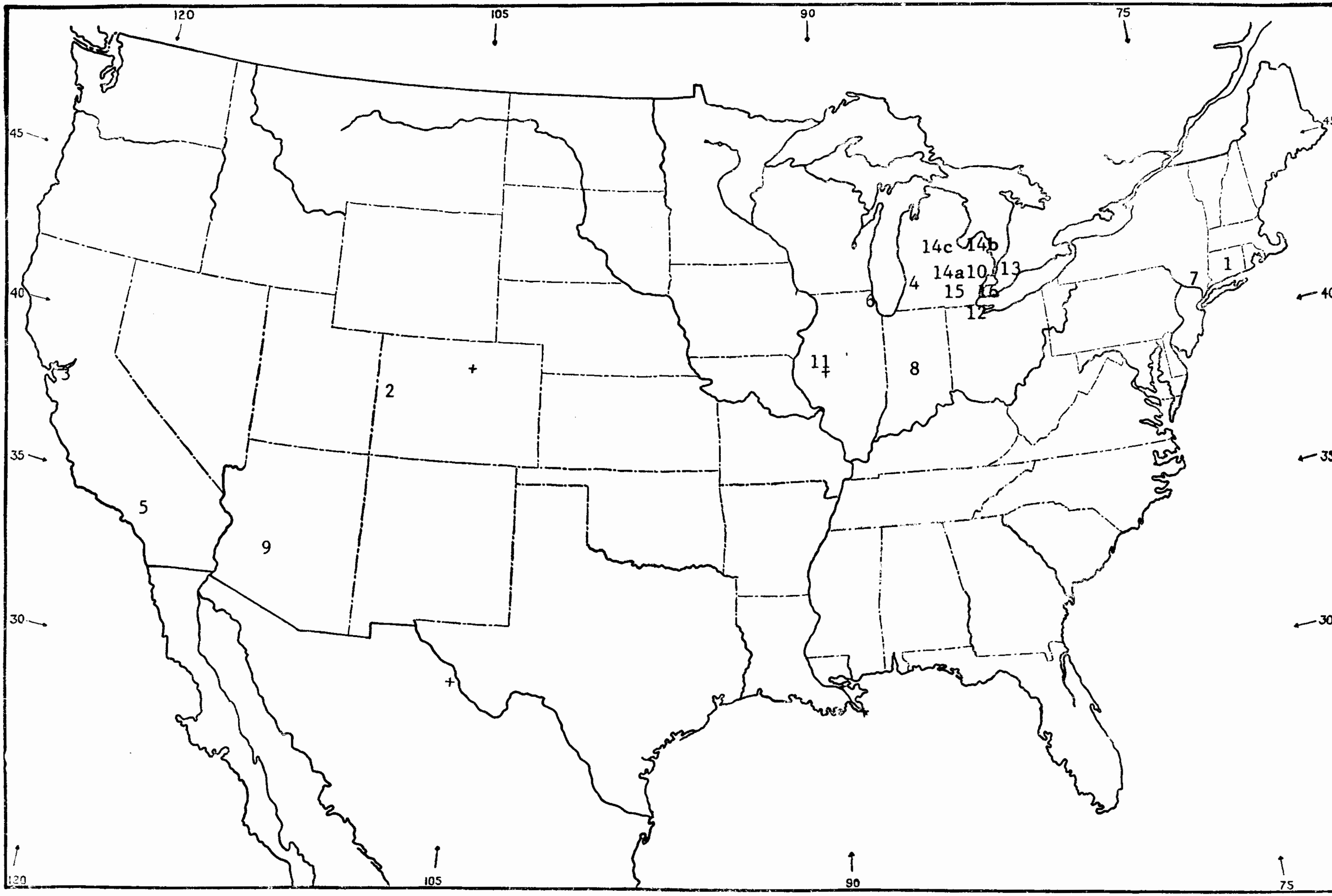
14. General Motors Corporation
    A. Oldsmobile Division
       Lansing, Michigan 48921
    B. Pontiac Division
       Pontiac, Michigan 48053
    C. Buick Motor Division
       Flint, Michigan 48550

15. Ford Motor Company
    20000 Rotunda Drive
    P. O. Box 2053
    Dearborn, Michigan 48121

16. Chrysler Corporation
    Dodge Division
    Detroit, Michigan

Occupational Information

In looking for information concerning occupations in the area of electronic ignitions, the writer was unable to discover specific data for use as supportive material. It was possible to generalize by using broad subject headings which would include people working in design, development, and production of electronic ignitions. It is beyond the scope of this paper to present an indepth report on occupational data. The following information should provide an insight into some of the more prominent occupational areas in the automotives field.



UNITED STATES. 300 MILES PER INCH. DRAW LINE OF LONGITUDE AND LATITUDE AS INDICATED BY CROSS MARKS. Published by J. S. Latta & Son, Cedar Falls, Iowa

GEOGRAPHICAL LOCATION OF ELECTRONIC IGNITION MANUFACTURERS
FIGURE 3

Electrical Engineer

> Electrical engineers perform a variety of engineering work in designing, planning, and overseeing manufacture, construction, installation, operation and maintenance of electrical or electronic components, equipment, systems, facilities, and machinery used in generation, transmission, distribution and utilization of electrical energy for domestic, commercial, and industrial consumption (Dictionary of Occupational Titles, Vol. 1, 1965, p. 237).
>
> It is estimated that more than 235,000 electrical engineers were employed in the United States in 1970 chiefly by manufacturers of electrical and electronic equipment, aircraft and parts, business machines, and professional and scientific equipment (Occupational Outlook Handbook, 1972-73, p. 72).

Mechanical Engineer

> Mechanical engineers perform a variety of engineering work in planning and design of tools, engines, machines, and other mechanically functioning equipment, and oversees installation, operation, maintenance, and repair of such equipment, including centralized heat, gas, water, and steam systems (Dictionary of Occupational Titles, Vol. 1, 1965, p. 459).

Employment figures for mechanical engineers compare closely to those of electrical engineers. "About 220,000 mechanical engineers were employed in the United States in 1970" (Occupational Outlook Handbook, 1972-73, p. 74).

Assembler, Electrical Accessories

> An electrical accessories assembler puts together mechanical parts of electrical equipment, such as light sockets, switches, terminal boards, and plugging devices, and fits together parts, such as socket bases, shafts, contact fingers, and springs, in specified sequence, using fixtures, screwdrivers, and air nut runners (Dictionary of Occupational Titles, Vol. 1, 1965, p. 24).

Engineering and Science Technicians

Another area where related occupations can be found is the area of service technicians. The technician works with the engineer to bring an idea or design into reality through the construction of a working model. Technicians enjoy good working conditions with a high degree of job responsibility and garner the rewards commensurate with such a position.

> An estimated 650,000 engineering and science technicians were employed in 1970, about 11 percent were women. In 1970 annual salaries of workers in responsible technician positions in private industry averaged almost $11,000 and approximately one-fourth of the workers had annual salaries above $11,900, according to a Bureau of Labor Statistics survey (Occupational Outlook Handbook, 1972-73, p. 223).

Automobile Mechanic

Automobile mechanics keep the nation's automobiles in good operating condition. Most of the work performed by an autmobile mechanic is aimed at the preventative maintenance of engines and chassis components. A typical example of their work would be the tune-up of an automobile engine by replacing spark plugs and ignition components and adjusting point dwell and engine timing. Major overhaul of engines, drive trains, and chassis components are also performed by capable mechanics. While there is no formal training required for auto mechanics at present, in the near future certification and licensing may be required by the state or federal government.

> Most of the more than 600,000 autmobile mechanics employed in 1970 worked for auto dealers, independent auto repair shops, and gasoline service stations. Skilled (journeymen) auto mechanics employed by auto dealers in 34 cities had average straight-time hourly earnings of $5.16, based on a survey in late 1969 (Ibid., 1972-73, p. 473-4).

Students interested in careers in auto mechanics may obtain additional information at the library, contact with their counselor, or by writing: Automotive Service Industrial Association, 168 North Michigan Avenue, Chicago, Illinois 60601.

Chapter 3

FINANCIAL TRENDS

Automobile manufacturing seems limited only by the nation's economic growth and the energy supplies required for their continued operation. The automotive industry has increased its unit production at a steady rate over the past ten years and has seen a recent trend to higher per unit prices as a result of inflation and the devaluation of the dollar overseas. This year, for the first time since World War II, automobile production is down due to a slump in new car sales caused by the energy shortage.

The writer has chosen the major automobile manufacturers in an attempt to illustrate the financial trends of the electronic ignition producing industries.

General Motors Corporation

General Motors is the largest of the four automobile manufacturers discussed in this report. General Motor's dividend earnings for 1974 are forecast to decline about $2.25 a share. The consumer trend away from big cars, currently General Motor's major profit source, and the subsequent retooling and production change-over to small cars will be primarily responsible for this decline.

> Dividends which averaged 71% of earnings in the decade through 1972, do not seem likely in 1974 to match the $5.25 a share paid in 1973, but still should provide

> an excellent yield at the stock's current market price. At 52 (NYSE), the shares are selling for only about eight times tentatively projected reduced 1974 profits, the lowest multiple since 1955. The stock merits retention in investment portfolios for ultimate recovery (Standard and Poor's Industry Survey, 1974, p. A130).

It would appear that this stock would be a secure investment depending upon the energy crisis. If fuel supplies become more available, the consumer might be inclined to buy the larger, more comfortable cars which would increase dividends.

Ford Motor Company

Ford Motor Company ranks second and although profits of approximately $10.00 per share may be reported for 1973, sales for 1974 may recede as demand for new cars falls off under the impact of the current gasoline shortage. Ford's new Mustang II, a smaller version of the mid-sized Mustang, has been well received by the American car buyer. Sales of the Mustang II, Maverick, Pinto, and Ford's import Capri should help stabilize dividends. "The stock (45, NYSE) offers excellent value relative to the reduced profits expected for 1974 and is well worth retaining for recovery by the patient investor" (Ibid., 1974, p. A130).

Chrysler Corporation

Chrysler, like other automobile manufacturers producing large domestic vehicles, is experiencing reduced unit sales due to inflation and the fuel shortage. It is likely that Chrysler will benefit from its emphasis on small and mid-sized cars. Small cars, such as Duster, Valiant, and

Scamp, account for 56% of Chrysler's production. These models are quite popular and fuel economy, from gas saving six cylinder engines, makes them an attractive alternative to the larger, less economical sedans. This, coupled with higher per unit prices, will offset decreased profits. "At current depressed levels (19, NYSE), the stock appears to be making more than ample allowance for the decline in 1974 profits and merits holding for ultimate price recovery" (Ibid., 1974, p. A130).

<u>American Motors</u>

American Motors is the smallest of the four companies, but is probably the only domestic auto maker to report higher profits for 1974. American Motor's success may be attributed to its concentration in the lower-priced segment of the auto market. The smaller Gremlin and Hornet, plus American Motor's highly successful warranty called the Buyer Protection Plan, have fostered record sales of $1.74 billion for fiscal year 1973. "The first cash dividend since 1965 is a strong prospect. Very reasonably valued relative to indicated profits, the shares (9, NYSE) have promise as a low-priced speculation for a potentially sizeable percentage gain" (Ibid., 1974, p. A130).

Since electronic ignitions incorporating breakerless distributors will be an integral part of emission control equipment required on automobiles manufactured with engines designed to meet 1976 emission standards, it can be assumed that companies producing these systems will experience increasing demand for their products. "Electronic applications in automobiles are expected to grow rapidly in coming years. Chrysler was the first to install electronic ignitions on all its cars with the 1973 models, and Ford and GM are likely to follow suit" (Standard and Poor's Industry Surveys, 1973, p. A146). With an increase in sales, one would assume that an investment in stocks of such companies as those producing electronic ignitions might be a worthwhile investment. "An RCA official has estimated that by 1980 the auto industry will be using $3 billion worth of electronic components and devices, or about as much as the cost of engines in cars" (Ibid., 1973, p. A146).

It is apparent to any well-informed person, that large cars are presently not selling well due to the energy crisis. C.B.S. news reported new car sales during the period of March 1, 1974 to March 10, 1974 were down 32.3% as compared to the same period last year. How this would affect the production and sales of electronic ignitions is difficult to predict. An increase in sales of small cars to offset the decline in full-sized car sales would indicate a more stable market for electronic ignitions. This, coupled with increased sales of ignition conversion kits, might mean a more secure investment with promising returns.

Gathering the information necessary to complete this portion of the paper has given the writer an insight into the factors affecting the stock market. It is the opinion of this writer, that there is a great deal more to learn about investments before venturing into the realm of stocks and bonds. It would be wise for anyone wishing to become an investor to seek the assistance of a reputable stock brokerage.

Chapter 4

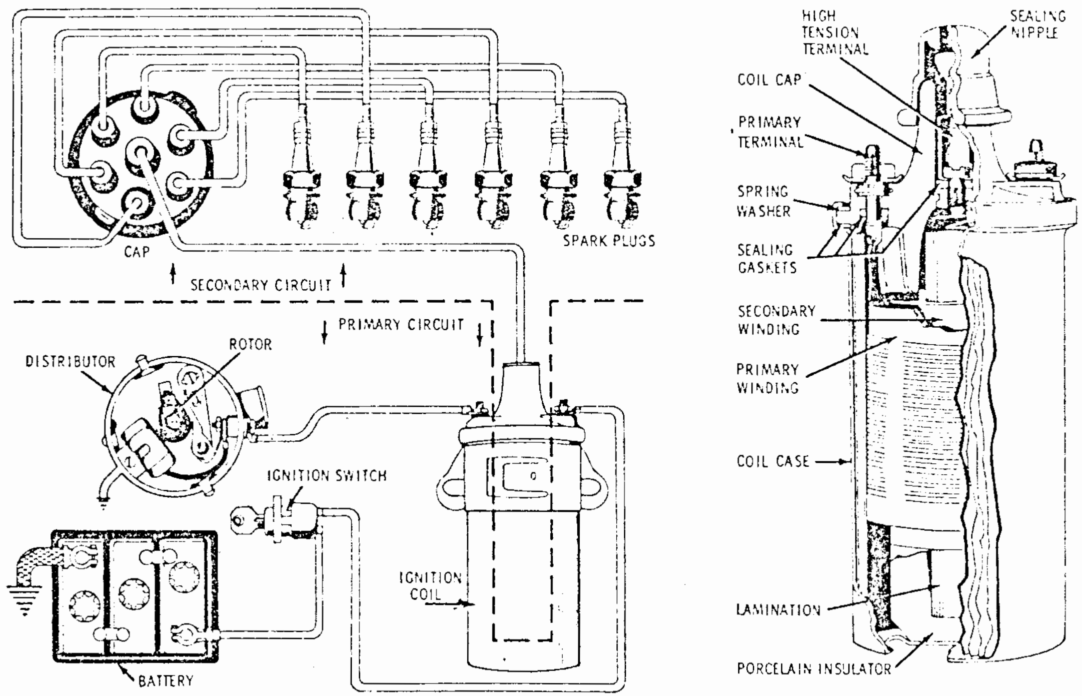
TECHNICAL INFORMATION

Kettering (conventional) Ignition

In the early 1900's George F. Kettering perfected an ignition system using a battery instead of a magneto to provide the electrical current necessary to fire the spark plugs. This system, because of its low cost and high reliability, was to become the major automobile ignition for many years. Its chief components (Figure 4) are; (1) a battery to provide electrical current, (2) an ignition switch for starting and stopping the engine, (3) an ignition coil designed to step-up battery voltage, (4) a distributor containing contact points, condensor, and advance mechanisms, (5) high tension (voltage) wiring, and (6) spark plugs.

The process involved in firing each spark plug at the correct time and with sufficient voltage to jump a .035 electrode gap, is an interesting one which is not difficult to understand. In a four-stroke cycle engine, the camshaft is rotating at one-half of the crankshaft speed. The cam which opens and closes the contact points in the distributor is driven by the camshaft and is also rotating at one-half the crankshaft speed. The distributor cam is shaped with a number of lobes corresponding to the number of cylinders in

Fig. 2-1. The Kettering ignition system.



(A) Wiring layout. *(B) Details of the coil.*

FIGURE 4

(Ward, 1965, p. 18).

the engine. As the rubbing block of the point contact arm follows the distributor cam, the points are opened and closed to switch current to the primary winding in the coil.

The ignition coil is basically a step-up transformer with a primary and secondary winding. The turns ratio of the conventional coil is in the neighborhood of 100 to 130 turns in the secondary to 1 turn in the primary. The primary has about 100 to 150 turns.

When the points close, current flows through the primary building up a magnetic field around it. The period of time that the points are closed is called the dwell angle. The dwell angle is expressed in degrees of distributor cam rotation. It is the period during which the magnetic field rises in the primary. The length of time plus the amount of current flowing against the inductance of the coil determines the strength of the field.

Since the secondary winding of the coil is wound around the primary, magnetic lines of force are also built up around it. The magnetic field stores energy. When the contact points open, current no longer flows to the primary and the magnetic field collapses in both the primary and secondary windings. This field falls much faster than it rises. The magnetic lines of force cut through the windings in the secondary. The speed of the collapsing field causes current to flow rapidly in the secondary and the subsequent high voltage produced overcomes the resistance of the air gap and fires the spark plug. "Most of the electrical energy stored in the magnetic field is dissipated as heat in the arc to initiate combustion" (Obert, 1973, p. 533). The available voltage at the high tension lead of the secondary under normal operating conditions is about 20,000 volts. This is an amount sufficient enough to fire the spark plug (Ibid., 1973, pp. 540-4).

The distributor cap is molded plastic with a terminal for each spark plug. A rotor, connected to the distributor shaft, rotates inside the distributor cap passing each terminal in succession according to the firing order of the cylinders. As the rotor approaches the terminal, the points begin to open. This allows the magnetic field built up in the primary winding of the coil to collapse. The voltage induced in the secondary winding of the coil is transferred to the terminal and then to the spark plug where it ignites the air-fuel mixture at the correct time.

The condensor, more technically referred to as a capacitor, is in parallel electrically with the contact points. The main purpose of the condensor is to prevent arcing of the points as current flow to the primary is interrupted by their opening. Without it in the circuit, the high current would cause rapid pitting and oxidation of the contact point surface.

The system, as far as it has been explained, would work very well at a constant speed and load.

> Since the spark occurs at the spark plug when the contact points separate, the engine is timed by ensuring that this event occurs about 5 degrees before TDC (top

> dead center) on the compression stroke of one of the pistons (Ibid., 1973, p. 535).

In reality, the automobile engine is constantly varying speed as it works under changing load conditions. Therefore, it is necessary to change the ignition spark timing as the engine changes its speed in relation to the changing load.

Varying spark timing is accomplished by two independent systems working to advance or retard the spark timing as speed and load conditions change. They are the load-retard or vacuum advance and the engine speed or centrifugal advance mechanisms.

> The vacuum advance on the spark timing is necessary because the lean mixtures in the economy range require an earlier spark timing than do full power mixtures which burn faster. The centrifugal advance is necessary to compensate for increase in engine speed, because the initial flame speed of burning is relatively constant since the spark plug is near the chamber walls (Ibid., 1973, p. 535).

The vacuum advance is operated by the engine intake manifold vacuum. A vacuum diaphram is connected to the contact points breaker plate by a mechanical linkage. As the vacuum decreases, the breaker plate is rotated and the spark is retarded which causes the plug to fire closer to top dead center of the piston stroke. Vacuum advance is primarily designed to increase engine fuel economy.

The centrifugal advance compensates for changes in engine speed. Weights are attached to the breaker plate in a manner which causes the breaker plate to rotate as the centrifugal force moves the weights outward. This rotation advances the spark directly proportional to the increase in engine speed. It is necessary to fire the spark plug further in advance of TDC as engine speed increases to ensure sufficient time for the air-fuel mixture to burn efficiently.

The advantages of the Kettering system, as mentioned earlier, are its low cost and high reliability. Unfortunately, there are more disadvantages than advantages in the conventional system. Some of the disadvantages become more pronounced in high compression engines or at high speed operation. Poor engine performance becomes noticeable at high engine speeds because of current limitations and contact point bounce due to inertia. With less voltage available at high engine speeds, the system is unable to fire fouled spark plugs. This leads to poor fuel economy and high hydrocarbon emissions. Contact point life is severely shortened due to the high current flow at low speeds. Consequently, engine performance must deteriorate more swiftly because of the changing dwell angle and erratic timing. Spark plugs must be replaced more often because of the high energy discharge at low speeds. Poor starting, particularly in cold weather, is a serious problem due to slow opening of the contact points at cranking speeds (Ibid., 1973, p. 537).

Though the disadvantages are higher in number than the advantages, the system worked well for the average automobile and has only recently come under fire because of increasing concern over exhaust emission control.

Transistorized Ignitions

The primary advantage of transistor assisted contact points is reduction of current actually flowing through the points. The points no longer carry the heavy current, but act as a switch to turn the transistor on and off. The transistor emitter-collector circuit carries the high current while the points, which trigger the base circuit, carry less than one amp (Figure 5). The lower current reduces pitting and corrosion to a minimum and prolongs point life. Other advantages are lower coil inductance with a resulting shorter time constant for more voltage in the primary due to the rapid build-up of the magnetic field.

> The coil is usually of conventional design, but modified with a higher turns ratio that has fewer primary turns at higher current. This results in increasing the amount of coil current, reducing its inductance, and hence obtaining a smaller time constant that is more favorable for rapid build-up in the primary (Cantonwine, 1972, p. 19).

The transistor system provides better starting ability and improved engine performance at high speeds.

Some disadvantages are inherent in the system. It is necessary to change the ignition coil to obtain the higher turns ratio. This is rather expensive considering the minimal gain in voltage at the spark plug. Other modifications require changing the ballast resistor and removing the condensor on some commercial models. The high cost of this type of system and the modifications required for operation prevented the transistorized ignitions from gaining acceptance by the automobile manufacturers and consumers. Improvements

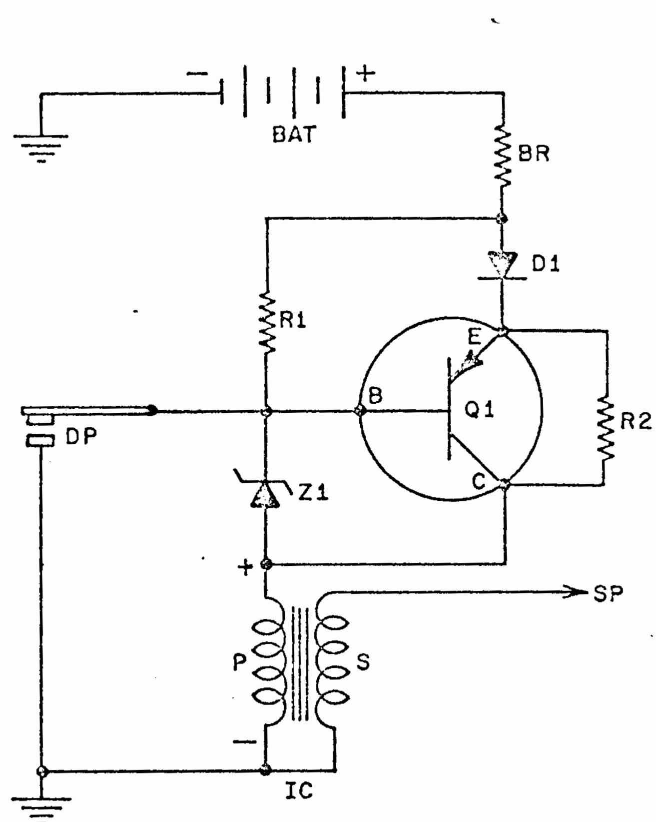


Figure 2-2 Transistorized ignition system using one transistor, typical. Source 16

FIGURE 5

(Cantonwine, 1972, p. 20).

to the system, discussed later in the section on magnetic pulse ignitions, and strict emission control standards have revived an interest in solid state systems.

Capacitive-Discharge Ignitions

The capacitive-discharge ignition system has a very sophisticated circuit and is more complicated electrically than the other solid state systems. C-D ignitions are not usually found as original equipment on automobile engines, but are available from several manufacturers as conversion kits for the existing conventional ignition. The system requires no major alterations to the standard system and takes only about 30 minutes to install.

The capacitive-discharge system (Figure 6) consists of a DC to DC convertor which converts battery voltage to a higher DC voltage for storage, a storage element in the form of a capacitor, a switching element, and a high voltage output transformer which raises the low voltage to a level that will fire the spark plugs.

Battery voltage is converted from 12 volts to approximately 400 volts by the convertor circuitry consisting of the transistors Q1, Q2 and transformer T1. The convertor operates as follows. The battery voltage applied to the primary of T1 causes current to flow through resistors R1, R2, R3, and R4. The two paths for current flow are unequal and one half of the primary will have a higher current flow. Assuming slightly higher current flow in the upper half, the voltage developed in the two feed-back windings tend to turn off Q1

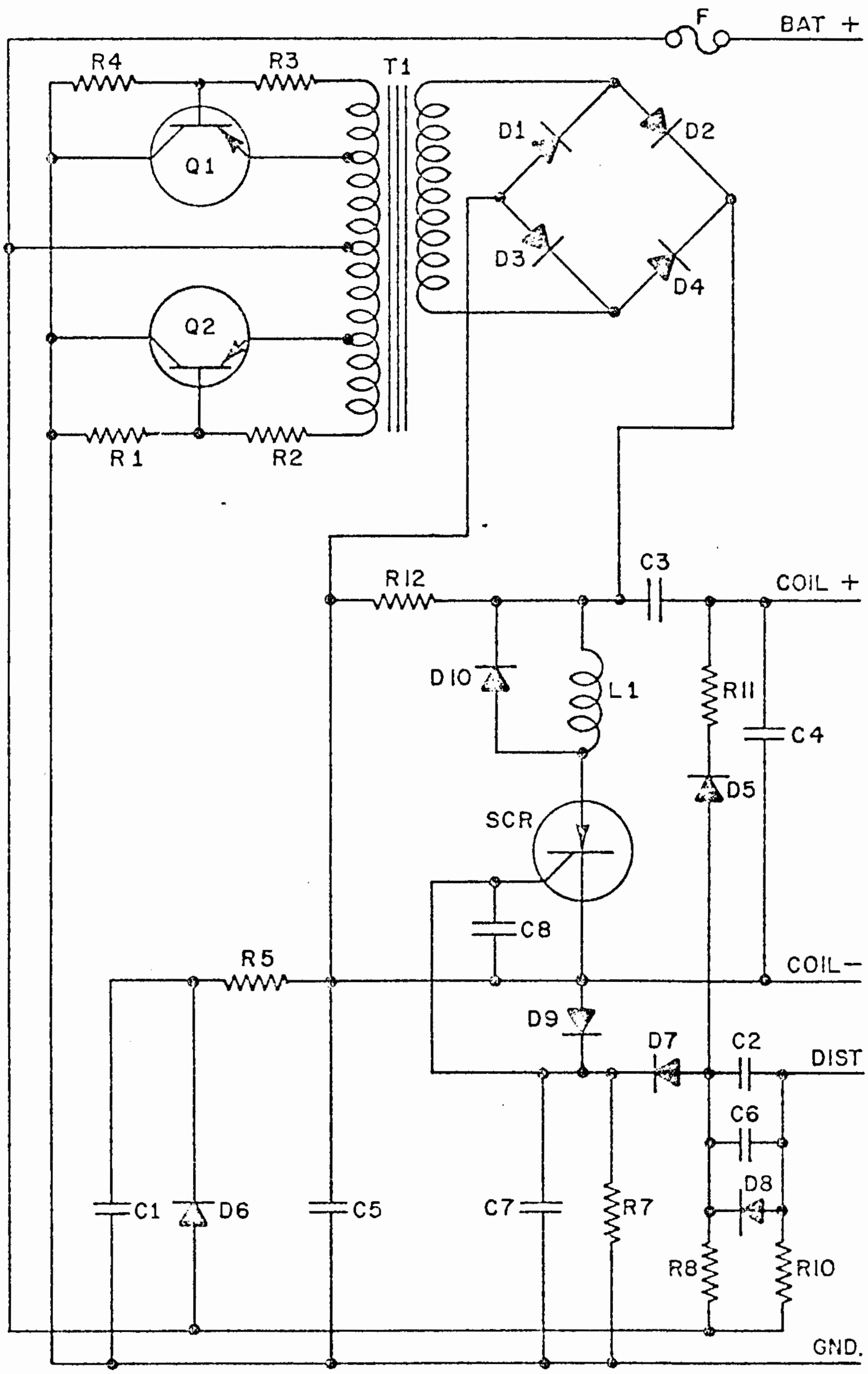


Figure 2-5 Capacitor-Discharge (C-D) ignition system, Source 7

FIGURE 6

(Cantonwine, 1972, p. 26).

and Q2. This increases the current flowing in the upper half and drives Q2 into conduction and Q1 into cutoff, simultaneously transferring energy to the secondary of T1.

When the secondary is saturated, the feedback signal drops to zero, turning Q2 off. This allows the magnetic field to collapse. As the field collapses, it reverses polarity and drives Q2 into cutoff and Q1 into conduction and simultaneously delivers power to the diode bridge. The diode full-wave bridge rectifier, consisting of D1, D2, D3, and D4, changes the AC to a DC potential of about 400 volts. This voltage charges the capacitor C3 through the coil, connected through the negative and positive terminals to the negative terminal of the diode bridge. The contact points turn on the silicon-controlled rectifier SCR. When the SCR is turned on, it carries the high voltage from capacitor C3 to the primary of the ignition coil and also momentarily stops the convertor operation. The SCR also connects the positive side of capacitor C3 to the lower coil connection. This forms a complete circuit and the energy stored in C3 can be delivered to the primary of the ignition coil.

A resonant circuit is formed by the primary of the coil and capacitor C3. The flywheel effect of this circuit restores unused energy to the capacitor in the reverse direction to approximately 300 volts. At this point, the current attempts to reverse through the SCR turning it off. The reverse voltage now causes the diode bridge to conduct as a short circuit, discharging the capacitor to zero and recharging it towards its normal state. When the current drops to zero in the ignition coil, the bridge returns to its normal state, the load is removed from transformer T1, and normal convertor operation resumes (Ibid., 1972, p. 25).

In the Kettering system, high voltage to fire the spark plug is produced by the collapsing magnetic field built up in the primary winding of the ignition coil. This magnetic field is built up in the primary by battery voltage flowing in the primary circuit. The rise time of the magnetic field in the conventional system is about 120 microseconds. This relatively slow rise time becomes very important at high engine speed and is one of the main disadvantages of the conventional system.

The faster speed limits the time available for the magnetic field to build up. Less build-up results in lower firing voltages and insufficient spark. Therein lies the beauty of the C-D ignition. Instead of using battery voltage to build up the magnetic field in the primary, energy stored as voltage in the capacitor, usually 350 to 400 volts, is used to produce the rising field. The system is designed to provide a very short rise time, approximately 2 microseconds, as the capacitor discharges through the primary of the ignition coil. This short period of time is well-suited to high engine speeds where less time is available per revolution. The C-D system is effective at well over 10,000 RPMs, while the conventional is limited to about 5,000 RPMs. In addition to very efficient high speed operation, higher voltages are available at cranking speeds which provide improved starting ability.

Also included in the list of advantages of C-D ignitions are such features as the ability to fire fouled spark plugs thereby extending spark plug life, longer contact point life meaning less frequent engine tune-ups, increased acceleration and general performance, more complete combustion, and greater fuel economy. "Although gas mileage will be improved, the real value and cost justification is the reduction in maintenance costs. It is not unusual to go 50,000 miles between changes of plugs and breaker points" (Graf, 1971, p. 100). Contact point life, as in the transistor ignition system, is limited only by rubbing block wear since the points carry a very low current to switch the silicon-controlled rectifier.

The C-D system seems to have only two disadvantages: high initial cost and a greater number of electronic components which could effect reliability. Engineering theory maintains that if there are more components then there are more chances for component failure. Improved electronic components found in most high quality C-D systems have a very low failure rate. Still there is the possibility of defective parts slipping past inspection and being installed in a unit. Most good C-D systems incorporate a switch which allows the driver to return to the conventional system if a failure occurs.

<u>Magnetic Pulse Transistorized Ignition Systems</u>

The next ignition system to be discussed is the magnetic pulse transistorized ignition system (Figures 7 and 8). The system consists of a specially designed magnetic pulse distributor, an ignition pulse amplifier, and a special coil. Basically, it is a transistor controlled ignition with a magnetic timer core instead of contact points. "As shown in Figure 6, an iron timer core TC replaces the conventional breaker cam" (Ibid., 1972, p. 29). The timer core, shaped like a gear with a tooth for each cylinder, rotates inside a magnetic pick-up assembly which replaces the breaker plate, contact points set, and condensor.

The timer core and pick-up assembly are housed in the distributor which looks similar to a conventional distributor. The assembly is mounted over the distributor shaft and is equipped with both vacuum and centrifugal advance. Figure 9 depicts Ford Motor Company's solid state ignition system distributor. The timer core in this system is referred to as an armature and the pick-up assembly is called the stator assembly.

The position of the armature tooth in relation to the pick-up coil determines the polarity of the electrical signal induced in the permanent magnet of the pick-up coil. As the tooth approaches the magnet (Figure 10), a positive signal is felt in the pick-up coil. When the armature tooth is aligned with the magnet (Figure 11), no signal is felt. Then, as the tooth rotates away from the magnet (Figure 12), a

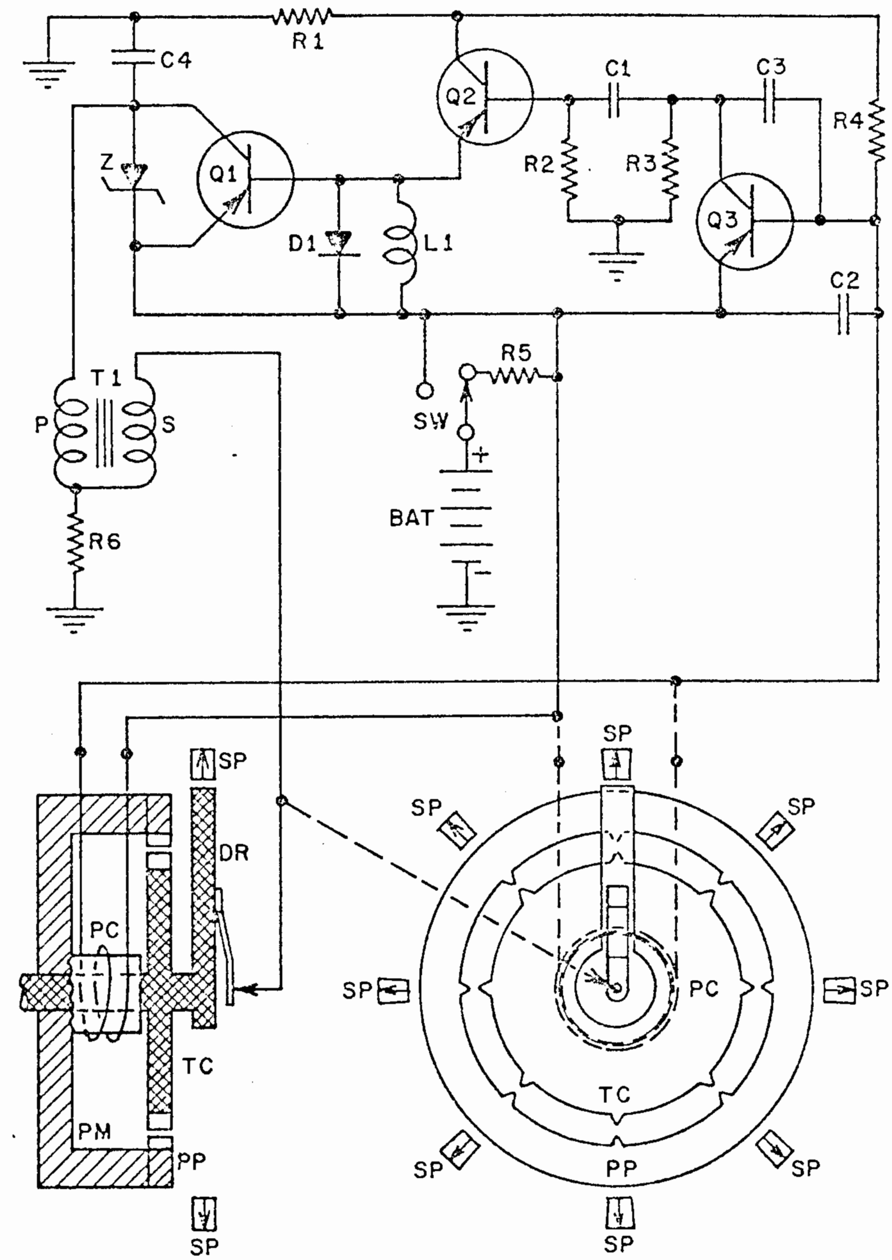


Figure 2-6 Magnetic pulse-type transistorized ignition system, Source 6

FIGURE 7

(Cantonwine, 1972, p. 30).

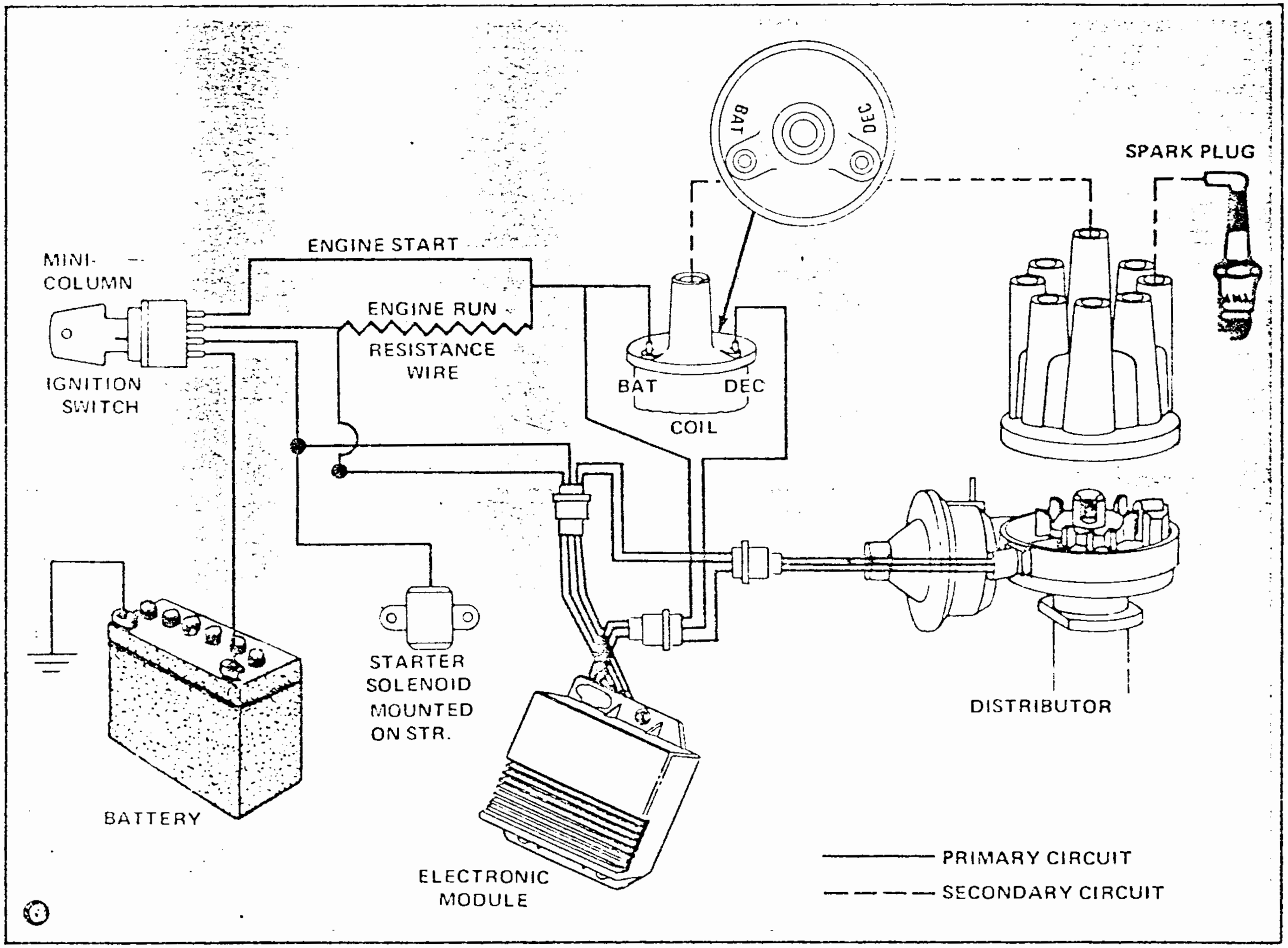


FIGURE 8

FORD SOLID STATE IGNITION SYSTEM
(Tech Talk, 1973, p. 5).

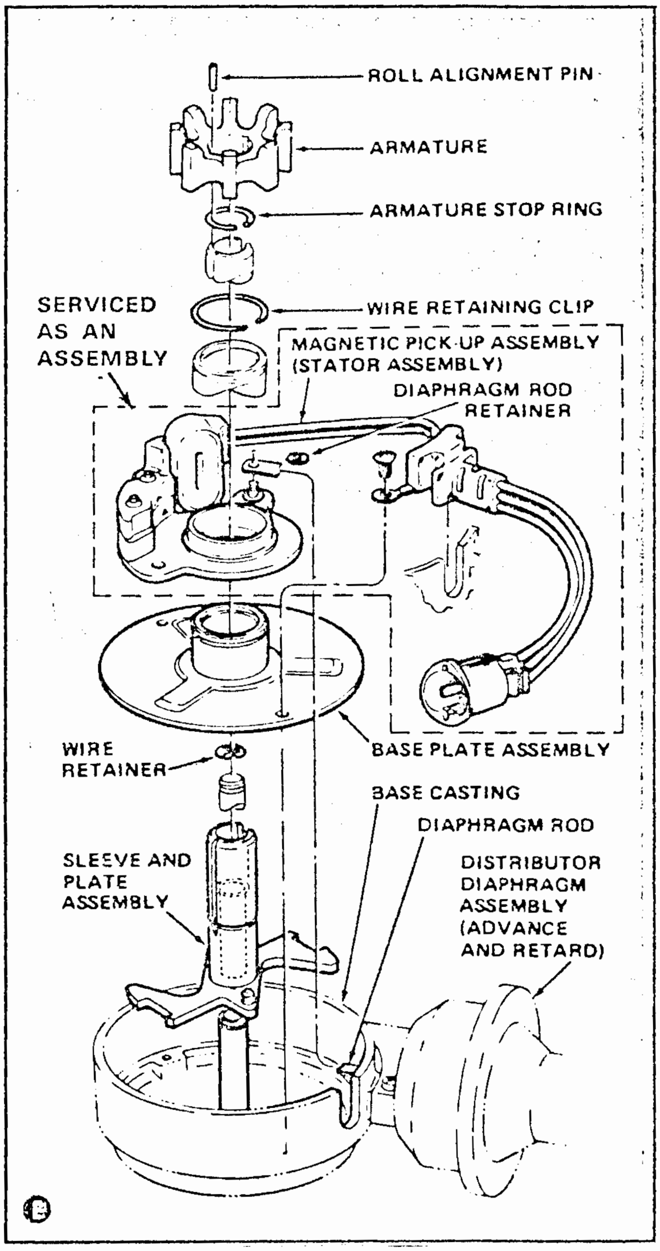


FIGURE 9

MAGNETIC PULSE DISTRIBUTOR

(Tech Talk, 1973, p. 6).

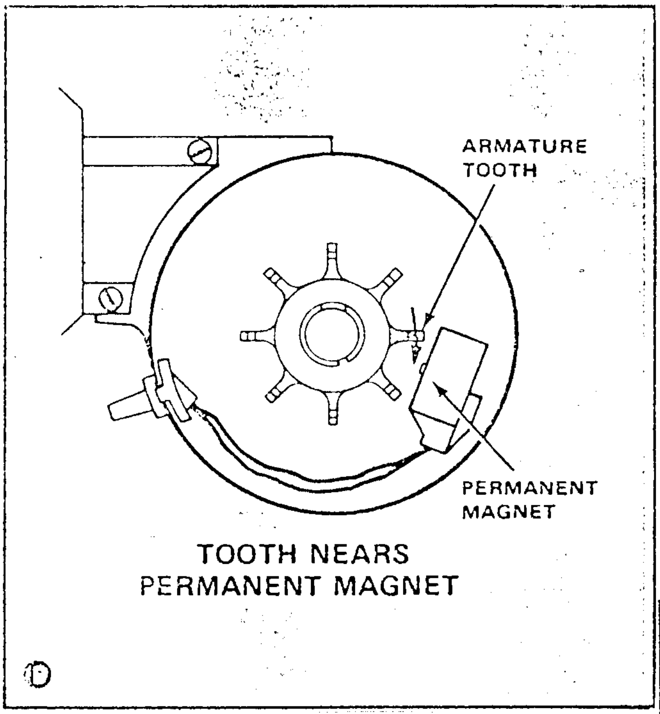


FIGURE 10

MAGNETIC PULSE ARMATURE
(Positive Signal)

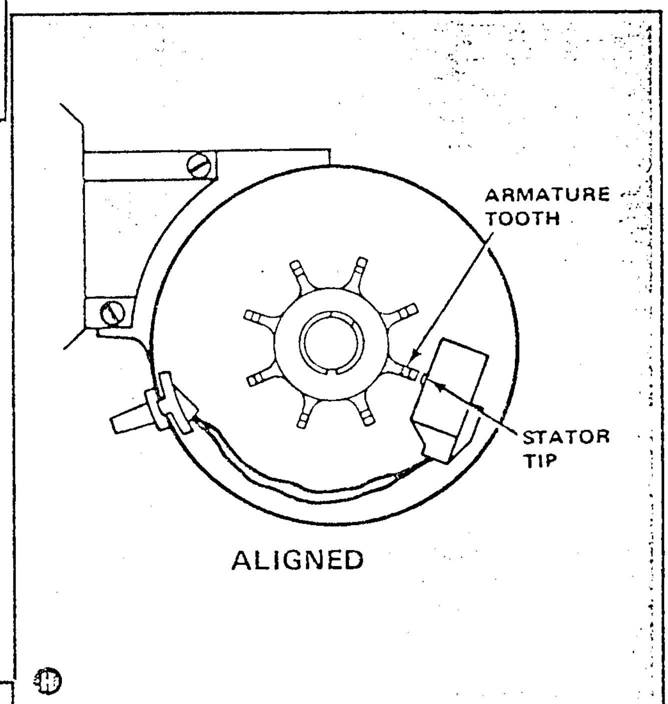


FIGURE 11

MAGNETIC PULSE ARMATURE
(Zero Signal)

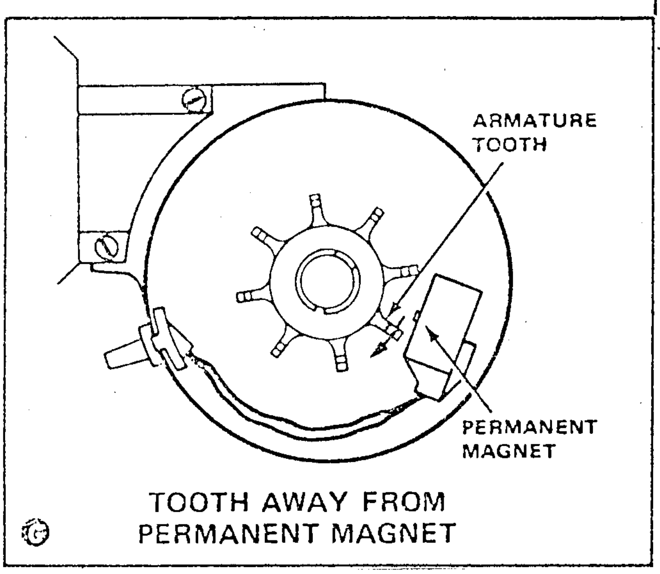


FIGURE 12

MAGNETIC PULSE ARMATURE
(Negative Signal)

(Tech Talk, 1973, p. 7).

negative signal is induced in the pick-up coil. When the signal is positive, it turns on the control module which feeds battery voltage to the primary winding of the ignition coil. This forces the magnetic field to rise in the primary just as it would in a conventional ignition. As the signal drops to zero, it tells the control module to turn off. This action allows the magnetic field to collapse, inducing a high voltage in the secondary and firing the spark plug. In this manner, the changing signal produces the same effect in the coil primary circuit as the opening and closing of the contact points in a conventional system.

The obvious advantage of this system is that there are no contact points to burn and no rubbing block to wear.

> Therefore, initial timing does not change via contact set wear and as a result, distributor tune-ups in the classical sense, are eliminated. A further advantage is that engine starting capability no longer degrades due to contact set arcing and the resulting poor circuit switching (Carlson, 1974, p. 2).

An integral part of this breakerless ignition system is the ignition pulse amplifier or control module. This unit is sealed and is replaced when faulty. It is connected between the ignition coil primary circuit and the battery, through the ignition switch. The electronic module allows the battery current to flow in the primary winding of the ignition coil. It also interrupts the flow of current on a signal from the distributor. This action permits the magnetic field to collapse, inducing a surge of high voltage in the secondary of the coil. This high voltage is directed to the correct spark plug by the rotor in the distributor cap at the correct time to fire the air-fuel mixture in the combustion chamber. A timing circuit in the control module senses when the spark plug has fired and redirects electrical current to the primary for the next firing cycle. The dwell angle varies with engine speed. This variation is normal and eliminates adjustments.

The ignition coil is of the conventional design, but has a special turns ratio to make it compatible with the system. It is also labeled differently, with the terminals marked BAT for battery and DEC for distributor electronic control (Tech Talk, 1973, p. 5).

The magnetic pulse system is an improvement over the transistor assisted contact points type. However, it still has some of its disadvantages. Available voltage at the spark plug is still limited by primary rise time, and as engine speed increases, available rise time decreases. Consequently, the system is not as efficient as the capacitive-discharge type at high engine speeds. A second drawback is the high initial cost of the system. This is a questionable disadvantage if the consumer considers the long term savings in maintenance costs and fuel economy.

> The owner of a vehicle equipped with the new solid state ignition system will have substantially reduced maintenance costs over the life of his vehicle, while obtaining the advantages of having 'just tuned' engine performance at all times (Carlson, 1974, p. 2).

The big three auto makers, General Motors, Ford, and Chrysler, have introduced the breakerless ignition system on some or all of their production automobiles. In the near future, with increasingly strict engine emission controls, all cars will probably be equipped with this system and both the consumer and the environment will benefit from this technological advance.

Chapter 5

PROJECT ACTIVITY INFORMATION

Project Description

It was decided by the writer to purchase, assemble, and install a capacitive-discharge ignition system on a late model V-8 engine. Comparison tests between the C-D and conventional ignition systems would be conducted in the automotives laboratory at the University of Northern Iowa. The tests were designed to determine the differences in spark plug firing voltage and brake horsepower rating of the two systems using the Sun 1120 electronic engine tester and the Clayton chassis dynamometer.

Project Assembly and Installation

The capacitive-discharge ignition system chosen for the project was a Heathkit, model CP-1060. This system is a conversion kit sold unassembled for $39.95. The same system is available preassembled from Delta Products Incorporated for $59.95.

Total assembly time for the CP-1060 kit was two hours and forty-five minutes. Operations included in the assembly were cutting wire to proper length, stripping insulation from wire, tinning wire for soldering, and soldering wire and miscellaneous electronic components to terminal boards. The terminal boards are then mounted in an extruded aluminum case to complete the unit.

The completed unit was then installed on a 307 cubic inch V-8 engine in a 1972 Pontiac Ventura. It was necessary to drill three holes, one-eighth inch in diameter, in the fenderwell to mount the unit using sheet metal screws. Electrical hook-up consisted of removing the ignition coil leads, connecting the C-D terminal boards to the coil terminals, and reconnecting the ignition coil leads to the terminal boards. Installation and hook-up time was thirty minutes. An additional thirty minutes was required to remove the spark plugs, widen the electrode gap .005, and reinstall the spark plugs. The .005 increase in plug gap is recommended by the kit manufacturer. The increase provides a longer spark ensuring more complete combustion of the air-fuel mixture in the combustion chamber. "Some capacitive-discharge systems actually operate better with a wider gap because a somewhat different pulse of energy is delivered to the plugs" (Ward, 1965, p. 10).

Experimental Tests

Using the Sun 1120 electronic engine tester and a polaroid camera, pictures of the primary and secondary voltages were obtained for the conventional systems with spark plugs at .035 electrode gap (Figures 13 and 14), and for the capacitive-discharge ignition with .040 electrode gap (Figures 15 and 16). The vertical line in Figure 14 and the series of vertical lines in Figure 16 represent the firing voltage at

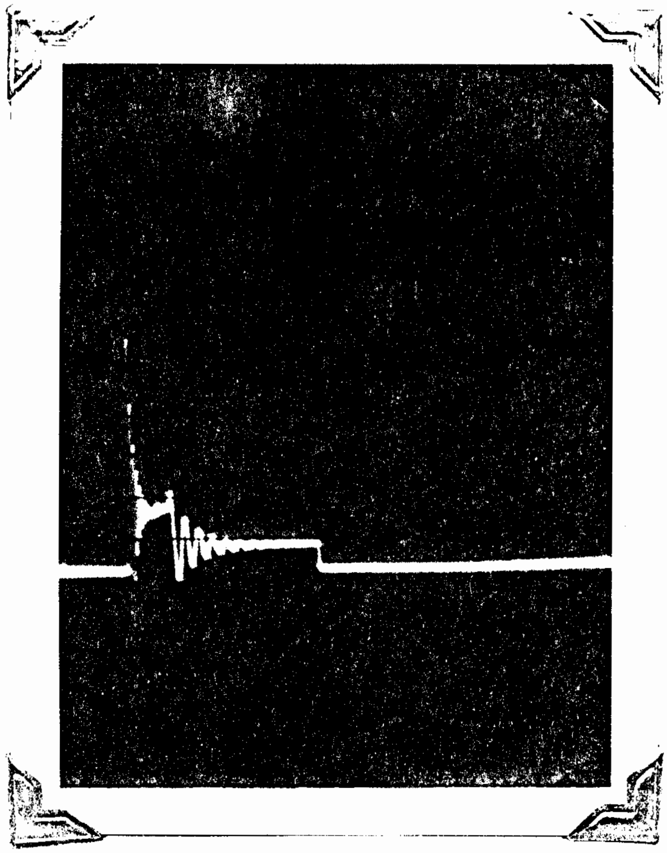


FIGURE 13

PRIMARY VOLTAGE WAVEFORM (Conventional)

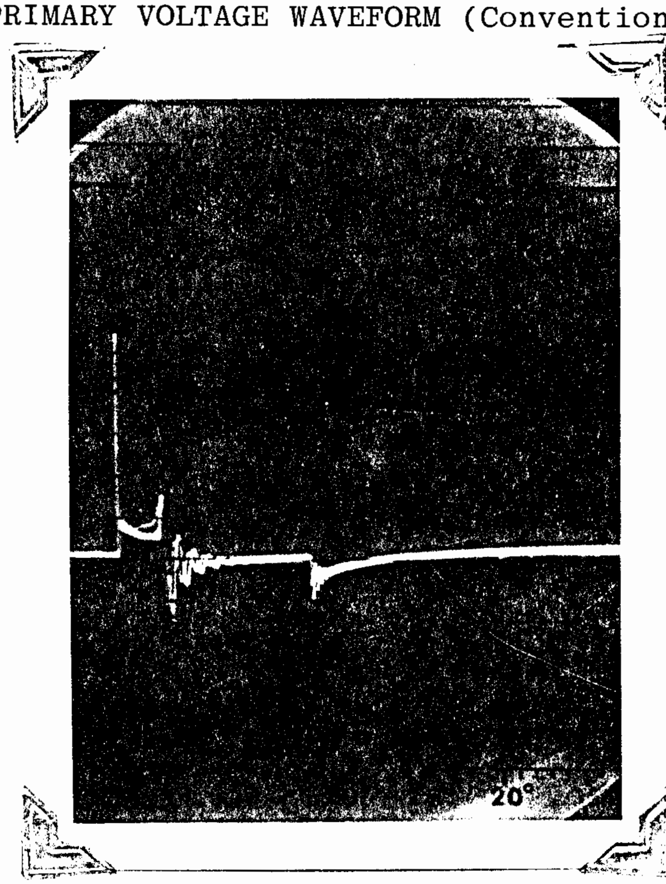


FIGURE 14

SECONDARY VOLTAGE WAVEFORM (Conventional)

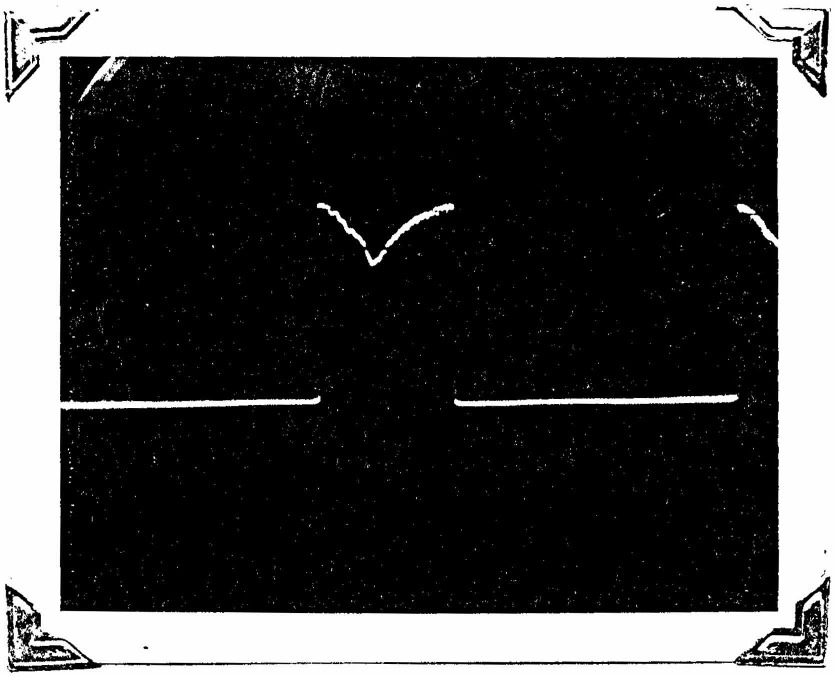


FIGURE 15

PRIMARY VOLTAGE WAVEFORM (Capacitive-Discharge)

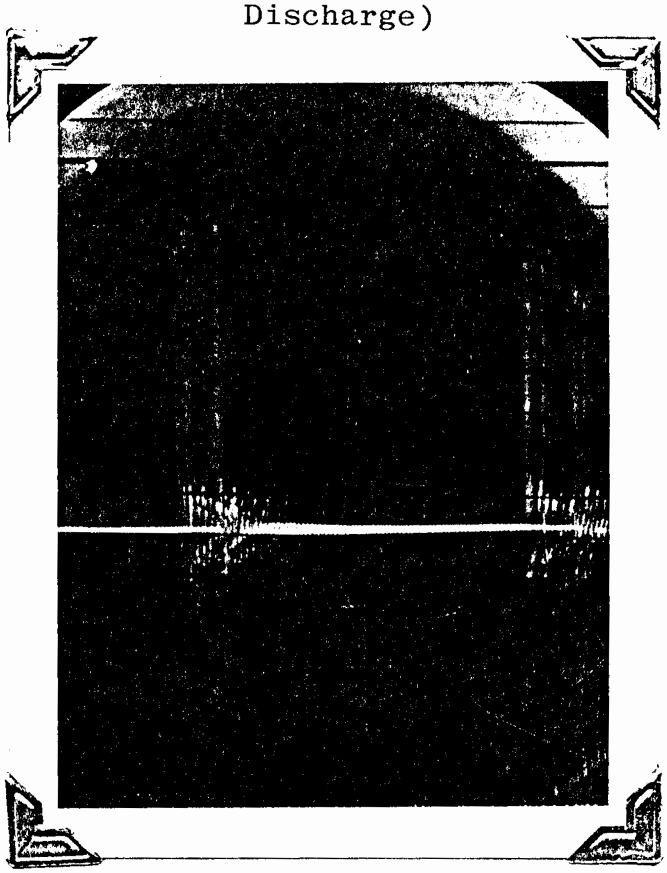


FIGURE 16

SECONDARY VOLTAGE WAVEFORM (Capacitive-Discharge) the spark plug. In Figure 14, the voltage is 11,000 volts. In Figure 16, the firing voltage of the C-D system is 15,000, an increase of 4,000 volts over the conventional ignition. It is this higher voltage that enables the C-D system to fire fouled spark plugs that a conventional system could not fire.

The second part of the experiment was conducted using the Clayton chassis dynamometer. This dynamometer measures brake horsepower at the rear wheels of the vehicle as it is in operation on the machine. The engine was first tested on the dynamometer with the conventional ignition system and the spark plugs gapped at .035. Then, the second test was conducted using the C-D ignition without changing the plug gap. It was intended that a third test be conducted using the C-D system and regapping the plugs at .040, but unexpected difficulties were encountered while running the engine on the dynamometer. It was impossible to attain engine speeds of more than 2500 RPMs while loading the dynamometer. The engine would miss, begin to shake, and cause the vehicle to become unstable on the dynamometer. It is interesting to note that during the first series of tests, the brake horsepower at the rear wheels was approximately 30 with the conventional system and about 60 with the C-D system. Although this is not peak brake horsepower, it was obvious there was a definite improvement using the capacitive-discharge system, even on an improperly tuned engine.

In an effort to remedy the problem, new points were installed with correct spring tension and the tests were repeated.

The second series of tests were more conclusive. The test conditions for this series were 60 miles per hour on the dynamometer at an engine speed of 2100 RPMs. With the engine running on the conventional ignition and the spark plugs set at .040 electrode gap, maximum brake horsepower at the rear wheels was 65. The engine was then switched to the capacitive-discharge ignition with the spark plug gaps remaining at .040. The maximum brake horsepower was 74, an increase of 9 BHP as compared with the conventional ignition. The test was repeated to validate the data. The spark plug gaps remained at .040. This time the brake horsepower was 68 with the conventional ignition and 72 with the C-D system.

The test data, in both instances, showed higher brake horsepower readings when using the capacitive-discharge ignition system. The higher readings indicate improved engine performance. This greater efficiency of the engine would enable it to get more power from a given amount of fuel, resulting in an increase in fuel economy.

Test Results

Ignition System	Test #	Brake Horsepower
Conventional	1	65
Conventional	2	68
	Test Average	66.5
Capacitive-discharge	1	74
Capacitive-discharge	2	72
	Test Average	73

Engine test speed	2100 RPM
Vehicle test speed on the chassis dynamometer	60 mph

Chapter 6

PATENT INFORMATION

When an individual discovers a new idea he is able to protect his idea by securing a patent. "A patent for an invention is a grant by the government to an inventor of certain rights" (General Information Concerning Patents, Jan., 1973, p. 1). The United States government has established the U. S. Patent Office, a distinct bureau since 1802, with the explicit function of granting patents on behalf of the government.

A patent is "the right to exclude others from making, using, or selling the invention" (Ibid., 1973, p. 2). A patent is granted to the inventor for a period of seventeen years. After this period of time, the idea is considered public domain.

The first step in securing a patent is to perform a search of United States patents to determine if the idea has been patented before.

> A search room is provided where the public may search and examine U. S. patents granted since 1836. Patents are arranged according to the Patent Office classification system of over 300 subject classes and 64,000 subclasses. By searching in these classified patents, it is possible to determine, before actually filing an application, whether or not an invention has been anticipated by a U. S. patent, and it is also possible to obtain the information contained in patents relating to any field of endeavor (Ibid., 1973, p. 9).

Once the inventor determines that no previous patent has been recorded the next step is to apply for the patent for his idea.

> Application is made to the Commissioner of Patents and includes; (1) a written document which comprises a specification (description and claims), and an oath or declaration, (2) a drawing in those cases in which a drawing is possible, and (3) the filing fee (Ibid., 1973, p. 12).

The written document must be witnessed by two people, usually before a notary public. This part of the document is required by statute, and contains a sworn statement by the applicant that he believes himself to be the original inventor of the idea. The patent drawing, which must be drawn to certain specifications is usually done by a patent draftsman. The basic filing fee is $65.00.

Anyone interested in additional information regarding patents is urged to contact the state regional office and request the following booklet: <u>General Information Concerning Patents</u>, (45¢). This booklet is available to the general public. The address of the Iowa Regional Office is:

United States Department of Commerce
609 Federal Building
210 Walnut Street
Des Moines, Iowa 50309

The process of filing a petition for a patent is an involved procedure and although the individual may seek to obtain his own patent, the process is usually carried out by a patent attorney. Iowans have an alternative course of action available to them when seeking a patent. The Center for Industrial Research and Service at Ames, Iowa, will provide the inventor with information concerning the patenting of his product, marketing, and production of it within the state. For this service, they receive a percentage of the profits gained by marketing the product.

General procedure for working with the Center is as follows: The inventor records the beginning of his idea and has his plans witnessed. He should also keep all sales receipts for material purchased. The inventor then submits the idea to the Center by completing a disclosure form. This will usually cost about $30.00 for the application and the search conducted by the Center to determine if any others have already patented the idea. The Center has one year to arrange for a sale, or a license to manufacture, if a patent for the invention is feasible. This sale or licensing is subject to the approval of the inventor. If arrangements are successful, the Center receives a small percentage of the proceeds (Iowa Development Commission Foundation, no date, pp. 2-3).

More detailed information concerning this alternate route of patenting may be obtained from: CIRAS/IDCF, Iowa State University, 303 Building E, Ames, Iowa 50010.

Chapter 7

INSTRUCTIONAL UNIT

Objectives: Upon successful completion of this unit, the student will be able to demonstrate a knowledge of:

1. the operation of the conventional ignition system;
2. the operation of electronic ignition systems;
3. testing and maintaining automobile ignition systems;
4. the advantages and disadvantages of these ignition systems; and,
5. the role of electronic ignitions in modern automobiles.

<u>Unit Outline</u>

I. Definition of Terms

II. History of Automobile Ignitions

III. Ignition Types and Operation

- A. Magnetos
- B. Kettering or Conventional
- C. Transistorized
- D. Capacitive-Discharge
- E. Magnetic Pulse

IV. Advantages and Disadvantages of Different Ignition Systems

V. Testing and Servicing Ignition Systems

VI. Applications of Electronic Ignitions

Sample Lesson Plan

The Kettering or Convention Ignition

I. History of Kettering Ignition

   A. George F. Kettering

   B. Conventional Ignition

II. Description and Operation of Components

   A. Battery

   B. Ignition Switch

   C. Distributor

   D. Contact Points

   E. Condensor

   F. Ignition Coil

   G. High Tension Wiring

   H. Spark Plugs

III. Advantages of Conventional System

IV. Disadvantages of Conventional System

V. Maintenance of Conventional System

   A. Testing

   B. Service

Student Evaluation

The objectives of the course would be evaluated using written tests and laboratory worksheets. The student would need to answer correctly at least 60% of the items on the written tests over each unit. The course would be designed to cover one semester of automotive mechanics with nine units, one of which would be automotive ignition systems. The test score would be one-ninth of the student's total test grade.

The laboratory worksheet grade would be based on the student's score for each activity. The scores for each worksheet would be determined by the instructor's evaluation of the laboratory work completed by the student.

The semester grade would be determined from scores achieved on the unit tests, the laboratory worksheets, and the semester final examination grade.

Mass Production

Since the learning situation in automotive courses is not oriented around the traditional project made by the student or a related industrial process, it is difficult to set up a mass production situation. An attractive alternative would be to arrange a field trip to an automobile assembly plant or an engine manufacturing plant. This would enable the student to see the relationship between automotives and mass production techniques.

Safety Precautions

The following precautions pertain to automotive laboratories in general and should be observed when working on any automobile system.

1. Wear safety glasses.
2. Keep hands clear of moving objects such as fans, fan belts, and pulleys.

3. Long hair must be restrained in such a manner as to prevent entanglement with equipment.

4. Rings, wristwatches, or bracelets must be removed before working in the laboratory.

5. Appropriate footwear must be worn at all times.

6. Seek instructor's assistance before operating unfamiliar equipment.

Reference Material and Visual Aids

The most useful reference materials in the area of electronic ignitions found by the writer were Internal Combustion Engines and Air Pollution by Edward F. Obert, Automotive Tune-up and Test Equipment by Charles R. Cantonwine, and Automotive Electronics by Rudolf W. Graf and George J. Whalen.

Obert's book is very good and gives in-depth technical information on conventional and electronic ignition systems. This reference would be too technical and also too expensive for use at the high school level.

The text by Cantonwine is also quite good. Though not as technical as Obert, it too is beyond the level of the average high school automotives student.

Automotive Electronics by Graf and Whalen is a comprehensive text including starting and charging systems, ignition systems, and lighting equipment. There is a good deal of general information which would be well suited to most high school automotive situations. This book is available in paperback from Howard W. Sams and Company, Indianapolis, Indiana 46206 for the price of $6.95.

Overhead transparencies of various ignition systems and components are available from school suppliers such as Brodhead-Garrett. These visual aids would be very helpful to the instructor and would improve the overall presentation of the instructional unit.

The following is a list of transparencies available from Brodhead-Garrett which would be useful to the instructor:

AM-8 Ignition System	$4.75
AM-9 Spark Plugs	5.10
AM-28 The Ignition Distributor	3.75
AM-29 The Ignition Coil and Condensor	2.15
AM-49 Generator and Conventional Ignition	4.25
AM-50 Alternator and Magnetic Pulse Ignition	4.25
AM-54 Breaker Plate Installation	3.75

Equipment Purchase Information

Assuming the automotives laboratory was equipped with an ignition simulator and a Sun electronic engine tester, the only additional equipment necessary would be a transistor ignition, a capacitive-discharge system, and a magnetic pulse system for demonstration purposes. This would be quite expensive and most small schools could not afford these items. As an alternative, the writer suggests the purchase of a Heathkit CP-1060 capacitive-discharge system by the instructor or the school. The Heathkit is inexpensive and would provide an excellent example of this type of ignition.

The Heathkit CP-1060 is available from Heath Company, Benton Harbor, Michigan 49022 for the price of $39.95 plus 95 cents postage. Examples of the magnetic induction system could be obtained on loan from local automobile dealers.

Chapter 8

SUMMARY

The purpose of this research project was twofold: to become familiar with electronic ignition systems, and to compare conventional ignition to capacitive-discharge ignition in terms of operation and efficiency. The writer feels that this purpose has been accomplished and that the knowledge gained has been well worth the effort.

The early pages of the paper have been devoted to supplemental information which has been provided to give the reader some knowledge of the background of ignition systems and their relationship to the automotives industry. The areas covered include: the history of ignition systems, descriptions of industries which design, produce, and market electronic ignitions, the locations of some of these companies, career information regarding occupations in the field of electronic ignitions, and the present trend of new car sales as an indicator of the future success of these sophisticated ignition systems.

Indepth research was conducted on four ignition systems and the material gained from this effort is presented in the technical section of the report. Comparisons of the four systems were made in terms of their components, operation, advantages, and disadvantages.

The project undertaken by the writer was designed to test experimentally the increase in efficiency of an automobile engine using a capacitive-discharge ignition in place of the conventional ignition system. To do this, a V-8 engine was tested both on an electronic engine tester and a chassis dynamometer in an effort to compare spark plug firing voltage and brake horsepower at the rear wheels. The engine was first tested using the conventional ignition. Then a capacitive-discharge ignition was installed and the engine was tested again. The results of these tests, showing a marked increase in engine efficiency using the electronic ignition are presented in Chapter 5. An instructional unit encompassing the four ignition systems and the project activity was developed for students at the senior high level. This unit and suggestions for its implementation are also included in the report.

Electronic ignitions are an important part of efficient engine operation. The use of these sophisticated ignition systems will become more widespread in the future. The benefits gained from their use, in terms of reduced maintenance costs and improved fuel economy, warrant total acceptance by automobile manufacturers and consumers.

In light of this trend, the writer feels that all automotive mechanics teachers should become familiar with those aspects of electronic ignition systems and pass this information on to their students. It is further hoped that the information presented in this paper might be of assistance to those instructors who wish to stay informed of new developments in the field of automotives.

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APPENDIX A

Sample Letter to Industry

Cedar Falls, Iowa 50613
February 18, 1974

Delta Products, Inc.
P. O. Box 1147
Grand Junction, Colorado 81501

Dear Sirs:

I am an Industrial Arts graduate student doing research in the area of electronic ignitions at the University of Northern Iowa. I am writing for technical information you may have available concerning the Delta Mark 10-B capacitive-discharge ignition system produced by your company.

The objectives of my research projects are to gain an understanding of the various ignition systems, and compare conventional systems to capacitive-discharge ignitions in terms of operation, performance, and fuel economy. With this information, I hope to develop an instructional unit on ignition systems for students at the high school level.

I would greatly appreciate any technical information you would be able to send. Thank you for your assistance.

Sincerely yours,

Leo A. Green, Jr.

Sample Thank You Letter to Industry

Cedar Falls, Iowa 50613
March 12, 1974

Kenneth D. Braa, Sales Manager
Delta Products, Inc.
P. O. Box 1147
Grand Junction, Colorado 81501

Dear Mr. Braa:

Thank you very much for the information you sent regarding the Delta Mark 10-B capacitive-discharge ignition system. The information has been a great help in preparing my research project.

Sincerely yours,

Leo A. Green, Jr.

APPENDIX B