Summer 6-2-1952

Development of a Test for Rapid Determination of Octane Ratings of Gasolines

Charles B. Gangwer

GANGWER — OCTANE RATINGS OF GASOLINES

DEVELOPMENT OF A TEST METHOD FOR RAPID DETERMINATION
OF
OCTANE RATINGS OF GASOLINES

By

Charles B. Gangwer

A Thesis

In partial fulfillment of the

Requirements for the Degree of

Master of Science in Mechanical Engineering

The University of New Mexico
1952

This thesis, directed and approved by the candidate's committee, has been accepted by the Graduate Committee of the University of New Mexico in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

E F Castetter
DEAN

6/2/52
DATE

Thesis committee

A. D. Ford
CHAIRMAN

Victor J Skoglund

E. C. Rightley

TABLE OF CONTENTS

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

CHAPTER I

HISTORY

Introduction

For many years, the Mechanical Engineering Department of the University of New Mexico has been interested in developing a more reliable and expedient method to determine octane ratings of gasolines than the conventional CFR Motor Method of Test for Knock Characteristics of Motor Fuels. A summary of the development of the conventional CFR test method and a brief discussion of the operational procedure of this method is necessary to better understand the need for a new fuel rating procedure. To further explain the disadvantages of the conventional test method, an introduction to the new test method to be developed herein will be made.

Summary of Cooperative Fuel Research History

The Cooperative Fuel Research Committee, formed in 1928, was composed of a group of fuel producers and engine manufacturers interested in the development of a standard test method for fuel rating based upon the interdependence of engine performance upon compression ratio and fuel

anti-knock property.[1] The actual problem of developing a test method and equipment for knock rating was assigned to a group designated as the Detonation Sub-Committee, and the first meeting of this group disclosed three requirements were essential to the pursuit of a comprehensive motor fuel research: (1) a standardized engine and accessories; (2) a common reference fuel and rating scale; (3) a uniform testing procedure. All three of these essential requirements were met by 1931. The Waukesha Motor Company had developed a fuel testing engine which met the approval of the Cooperative Fuel Research Committee. Iso-octane and normal heptane, both stable hydrocarbons, were adopted as reference fuels at the suggestion of Dr. Graham Edgar of the Ethyl Gasoline Corporation. A rating scale based upon these reference fuels was adopted, and a uniform test procedure was tentatively approved. All reference fuels referred to hereafter will be blends of iso-octane and normal heptane. The octane rating of each reference fuel is expressed as the percent by volume of iso-octane contained in the reference fuel blend.

A correlation between laboratory knock ratings and the behavior of motor fuels in service was undertaken in 1932

---

[1] ASTM-CFR Knock Testing Unit, Care and Operation (ninth edition; Waukesha, Wisconsin: Waukesha Motor Company, 1932), 47 pp.

anti-knock property.[1] The actual problem of developing a test method and equipment for knock rating was assigned to a group designated as the Detonation Sub-Committee, and the first meeting of this group disclosed three requirements were essential to the pursuit of a comprehensive motor fuel research: (1) a standardized engine and accessories; (2) a common reference fuel and rating scale; (3) a uniform testing procedure. All three of these essential requirements were met by 1931. The Waukesha Motor Company had developed a fuel testing engine which met the approval of the Cooperative Fuel Research Committee. Iso-octane and normal heptane, both stable hydrocarbons, were adopted as reference fuels at the suggestion of Dr. Graham Edgar of the Ethyl Gasoline Corporation. A rating scale based upon these reference fuels was adopted, and a uniform test procedure was tentatively approved. All reference fuels referred to hereafter will be blends of iso-octane and normal heptane. The octane rating of each reference fuel is expressed as the percent by volume of iso-octane contained in the reference fuel blend.

A correlation between laboratory knock ratings and the behavior of motor fuels in service was undertaken in 1932

---

[1] ASTM-CFR Knock Testing Unit, Care and Operation (ninth edition; Waukesha, Wisconsin: Waukesha Motor Company, 1932), 47 pp.

when road tests were conducted at Uniontown, Pennsylvania. Correlation of these road tests at the Waukesha Motor Company Laboratories brought about a modification and improvement of the standard testing unit and its operating technique. This improved test method was named the "CFR Motor Method," but the old method was not discarded since it had proved itself indispensable from the experimental standpoint as an aid to the refiner in developing suitable gasolines and to the automotive engineer in improving combustion characteristics of his engine. The old method was retained under the name "CFR Research Method." Additional road tests were conducted at Uniontown, Pennsylvania in 1934 and confirmed the findings of the 1932 tests.

The CFR Motor Method has been accepted as the industry's yardstick for gasoline motor fuel rating and has been formally endorsed by the following organizations: The U. S. Bureau of Standards, American Society for Testing Materials, Society of Automotive Engineers, American Petroleum Institute, and the Automobile Manufacturers' Association.

The CFR Motor Method Test Procedure

The conventional Cooperative Fuel Research Motor Method of Test for Knock Characteristics of Motor Fuels, (CFR Motor Method) provides a reliable but extremely tedious method for determining octane ratings of gasolines. The

when road tests were conducted at Uniontown, Pennsylvania. Correlation of these road tests at the Bureau and other company laboratories brought about a modification and improvement of the standard heating unit and the operating technique. This improved test method became the "CFR Motor Method," but the old method [illegible] and has proved itself in laboratory [illegible] as an aid to the refiner in developing suitable gasolines and to the automotive engineer in improving combustion characteristics of his engine. The old method was retained under the name "CFR Research Method." Further road tests were conducted at Uniontown, Pennsylvania in 1934 and confirmed the findings of the 1932 tests.

The CFR Motor Method has been accepted as the industry's yardstick for gasoline antiknock ratings and has been formally endorsed by the following organizations: The U.S. Bureau of Standards, American Society for Testing Materials, Society of Automotive Engineers, American Petroleum Institute, and the Automobile Manufacturers' Association.

The CFR Motor Method Test Procedure

The conventional Cooperative Fuel Research Committee Method of Test for Knock Characteristics of Motor Fuels (CFR Motor Method) provides a reliable but comparatively tedious method for determining octane ratings of gasolines.

standard operating conditions and the many adjustment requirements prescribed by the CFR Motor Method are not included here as they are readily available in numerous text books, ASTM publications, and Waukesha Motor Company publications on the CFR Fuel Research Engine and the ASTM-CFR Knock Testing Unit. However, a description of the bouncing pin device and knockmeter and a brief summary of the test procedure prescribed by the CFR Method are included for comparison with applicable parts of the new test method.

The bouncing pin device consists of a cylindrical steel pin with a bakelite insulating button on the upper end. The pin is maintained in a vertical position on the engine by two bushings in a hollow barrel. The bottom end of the pin rests on a hardened spring-steel diaphragm which is locked in the lower end of the barrel with a hollow lock nut. Attached to the head of the barrel, and suitably insulated, are two flat leaf springs having contact points immediately above the bouncing pin. Adjusting screws are provided for the adjustment of the bouncing pin sensitivity and gap clearance. The bouncing pin device is located on the top of the cylinder head in a threaded hole opposite the spark plug location. Actuation of the bouncing pin depends upon the reaction of the diaphragm which is flexed by the pressure variations due to knock.

standard operating conditions and the many adjustment requirements prescribed by the ASTM-Motor Method are not included here as they are readily available in numerous text books, ASTM publications, and Waukesha Motor Company publications on the CFR Fuel Research Engine and the ASTM-CFR Knock Testing Unit. However, a description of the bouncing pin device and knockmeter and a brief summary of the test procedure prescribed by the CFR-Method are included for comparison with applicable parts of the new method of rating.

The bouncing pin device consists of a cylindrical steel pin with a bakelite insulating button on the upper end. The pin is maintained in a vertical position on the engine by two bushings in a hollow barrel. The bottom end of the pin rests on a hardened spring steel diaphragm which is locked in the lower end of the barrel with a hollow lock nut. Attached to the head of the barrel, and suitably insulated, are two flat leaf springs having contact points immediately above the bouncing pin. Adjusting screws are provided for the adjustment of the bouncing pin sensitivity and gap clearance. The bouncing pin device is located on the top of the cylinder head in a threaded hole opposite the spark plug location. Actuation of the bouncing pin depends upon the reaction of the diaphragm which is flexed by the pressure variations due to knock.

The knockmeter is a device for indicating the effective current which flows in the bouncing pin circuit when the contacts are closed by the upward movement of the bouncing pin that results from knock. Current is supplied from a small direct-current generator which is belt-driven from the power-absorbing unit. The current flow resulting from intermittent bouncing pin contact closures passes through a resistance heating element located near a thermocouple. The potential produced at the thermocouple junction when current flows through the heating element actuated the knockmeter and produces a continuous indication of knock intensity.

The CFR Method utilizes a standard knock intensity to determine octane ratings of unknown fuels. This standard knock intensity is that knock intensity obtained with a blend by volume of 65 parts of iso-octane and 35 parts of normal heptane, at a compression ratio of 5.30:1 and having the carburetor set for maximum knock. The prescribed knockmeter reading at standard knock intensity is 55 to 60. It may be necessary to alter the bouncing pin sensitivity and gap clearance to achieve the prescribed knockmeter reading at standard knock intensity.

To determine the octane rating of an unknown gasoline, the test engine is operated with the unknown gasoline and the compression ratio is adjusted to produce a knockmeter reading of 55 to 60 with the carburetor adjusted to

give maximum knock. The knock intensity thus produced is referred to as the proper knock intensity. With the proper knock intensity as a basis, the octane rating of the unknown gasoline is ascertained by comparing the knock intensity for the unknown gasoline with knock intensities for various reference fuels until two reference fuels differing in knock intensity by not more than two octane numbers are found, one of which gives a higher knock intensity than the unknown gasoline and the other a lower knock intensity. The knock intensity, in all cases, is measured by the bouncing-pin indicator in conjunction with the knockmeter.

The CFR Method requires that the unknown gasoline be bracketed between the two reference fuels at least three times, as determined by knockmeter readings. The knockmeter readings obtained for the unknown gasoline and the two reference fuels are averaged, and the octane rating of the unknown gasoline is obtained by interpolation from the averages so obtained.

Introduction to Proposed Test Method

The CFR Method is time consuming and extremely tedious because of the required adjustments to the engine and its auxiliary test apparatus and because of the sensitivity of the knockmeter circuit to variations in ambient temperature and to ignition interruption. Relatively small variations

give maximum knock. The knock intensity thus produced is referred to as the proper knock intensity. With the proper knock intensity as a basis, the octane rating of the unknown gasoline is determined by comparing the knock intensity for the unknown gasoline with knock intensities for various reference fuels until two reference fuels differing in knock intensity by not more than two octane numbers are found, one of which gives a higher knock intensity than the unknown gasoline and the other a lower knock intensity. The knock intensity, in all cases, is measured by the bouncing-pin indicator in conjunction with the knockmeter.

The CFR method requires that the unknown gasoline be bracketed between the two reference fuels at least three times, as determined by knockmeter readings. The knockmeter readings obtained for the unknown gasoline and the two reference fuels are averaged, and the octane rating of the unknown gasoline is obtained by interpolation from the averages so obtained.

Introduction of Proposed Test Method

The CFR Method is time consuming and extremely tedious because of the required adjustments to the engine and its auxiliary test apparatus and because of the sensitivity of the knockmeter circuit to variations in ambient temperature and to ignition interruption. Relatively small variations

in ambient temperature can result in completely unreliable knockmeter readings, and a single misfire per hour cannot be tolerated if reasonably accurate results are to be expected. The CFR Method for determining octane ratings of gasolines provides reliable results, but the many disadvantages of the method leave much to be desired with respect to simplicity, accuracy, and expediency.

The purpose of the proposed test method for determining octane ratings of gasolines is to present a simple, accurate, and expedient test method, which requires a minimum of adjustments to equipment, which is relatively insensitive to variations in ambient temperature and to ignition interruption, and which provides results well within the accuracy of the CFR Method. A comparison of actual test results from both the CFR Method and the proposed test method is contained in Chapter V, Results of Tests.

CHAPTER II

THEORY

Knock Testing

As stated by L. C. Lichty,[2] optimum engine performance can be obtained only with gasolines having knock characteristics that will permit optimum spark advance with little or no detonation. It is, therefore, desirable to rate gasolines for knocking tendency in order to control and maintain this fuel characteristic in the interest of satisfactory engine operation.

Numerous methods of gasoline rating have been attempted, but most of them have been abandoned for one reason or another. The chemical analysis of gasolines as a rating method was eliminated because of its complexity, while the combustion in a bomb method was eliminated because it did not simulate engine operating conditions. Most rating methods that have shown promise were based upon knock intensity as obtained under engine operating conditions. These rating methods may be classified by two principal groups as follows:

---

[2] Lester C. Lichty, Internal Combustion Engines (fifth edition; New York: McGraw-Hill Book Company, Inc., 1939), pp. 185-87.

A. Knock intensity for each fuel run under identical test conditions:

1. Knock intensity by sound:

    a. By human ear.

    b. By microphone or other sound apparatus.

2. Knock intensity by blow struck on diaphragm in combustion-chamber wall.

3. Knock intensity from temperature of plug in combustion-chamber wall.

B. Rating at equal knock intensity:

1. Varying one of the following test conditions:

    a. Compression ratio.

    b. Throttle opening.

    c. Spark advance

    d. Speed.

    e. Cooling medium temperature.

2. Varying fuel composition. Assume an unknown fuel X which knocks more than reference fuel C and less than reference fuel A, both of known antiknock characteristics. Also assume S is a knock suppressor and I is a knock inducer. Then the ratings may be made as follows:

    a. Amount of S required to make X match C.

    b. Amount of I required to make X match A.

    c. Mixture of C and A required to match X.

In Group A an engine is run under fixed test conditions, and fuels are rated according to the degree of intensity of knock. However, the intensity of knock changes from time to time because of some change in engine or operating conditions when apparently all conditions have been maintained constant.

In Group B. 1. the variation of one of the test conditions to obtain a given knock intensity also presents difficulty in evaluating knock-intensity.

Varying the fuel composition and matching the knock intensity of the unknown fuel eliminate much of the effect of changing conditions over which the operator has no control. Any such change in conditions is assumed to have a similar effect on all fuels, which is not always true.

The proposed test method to determine octane ratings of gasolines is based upon knocking characteristics obtained under engine operating conditions. The only variable condition associated with this method is the compression ratio. The other test conditions remain fixed or are maintained as nearly constant as possible. The proposed test method is more fully discussed under the heading "Proposed Test Method."

Proposed Test Method

The proposed test method, hereafter referred to as The "New Method," utilizes the electro-mechanical equipment developed by Mr. R. W. Ebacher.[3] The New Method is based upon the knock intensity obtained under engine operating conditions. Knock intensity is determined by measuring cylinder-pressure variations, which result from knocking, in terms of electrical energy. The New Method utilizes a pressure-sensitive device which is capable of instantaneous conversion of mechanical pressures to electrical energy and is used in conjunction with an amplifier and an instrument for measuring the magnitude of the mechanical pressures in terms of the electrical energy output of the pressure-sensitive device.

The pressure-sensitive device selected for this application is a quartz pressure element which utilizes quartz crystals as the medium for converting mechanical pressures to electrical energy.[4] When a quartz crystal, properly cut

---

[3] R. W. Ebacher, Development of Electro-Mechanical Equipment for the Measurement of Knock Characteristics of Gasolines (unpublished Master's thesis, The University of New Mexico, Albuquerque, 1952).

[4] Type 3 Cox Quartz Pressure Element (Detroit, Michigan: Commercial Research Laboratories, Inc., n.d.), 16 pp.

Proposed Test Method

The proposed test method, hereafter referred to as the "New Method," utilizes the electro-mechanical equipment developed by Mr. R. W. Ebacher.[3] The New Method is based upon the knock intensity obtained under engine operating conditions. Knock intensity is determined by measuring cylinder-pressure variations, which result from knocking, in terms of electrical energy. The New Method utilizes a pressure-sensitive device which is capable of instantaneous conversion of mechanical pressures to electrical energy and is used in conjunction with an amplifier and an instrument for measuring the magnitude of the mechanical pressures in terms of the electrical energy output of the pressure-sensitive device.

The pressure-sensitive device selected for this application is a quartz pressure element which utilizes quartz crystals as the medium for converting mechanical pressures to electrical energy.[4] When a quartz crystal, properly cut

---

[3] R. W. Ebacher, *Development of Electro-Mechanical Equipment for the Measurement of Knock Characteristics of Gasolines* (unpublished Master's thesis, The University of New Mexico, Albuquerque, 1952).

[4] *Type 3 Cox Quartz Pressure Element* (Detroit, Michigan: Commercial Research Laboratories, Inc., n.d.), 16 pp.

with respect to its electrical axis, is subjected to pressure, an electrical charge will appear on two of its surfaces. This electrical charge, besides being in exact proportion to the pressure exerted, varies instantaneously with changes of pressure.

Since the average response of the selected quartz pressure element is .003 volt per 100 pounds per square inch pressure, amplification is necessary to satisfactorily measure the voltage output of the pressure element.

A discussion of the complete set of testing equipment is presented in Chapter III, Equipment.

CHAPTER III

EQUIPMENT

Description of Test Equipment

The New Method for determining octane ratings of gasolines utilizes the variable compression CFR Fuel Testing Engine which has the CFR two-bowl type carburetor with specimen fuel tanks and air intake silencer. A quartz pressure element which replaces the bouncing pin assembly is used with a voltage amplifier, an oscilloscope, a recording camera, and a vacuum tube voltmeter which is used to indicate octane ratings.[5] The equipment, readied for testing, is shown in Figures I and II.

The quartz pressure element, shown in Figure III, is a Type 4 Cox Ignition Quartz Pressure Element.[6] The ignition electrode feature of the pressure element was not used because of the lack of a location in the cylinder head suitable for both ignition and pressure response purposes. Therefore,

---

[5] R. W. Ebacher, Development of Electro-Mechanical Equipment for the Measurement of Knock Characteristics of Gasolines (unpublished Master's thesis, The University of New Mexico, Albuquerque, 1952).

[6] Type 4 Cox Ignition Quartz Pressure Element (Detroit, Michigan: Commercial Research Laboratories, Inc., n.d.), 2 pp.

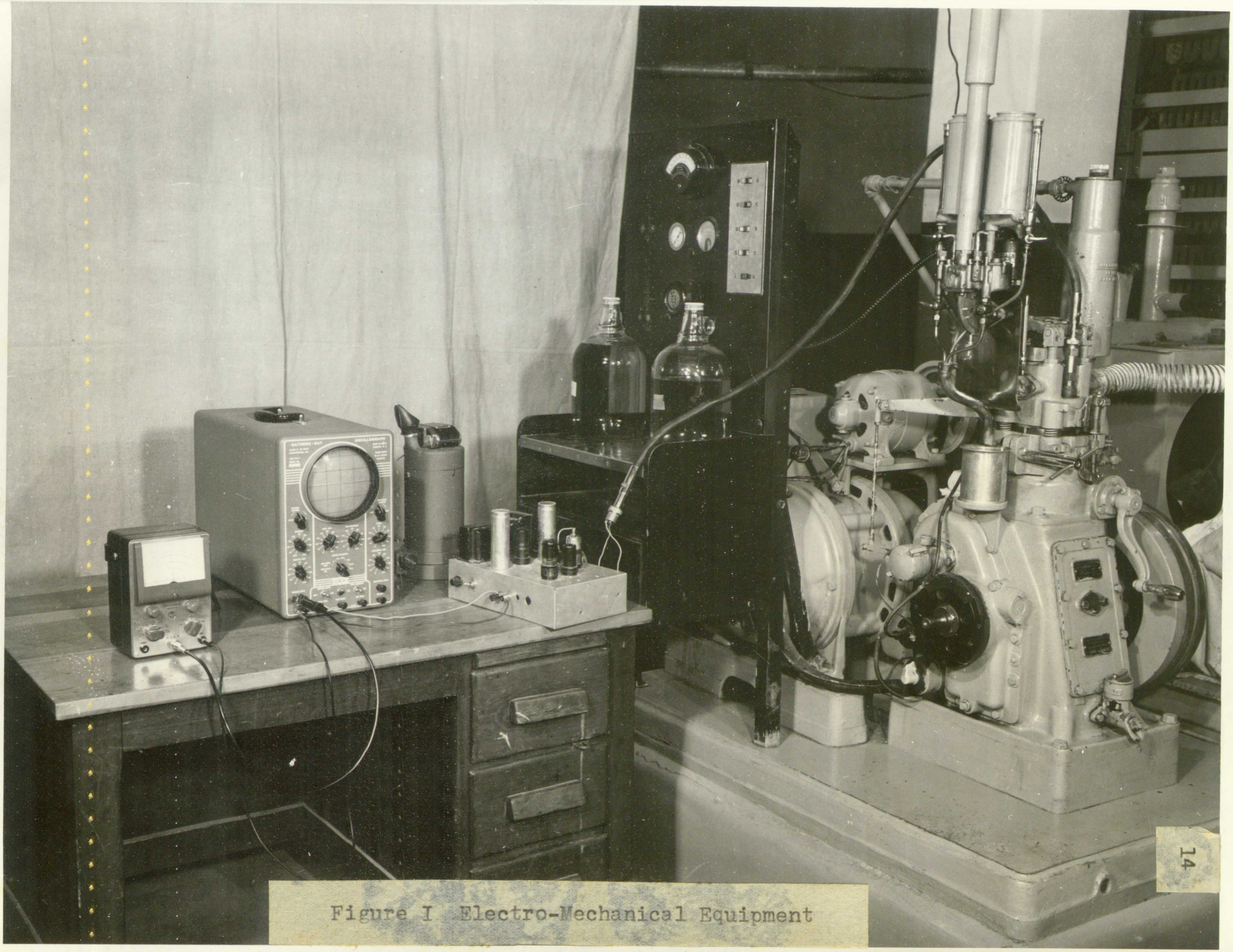


Figure I Electro-Mechanical Equipment

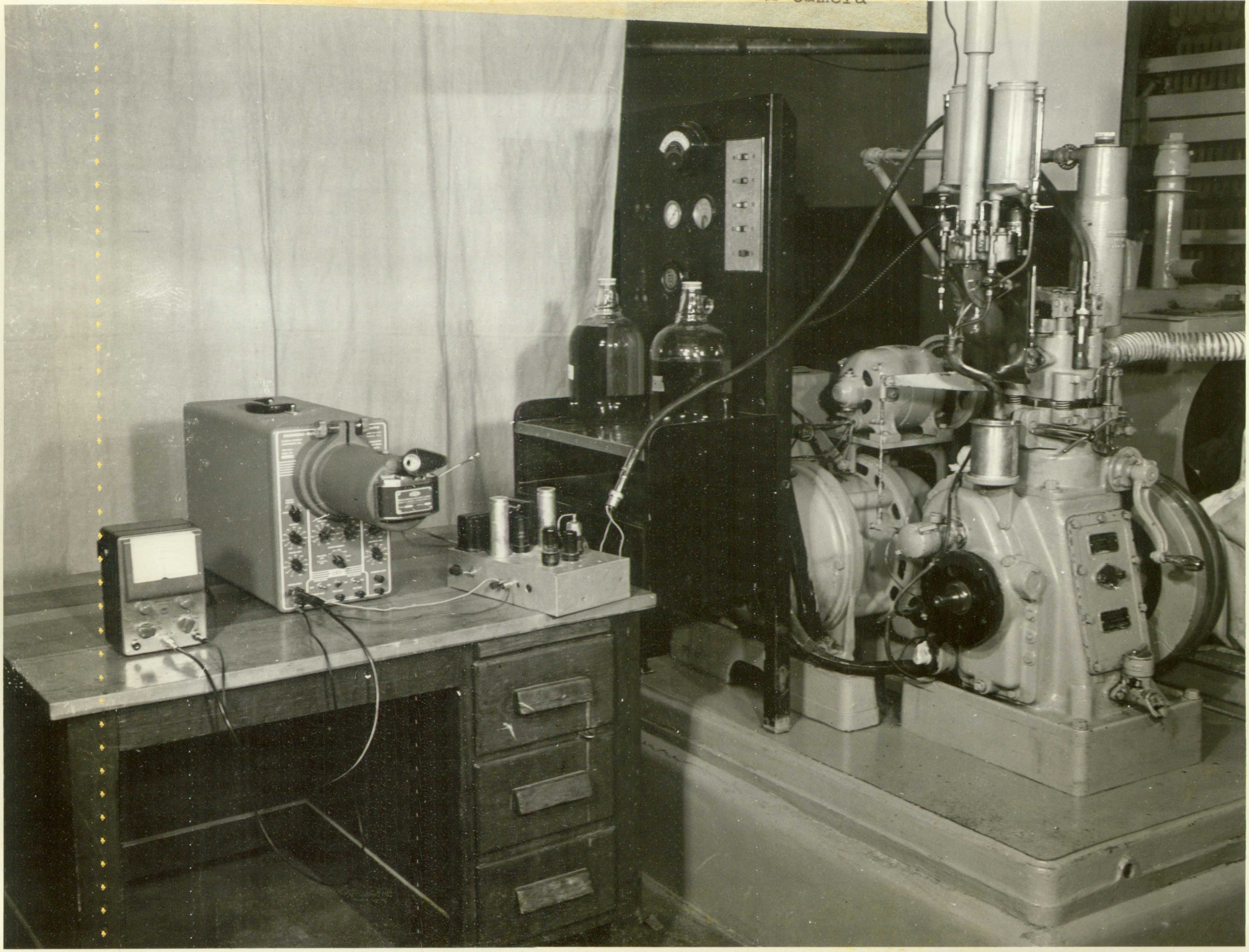


Figure 11 Electro-Mechanical Equipment with Camera

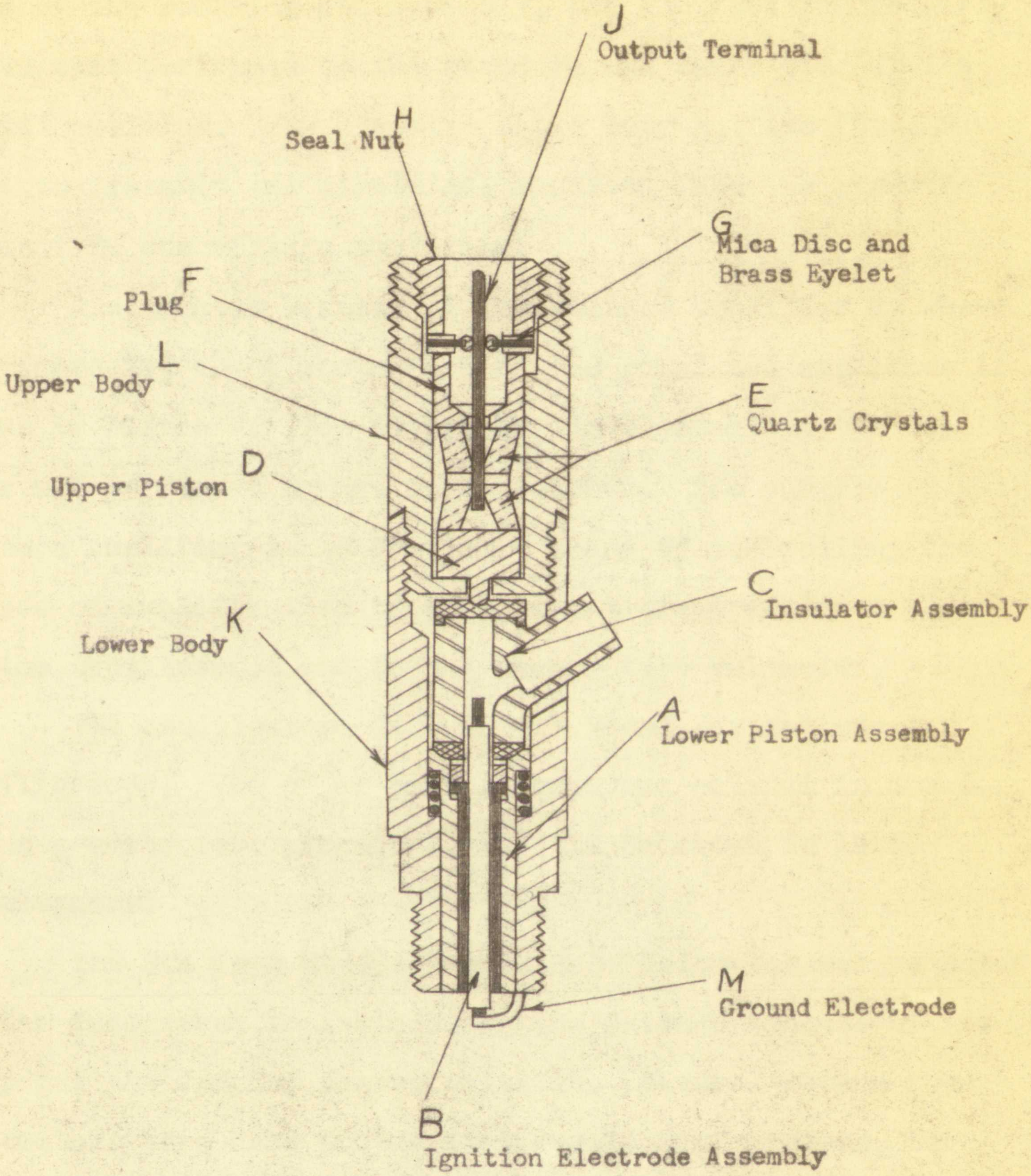


Figure III Type 4 Cox Quartz Pressure Element

the pressure element was assembled in the location formerly used by the bouncing pin assembly, and the ignition requirements were performed by the standard CFR spark plug in its normal position. The standard cable length, five feet, was used to transmit the electrical impulses from the pressure element to the voltage amplifier.

A schematic diagram of the voltage amplifier is shown in Figure IV, and a photograph of the completed amplifier is shown in Figure V. The design and development of the amplifier was performed by Mr. R. W. Ebacher. The purpose of the voltage amplifier is to provide a means of controlling the degree of amplification to produce satisfactory input signals to the oscilloscope and to the vacuum tube voltmeter.

The oscilloscope is a Dumont Model 274 Cathode-Ray Oscilloscope. Use of an oscilloscope was helpful in developing a sound test procedure, as will be shown in later development.

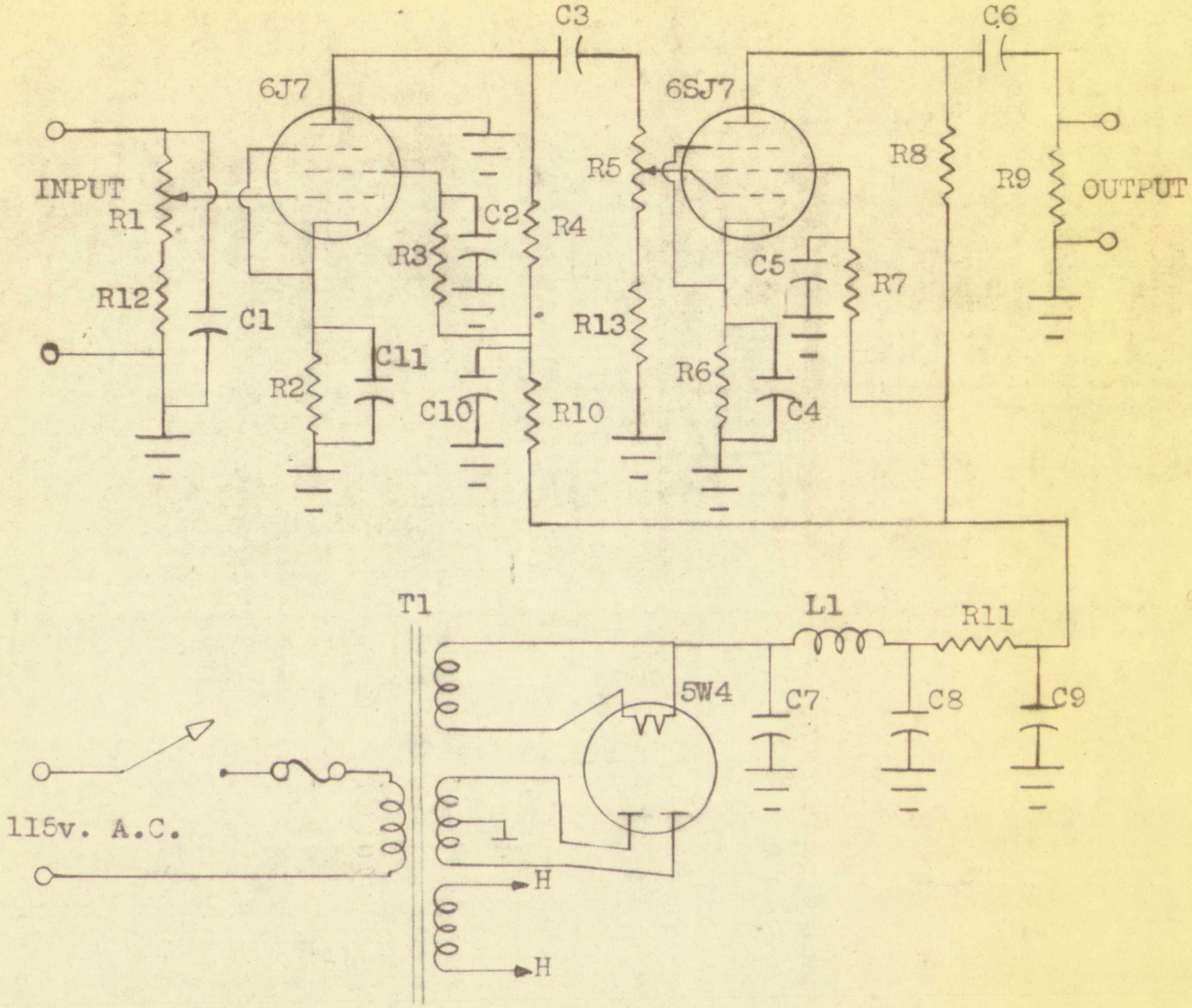
The RCA Type WV-97A Vacuum Tube Voltmeter was selected as the instrument to indicate octane ratings because of its response and damping characteristics. Several vacuum tube voltmeters were used in the test development process, but the RCA Type WV-97A was selected for its superior performance.

the pressure element was assembled in the location formerly used by the bouncing pin assembly, and the ignition requirements were performed by the standard CFR spark plug in its normal position. The standard cable length, five feet, was used to transmit the electrical impulses from the pressure element to the voltage amplifier.

A schematic diagram of the voltage amplifier is shown in Figure IV, and a photograph of the completed amplifier is shown in Figure V. The design and development of the amplifier was performed by Mr. R. W. Thacher. The purpose of the voltage amplifier is to provide a means of controlling the degree of amplification to produce satisfactory input signals to the oscilloscope and to the vacuum tube voltmeter.

The oscilloscope is a Dumont Model 274 Cathode-Ray Oscilloscope. Use of an oscilloscope was helpful in developing a sound test procedure, as will be shown in later development.

The RCA Type WV-97A Vacuum Tube Voltmeter was selected as the instrument to indicate octane ratings because of its response and damping characteristics. Several vacuum tube voltmeters were used in the test development process, but the RCA Type WV-97A was selected for its superior performance.



R1-Volume-control pot.
R2,R6-600 ohms, .5 w.
R3,R7,R9-500,000 ohms, .5 w.
R4,R8-100,000 ohms, .5 w.
R5-250,000 ohm volume-
control pot., ganged
with R1.
R10-470,000 ohms, 1 w.
R11-22,000 ohms, 1 w.
R12,R13-250,000 ohms, 1w.

C11,C4-8 mfd., 25 v., elec.
C2,C5-.06 mfd., 450 v.
C3,C6-.006 mfd., 450 v.
C7,C8-8 mfd., 450 v., elec.
C9-16 mfd., 450 v., elec.
C10-5 mfd., 450 v., elec.
L1-12 henries, 120 ohms, 100 ma.
T1-425-0-425 V (RMS), 100 ma.
C1-.002 mfd., 400 v.

Figure IV Schematic Diagram of Voltage Amplifier

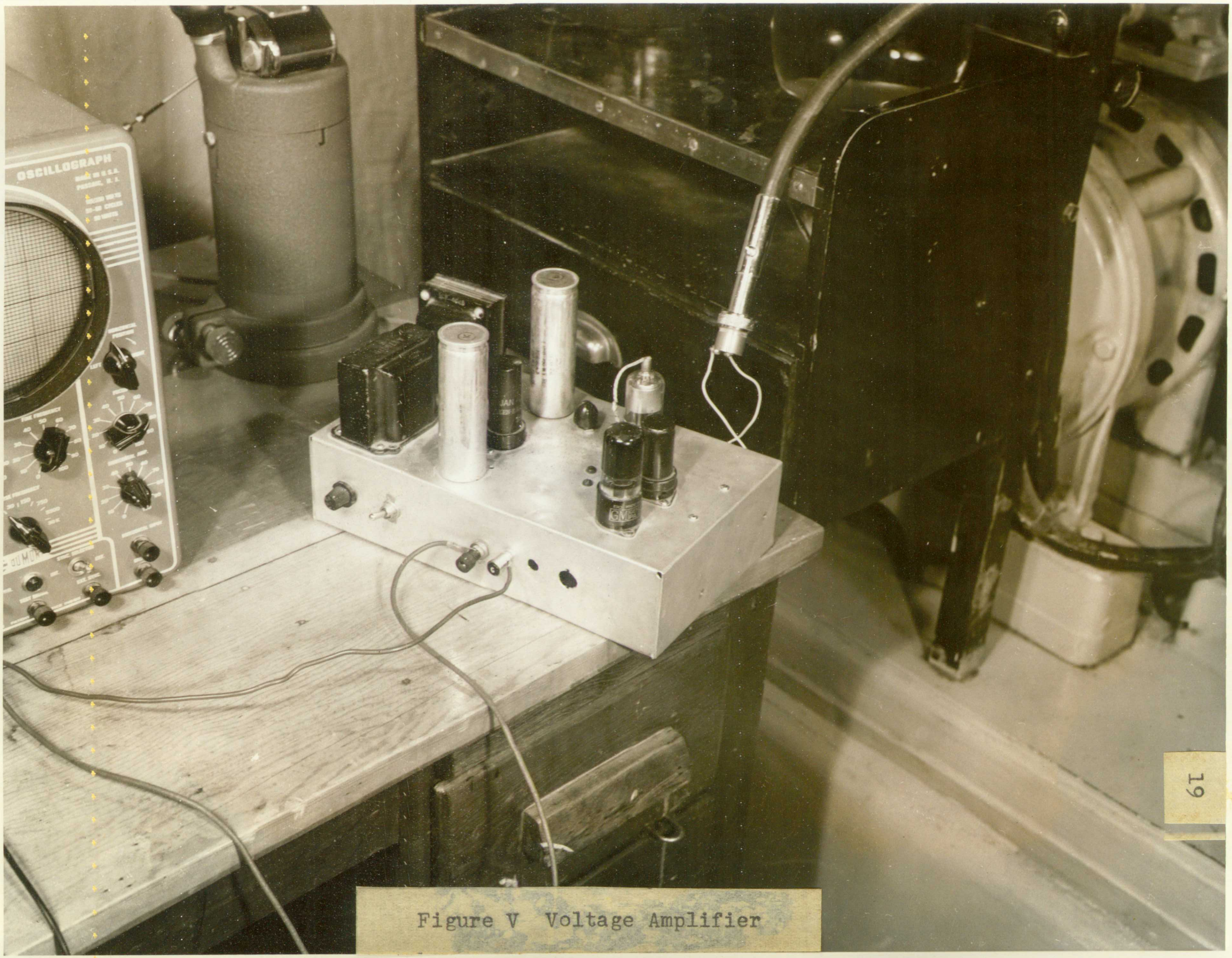


Figure V Voltage Amplifier

Summary of Characteristics of Test Equipment

The characteristics and limitations of the various pieces of equipment used in the New Method for determining octane ratings of gasolines are summarized here. The Type 4 Cox Ignition Quartz Pressure Element has an average voltage response of .003 volts per 100 pounds per square inch pressure, a maximum operating temperature of 350°C, and a minimum frequency response of approximately 10 cycles per second.[7] The voltage amplifier has a voltage gain of 9000 with good linear response between 6 cycles per second and 20,000 cycles per second.[8] The oscilloscope is a standard commercial Dumont Model 274. The RCA Type WV-97A Vacuum Tube Voltmeter has a full scale accuracy of ±5% with a frequency response of 30 cycles per second to 3 megacycles on the RMS scale.

Details on the development and construction of the electro-mechanical equipment used for the New Method are presented in the _Development of Electro-Mechanical Equipment for the Measurement of Knock Characteristics of Gasolines_ by Mr. R. W. Ebacher.

---

[7] _Type 4 Cox Ignition Quartz Pressure Element_, _loc. cit._

[8] Ebacher, _loc. cit._

Summary of Characteristics of Test Equipment

The characteristics and limitations of the various pieces of equipment used in the New Method for determining octane ratings of gasolines are summarized here. The Type 4 Cox Ignition Quartz Pressure Element has an average voltage response of .04 volts per 100 pounds per square inch pressure, a maximum operating temperature of 350° C, and a minimum frequency response of approximately 10 cycles per second.[7] The voltage amplifier has a voltage gain of 9000 with good linear response between 6 cycles per second and 20,000 cycles per second.[8] The oscilloscope is a standard commercial Dumont Model 274. The RCA Type WV-97A Vacuum Tube Voltmeter has a full scale accuracy of ± 5% with a frequency response of 30 cycles per second to 3 megacycles on the RMS scale.

Details on the development and construction of the electro-mechanical equipment used for the New Method are presented in the Development of Electro-Mechanical Equipment for the Measurement of Knock Characteristics of Gasolines by Mr. E. W. Ebscher.

---

[7] Type 4 Cox Ignition Quartz Pressure Element, loc. cit.

[8] Ebscher, loc. cit.

CHAPTER IV

NEW METHOD OF TEST

Development

A relatively simple but rapid and apparently reliable method for determining octane ratings of gasolines was developed by using the electro-mechanical equipment designed by Mr. R. W. Ebacher. A large part of the test development was performed by varying knock intensity by changing compression and air-fuel ratios and observing the pressure wave forms for various fuels on the oscilloscope. In this way, it was possible to note the variations in the pressure wave forms for the various gasolines and reference fuels tested and to predict the effect that varied compression ratio or air-fuel ratio would have on the pressure wave forms of the respective fuels.

The oscilloscope provided an excellent observation of the pressure wave forms of gasolines; but the final octane ratings, while correlated to the pressure wave forms, had to be indicated on an instrument which would express the octane ratings in terms of the potential generated by the quartz pressure element. Since the output of the quartz pressure element was in terms of voltage, the next step was to provide an indicating instrument that would measure the

effective or root-mean-square (RMS) of the voltage output of the quartz pressure element for the various gasolines and reference fuels being tested. A vacuum tube voltmeter having suitable response and damping characteristics was needed to provide an octane-rating indicator; so an investigation was conducted using all the vacuum tube voltmeters immediately available. The RCA Type WV-97A gave the best performance and was installed as the octane rating indicator.

Numerous tests were performed to observe the correlation between the pressure wave forms and the octane ratings indicated on the vacuum tube voltmeter. Several extensive tests, using reference fuels ranging from 55 octane to 95 octane, were performed to provide data to establish the validity of the octane ratings indicated on the vacuum tube voltmeter. The range of compression ratios were established for the various reference fuels to provide indications of adequate amplitudes on the same scale of the indicating instrument. The confining of octane ratings of such a wide range to a single scale on the indicating instrument was considered a major accomplishment. By confining the entire range of octane ratings to a single scale, the required adjustments to the test equipment, after initial adjustments, were reduced to only one - varying the compression ratio.

More than thirty gallons of commercial gasoline, representing thirty different grades, and approximately

fifteen gallons of reference fuel were consumed in developmental testing before the New Method was considered practical. One of the prime considerations during the developmental testing was reproducibility of results. The reproducibility aspect of the New Method was determined by performing a series of tests using identical fuels and having identical engine operating conditions. The time intervals of the tests ranged from 24 to 72 hours. Since the test engine was reserved for this developmental work, it was possible to maintain the initial engine and equipment adjustments for the complete series of reproducibility tests. The reproducibility of results obtained under these conditions was exceptionally good, as witnessed on numerous occasions by Professor A. D. Ford.

A set of standard operating conditions similar to those of the CFR Method was adopted for the New Method and is as follows: (1) Engine speed--900 r.p.m. ± 9 r.p.m.; (2) Oil pressure--25 to 30 pounds per square inch under operating conditions; (3) Valve clearances--intake 0.008 inch cold, exhaust 0.010 inch cold; (4) Spark advance--automatically controlled, 19.0 degrees at 7:1 compression ratio; (5) Throttle opening--75 degrees on the throttle quadrant; (6) Carburetor adjustment--maximum knock for initial setting with 85 octane reference fuel, constant thereafter; (7) Mixture temperature--maintained at 300°F. ± 2°F. as indicated on the mercury stem thermometer.

fifteen gallons of reference fuel were consumed in developmental testing before the New Method was considered practical. One of the prime considerations during the developmental testing was reproducibility of results. The reproducibility aspect of the New Method was determined by performing a series of tests using identical fuels and keeping identical engine operating conditions. The time intervals of the tests ranged from 24 to 72 hours. Since the engine was reserved for this development work, it was possible to maintain the initial engine and equipment adjustments for the complete series of reproducibility tests. The reproducibility of results obtained under these conditions was exceptionally good, as witnessed on numerous occasions by Professor A. P. [illegible].

A set of standard operating conditions similar to those of the CFR Method was adopted for the New Method and is as follows: (1) Engine speed--[illegible] r.p.m. ± [illegible] r.p.m.; (2) Oil pressure--25 to 30 pounds per square inch under operating conditions; (3) Valve clearances--intake 0.008 inch cold, exhaust 0.010 inch cold; (4) Spark advance--automatically controlled, 19.0 degrees at 7:1 compression ratio; (5) Throttle opening--75 degrees on the throttle quadrant; (6) Carburetor adjustment--maximum knock for initial setting with 85 octane reference fuel, constant thereafter; (7) Mixture temperature--maintained at 300°F. ± 2°F. as indicated on the mercury stem thermometer.

New Method for Rating Gasolines

A description of the procedure to be followed for determining octane ratings of gasolines by the New Method, together with a few suggestions on technique, is presented here. This is the calibration used in the final tests which are discussed in Chapter V, Results of Tests.

During the entire test procedure, the gain control on the voltage amplifier is maintained at its lower limit, and the vacuum tube voltmeter is set for AC volts on the 15v scale. This adjustment permits the use of a single scale on the octane rating indicating instrument and simplifies the test procedure.

If any doubt exists regarding the proper functioning of the carburetor bowls, confine the operation to a single bowl and specimen tank. This procedure reduces the possibility of fuel mixtures caused by leaking valves. When changing fuels, drain the specimen tank and carburetor bowl by opening the proper drain cocks and allow a small portion of the new fuel to flow through the lines before closing the drain cocks. This purging operation helps prevent fuel mixtures. Do not rush the fuel changing process. It is better to let the engine motor a few seconds without fuel than to rush the process and mix the fuels. However, the engine should not be allowed to motor more than a few seconds because

New Method for Rating Gasolines

A description of the procedure to be followed for determining octane ratings of gasolines by the New Method, together with a few suggestions on technique, is presented here. This is the calibration used in the Plant tests which are discussed in chapter [illegible].

During the entire test procedure, the gain control on the voltage amplifier is maintained at the lower limit, and the vacuum tube voltmeter is set for 12 volts on the low scale. This adjustment permits the use of a single scale on the octane rating indicating instrument and simplifies the test procedure.

If any doubt exists regarding the proper functioning of the carburetor bowls, confine the operation to a single bowl and specimen tank. This procedure reduces the possibility of fuel mixtures caused by leaking valves. When changing fuels, drain the specimen tank and carburetor bowl by opening the proper drain cocks and allow a small portion of the new fuel to flow through the lines before closing the drain cocks. This purging operation helps prevent fuel mixtures. Do not rush the fuel changing process. It is better to let the engine motor a few seconds without fuel than to rush the process and mix the fuels. However, the engine should not be allowed to motor more than a few seconds because

the mixture temperature will rise rapidly in the absence of fuel vaporization. When changing from one fuel to another, allow a time interval of from one to two minutes for the engine and test equipment to reach equilibrium before readings are taken.

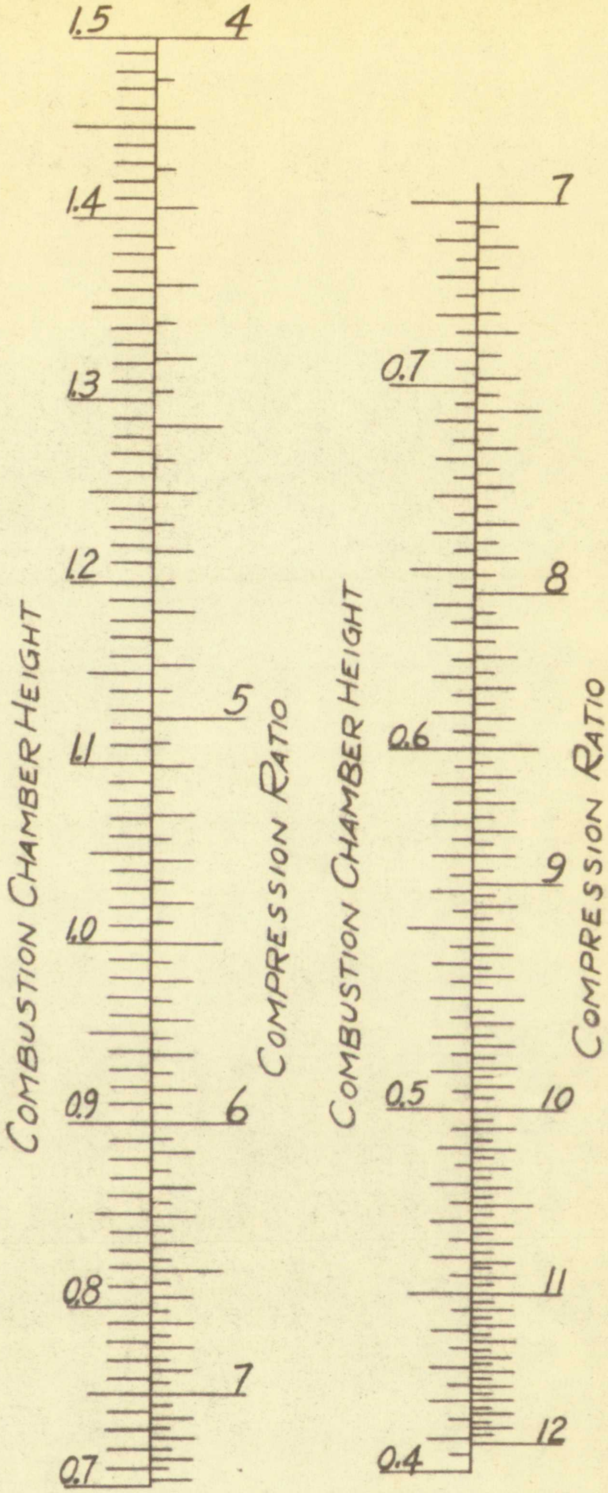
When the test equipment is connected as shown in Figure I and the engine is operating at standard operating conditions, perform the calibration procedure. The octane-rating scale is calibrated for octane ratings ranging from 65 octane to 90 octane, for this calibration encompasses the existing commercial grades of gasolines.

When the engine is operating on a reference fuel of 85 octane, set the compression ratio to 10:1 by lowering the cylinder head until a reading of zero is reached on the micrometer attached to the cylinder. Micrometer readings are converted to compression ratios by using the conversion scale shown in Figure VI. Set the air-bleed adjustment, B, Figure VII, for maximum knock. This setting of the air-bleed adjustment remains constant for the complete calibration and test procedure. The reading on the 15v scale of the vacuum tube voltmeter, corresponding to 85 octane fuel at a compression ratio of 10:1, is 11.5v $\pm \frac{1}{2}$v. Change the fuel to 90 octane reference fuel, following the procedure previously outlined, and maintain the 10:1 compression ratio. The reading on the 15v scale of the vacuum tube voltmeter,

the mixture temperature will rise rapidly in the absence of fuel vaporization. When changing from one fuel to another, allow a time interval of from one to two minutes for the engine and test equipment to reach equilibrium before readings are taken.

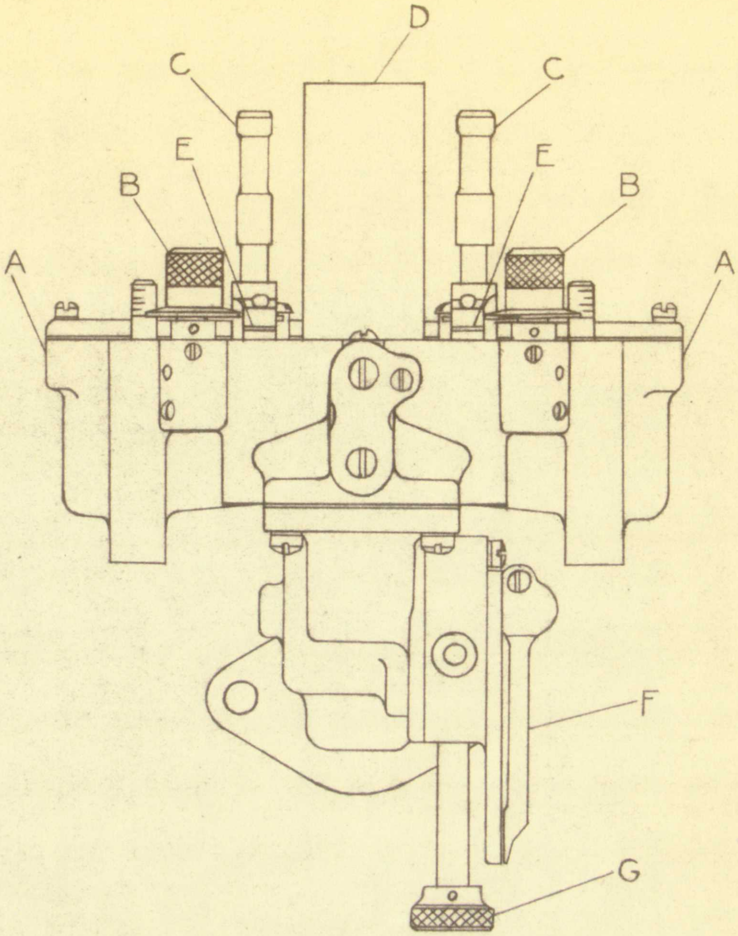
When the test equipment is connected as shown in Figure I and the engine is operating at standard operating conditions, perform the calibration procedure. The octane-rating scale is calibrated for octane ratings ranging from 65 octane to 90 octane, for this calibration encompasses the existing commercial grades of gasoline.

When the engine is operating on a reference fuel of 85 octane, set the compression ratio to 10:1 by lowering the cylinder head until a reading of zero is reached on the micrometer attached to the cylinder. Micrometer readings are converted to compression ratios by using the conversion scale shown in Figure VI. Set the air-bleed adjustment, B, Figure VII, for maximum knock. The setting of the air-bleed adjustment remains constant for the complete calibration and test procedure. The reading on the 15v scale of the vacuum tube voltmeter, corresponding to 85 octane fuel at a compression ratio of 10:1, is 11.5v dc. Change the fuel to 90 octane reference fuel, following the procedure previously outlined, and maintain the 10:1 compression ratio. The reading on the 15v scale of the vacuum tube voltmeter,



COMBUSTION CHAMBER HEIGHT = MICROMETER READING + 0.500"

Figure VI Compression Ratio Conversion Scale



A Float Chambers
B Air Bleed Adjustment Valve
C Hooked Levers for Selection of Fuel
D Main Air Intake
E Fuel Valves
F Throttle Valve Indicator
G Throttle Valve Operating Screw

Figure VII CFR Two-Bowl Carburetor

corresponding to 90 octane fuel at a compression ratio of 10:1, is 6.0v $\pm\frac{1}{4}$v.

The calibration procedure is continued, in accordance with the preceding method, for the following groups of reference fuels and their respective micrometer readings: 80 octane, 82.5 octane, and 85 octane at a micrometer reading of 0.059 inch; 75 octane, 77.5 octane, and 80 octane at a micrometer reading of 0.170 inch; 70 octane, 72.5 octane, and 75 octane at a micrometer reading of 0.237 inch; 65 octane and 70 octane at a micrometer reading of 0.279 inch.

Complete calibration data for the reference fuels in the range of 65 octane to 90 octane are shown in Figure VIII. The preceding calibration was performed as the final calibration for use in rating the commercial gasolines as discussed in Chapter V, Results of Tests.

Comparison with CFR Method

To emphasize the simplicity and expediency of the New Method, a comparison of the requirements of the CFR Method and the New Method is presented.

Data provided by the CFR Method are largely dependent, from a reliability standpoint, upon a constant ambient temperature as well as the maintenance of the mixture temperature at 300°F. ±2°F. Very small variations in ambient temperature can result in completely unreliable octane rating data.

corresponding to 90 octane fuel at a compression ratio of 10:1, is 6.0v ±½v.

The calibration procedure is continued, in accordance with the preceding method, for the following groups of reference fuels and their respective micrometer readings: 80 octane, 82.5 octane, and 85 octane at a micrometer reading of 0.059 inch; 75 octane, 77.5 octane, and 80 octane at a micrometer reading of 0.250 inch; 70 octane, 72.5 octane, and 75 octane at a micrometer reading of 0.277 inch; 65 octane and 70 octane at a micrometer reading of 0.279 inch.

Complete calibration data for the reference fuels in the range of 65 octane to 90 octane are shown in Figure VIII. The preceding calibration was performed as the final calibration for use in rating the commercial gasolines as discussed in Chapter V, Results of Tests.

Comparison with CFR Method

To emphasize the simplicity and expediency of the New Method, a comparison of the requirements of the CFR Method and the New Method is presented.

Data provided by the CFR Method are largely dependent, from a reliability standpoint, upon a constant ambient temperature as well as the maintenance of the mixture temperature at 300°F. ±2°F. Very small variations in ambient temperature can result in completely unreliable octane rating data.

The New Method for determining octane ratings of gasolines is relatively insensitive to variations in ambient temperature; the only close temperature requirement being the maintenance of the mixture temperature at 300°F. ±2°F.

The CFR Method cannot tolerate a test engine that misfires once an hour, while the New Method requires only a time interval of from one to two minutes for the engine to reach equilibrium after an ignition interruption. The sensitivity of the CFR Method to engine misfires places very strict requirements upon the fuel changing procedure.

The CFR Method requires that each test sample be bracketed at least three times between two blends of reference fuels which differ by not more than two octane numbers. The octane rating of the test sample is obtained by interpolation from the averages of the knockmeter readings of the test sample and the two reference fuels. A test sample is rated by the New Method by selecting predetermined compression ratios until the test sample matches a reference fuel calibration. If there is any doubt concerning a test sample rating, the New Method permits a check of the previously determined rating at any time during the test procedure. This is accomplished by selecting the compression ratio corresponding to the previous rating and checking for reproducibility of results. The CFR Method of checking ratings is much more complicated and usually requires a new test run

The New Method for determining octane ratings of gasolines is relatively insensitive to variations in ambient temperature; the only close temperature requirement being the maintenance of the mixture temperature at 300°F. ± 2°F.

The CFR Method cannot tolerate a test engine that misfires once an hour, while the New Method requires only a time interval of from one to two minutes for the knock to reach equilibrium after an ignition interruption. The sensitivity of the CFR Method to small variations places very strict requirements upon the test engine's operation.

The CFR Method requires that each test sample be bracketed at least three times between two blends of reference fuels which differ by not more than two octane numbers. The octane rating of the test sample is obtained by interpolation from the averages of the knockmeter readings of the test sample and the two reference fuels. A test sample is rated by the New Method by selecting predetermined compression ratios until the test sample matches a reference fuel calibration. If there is any doubt concerning a test sample rating, the New Method permits a check of the previously determined rating at any time during the test procedure. This is accomplished by selecting the compression ratio corresponding to the previous rating and checking the reproducibility of results. The CFR Method of checking ratings is much more complicated and usually requires a new test run

of three sets of readings.

A comparative study indicates that the New Method is superior to the CFR Method with respect to ease of operation and reduction of restrictive requirements. Chapter V, Results of Tests, will present the accuracy and time saving concepts of the New Method.

of three sets of readings.

A comparative study indicates that the New Method is superior to the OTM Method with respect to ease of operation and reduction of restrictive requirements. Chapter V, Results of Tests, will present the accuracy and time saving concepts of the New Method.

CHAPTER V

RESULTS OF TESTS

Ratings by New Method

Sixteen commercial gasolines were rated by the New Method, using the final calibration described in Chapter IV and illustrated in Figure VIII, as final tests. A photograph of the reference fuels and commercial gasolines used for the final calibration and gasoline ratings is shown in Figure IX. The individual commercial gasoline ratings are shown graphically in Figure X. The final calibration procedure and the octane rating procedure for the sixteen commercial gasolines were performed in approximately four hours. This included several check runs on doubtful readings and a final check on the initial setting with 85 octane at 10:1 compression ratio. The initial setting was checked for reproducibility as well as for permanency of the air-bleed valve setting. This time element may be compared with the time required for octane ratings by the CFR Method which is presented later in this chapter. For reference purposes, final calibration and gasoline rating data are presented in tabulated form in Appendix A.

In order to present data on the variations of the pressure wave form of fuels of known octane ratings at

CHAPTER V

RESULTS OF TESTS

Ratings by New Method

Sixteen commercial gasolines were rated by the New Method, using the final calibration described in Chapter IV and illustrated in Figure VIII, as in all tests. A photograph of the reference fuels and commercial gasolines used for the final calibration and gasoline ratings is shown in Figure IX. The individual commercial gasoline ratings are shown graphically in Figure X. The final calibration procedure and the octane rating procedure for the sixteen commercial gasolines were performed in approximately three hours. This included several check runs on doubtful readings and a final check on the initial setting with cyclohexane at 10:1 compression ratio. The initial setting was checked for reproducibility as well as for permanency of the air-bleed valve setting. This time element may be compared with the time required for octane ratings by the CFR Method which is presented later in this chapter. For reference purposes, final calibration and gasoline rating data are presented in tabulated form in Appendix A.

In order to present data on the variations of the pressure wave form of fuels of known octane ratings at

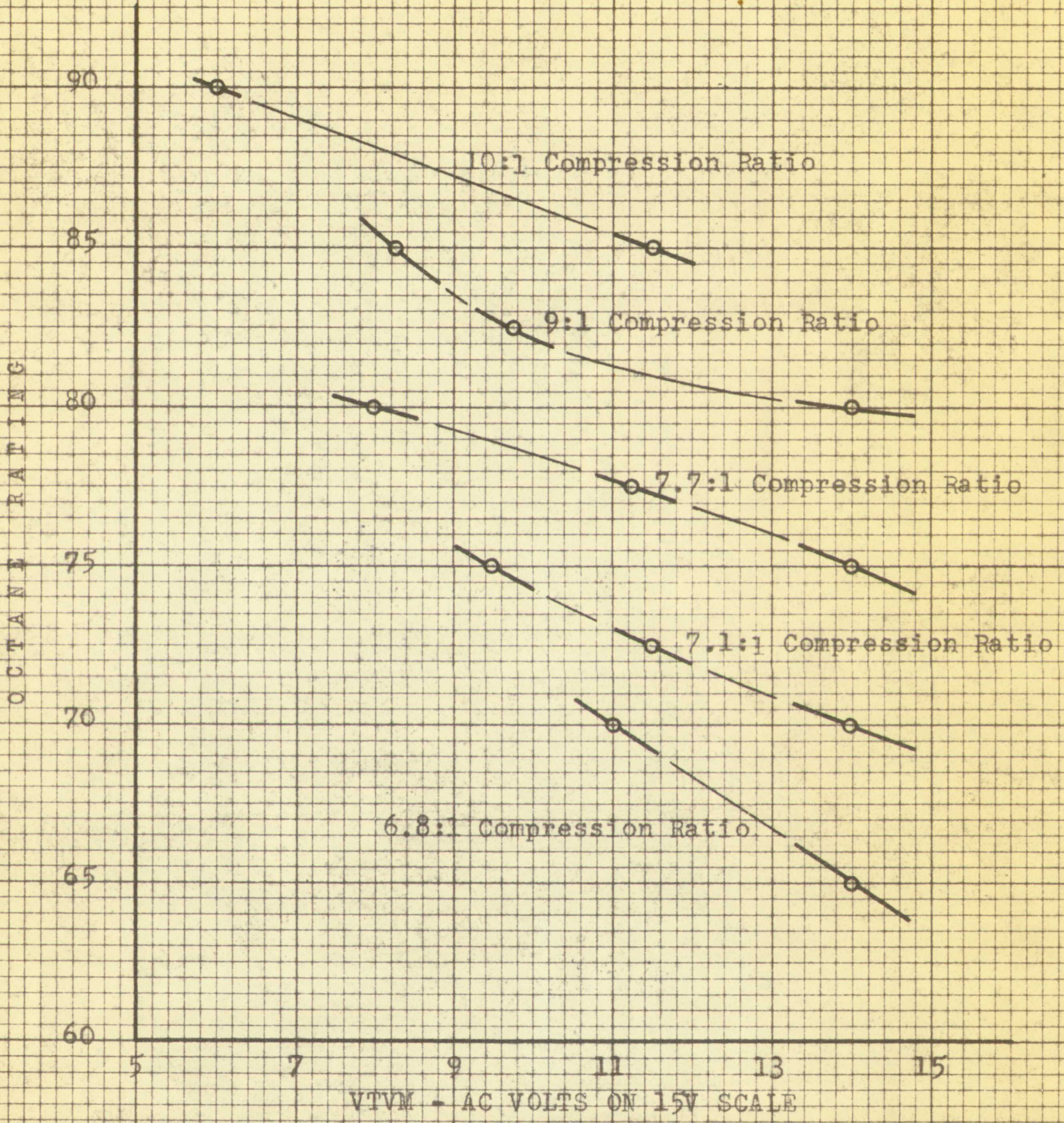


Figure VIII Calibration Curves - 65 to 90 Octane

Figure IX Reference Fuels and Commercial Gasolines

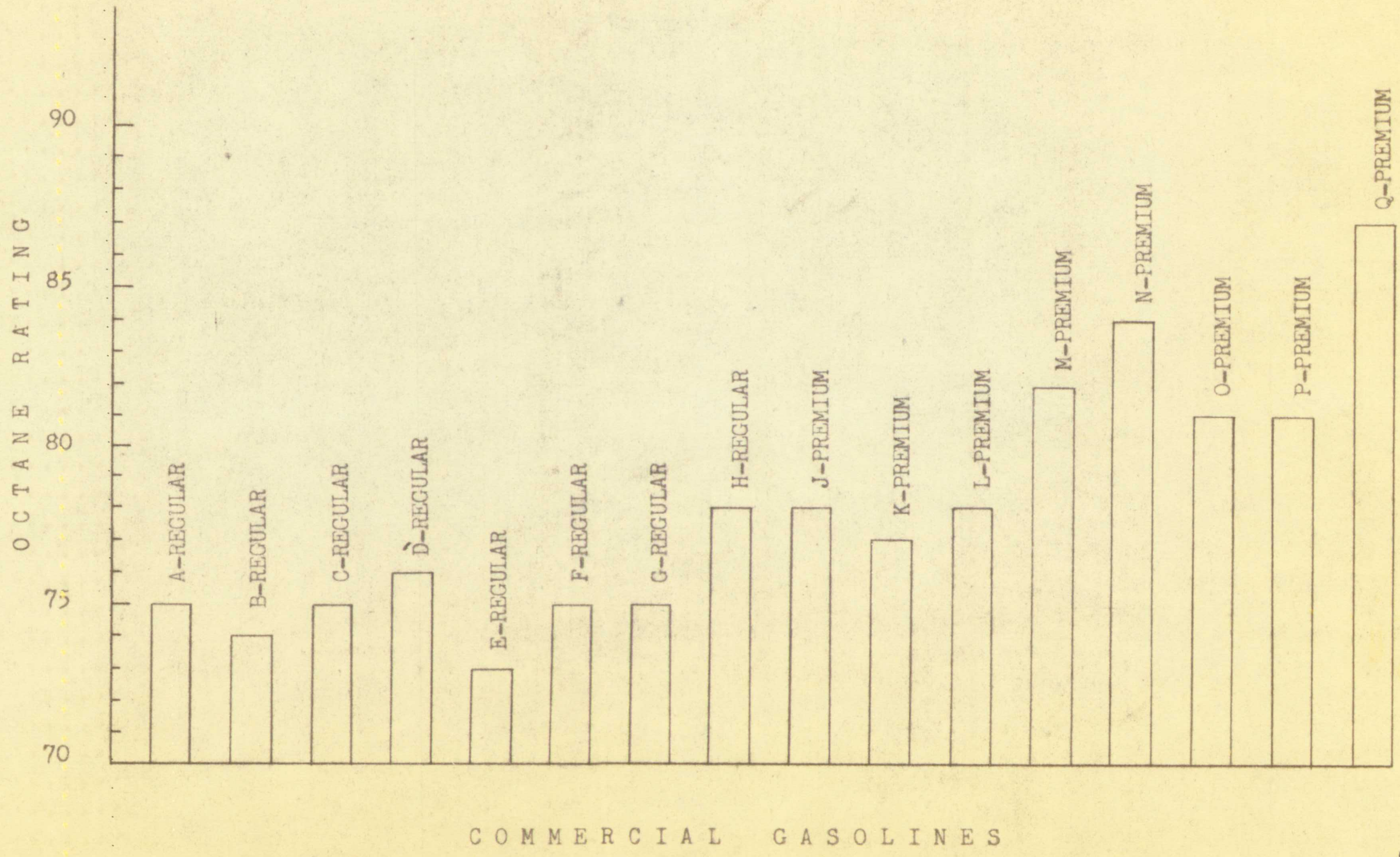


Figure X Commercial Gasoline Octane Ratings

different compression ratios, the pressure wave forms of five known fuels were photographed at different compression ratios. These photographs, with respective data on octane ratings and compression ratios, are presented in Figures XI, XII, XIII, XIV, and XV. A definite relation exists between the frequency make-up of the pressure wave forms and the variations in intensity of the oscilloscope traces of the pressure wave forms. The intensity of the oscilloscope traces of the pressure wave forms varies inversely with the frequency make-up of the wave forms. This relationship is clearly shown by the photographs of the oscilloscope traces for the respective fuels and compression ratios.

Ratings by CFR Method

For comparative purposes, the octane ratings of two commercial gasolines, previously rated by the New Method, were determined by the CFR Method. These gasolines carry the code designations K-Premium and J-Premium. Three gasolines were actually tested in this procedure, but the supply of one of them, H-Regular, was exhausted before satisfactory results could be obtained. Data and results of the rating procedure by the CFR Method are presented in Appendix B.

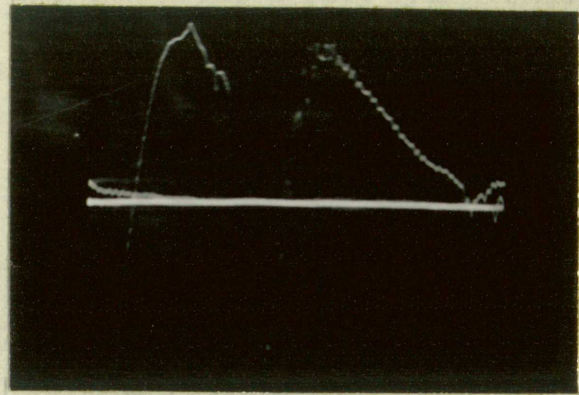
Considerable difficulty was encountered during the rating procedure by the CFR Method because of varying ambient temperature and blowing fuses in the knockmeter circuit.

different compression ratios, the pressure wave forms of five known fuels were photographed at different compression ratios. These photographs, with respective octane ratings and compression ratios, are presented in Figures XI, XII, XIII, XIV, and XV. A definite relation exists between the frequency make-up of the pressure wave forms and the variations in intensity of the oscillograph traces of the pressure wave forms. The intensity of the oscillograph traces of the pressure wave forms varies inversely with the frequency make-up of the wave forms. This relationship is clearly shown by the photographs of the oscillograph traces for the respective fuels and compression ratios.

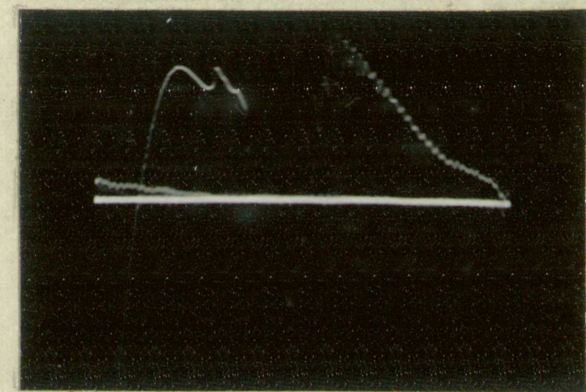
Ratings by CFR Method

For comparative purposes, the octane ratings of two commercial gasolines, previously rated by the new method, were determined by the CFR method. These gasolines carry the code designations X-Premium and X-Premium. Three gasolines were actually tested in this procedure, but the supply of one of them, X-Regular, was exhausted before satisfactory results could be obtained. Data and results of the rating procedure by the CFR Method are presented in Appendix II.

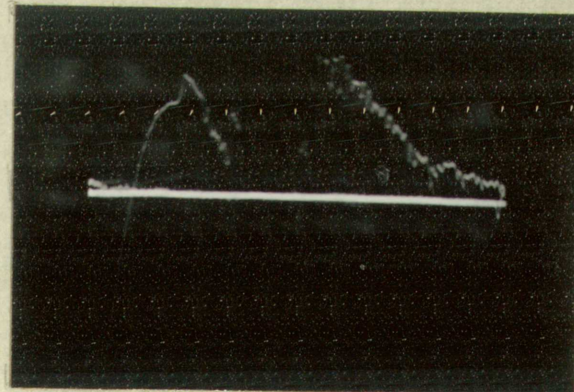
Considerable difficulty was encountered during the rating procedure by the CFR Method because of varying ambient temperature and blowing fuses in the knockmeter circuit.



7:1 Compression Ratio

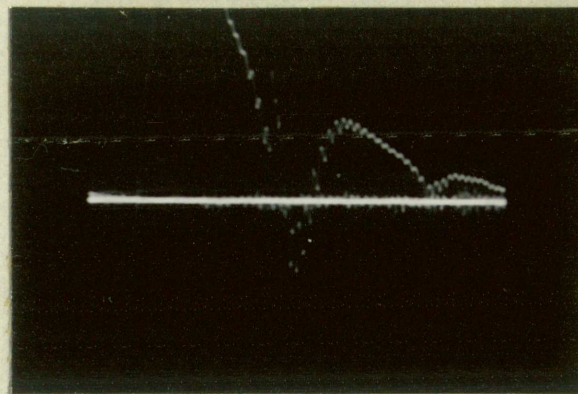


8:1 Compression Ratio

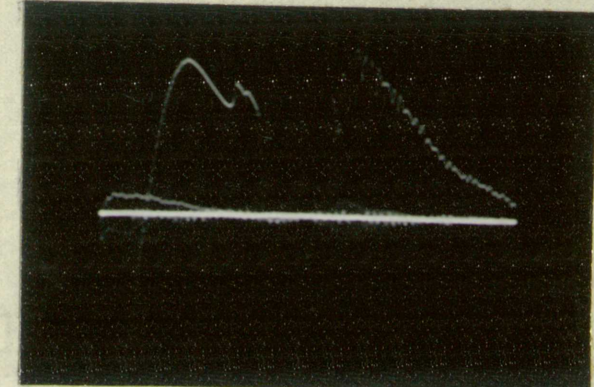


9:1 Compression Ratio

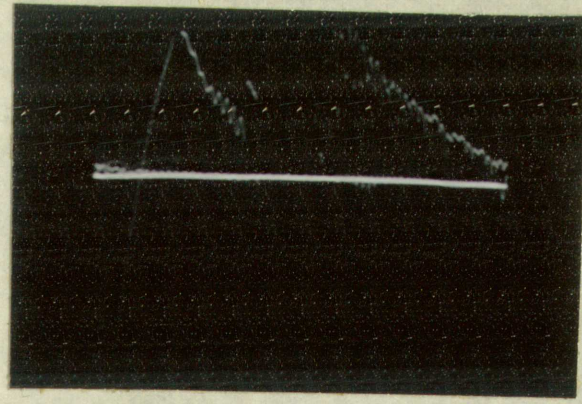
Figure XI 0-Premium Gasoline-Pressure Wave Forms



7:1 Compression Ratio



8:1 Compression Ratio



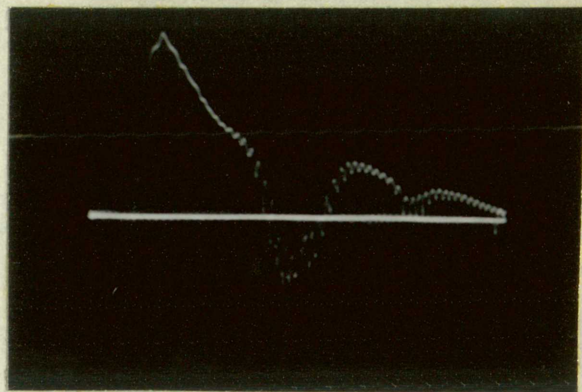
9:1 Compression Ratio

Figure XII K-Premium Gasoline-Pressure Wave Forms

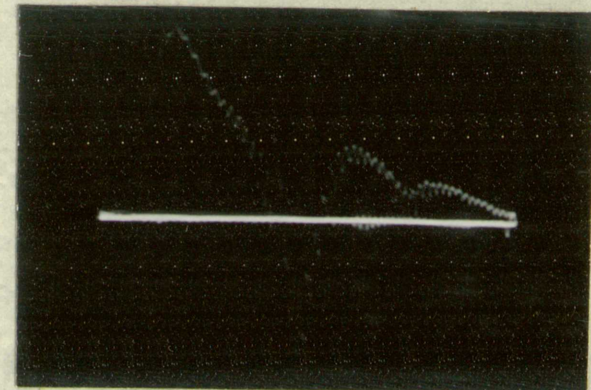
XII 18-19

XII 19-20

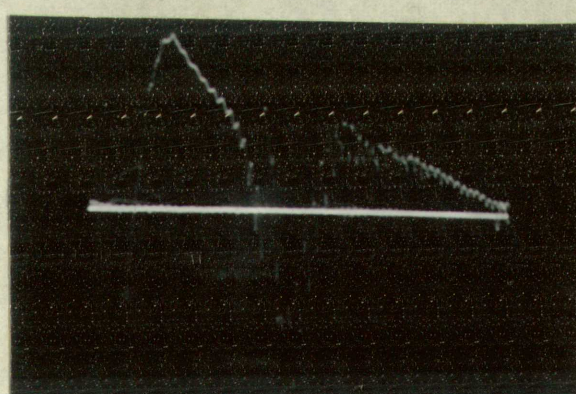
XII 21-22



7:1 Compression Ratio



8:1 Compression Ratio



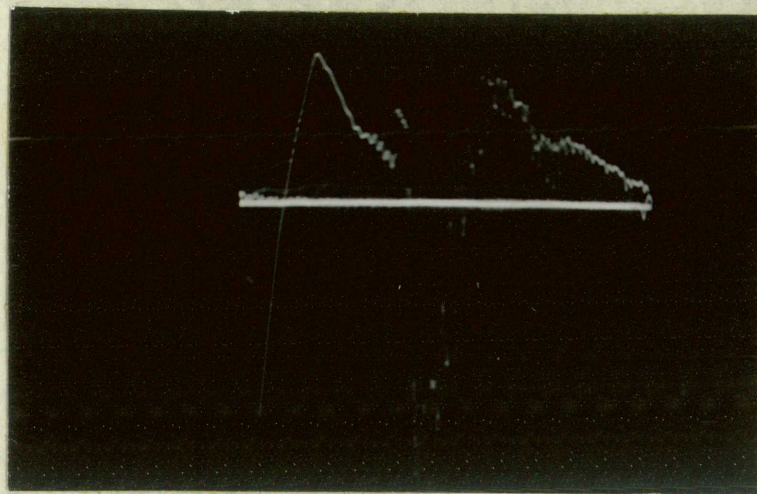
9:1 Compression Ratio

Figure XIII 85 Octane-Pressure Wave Forms

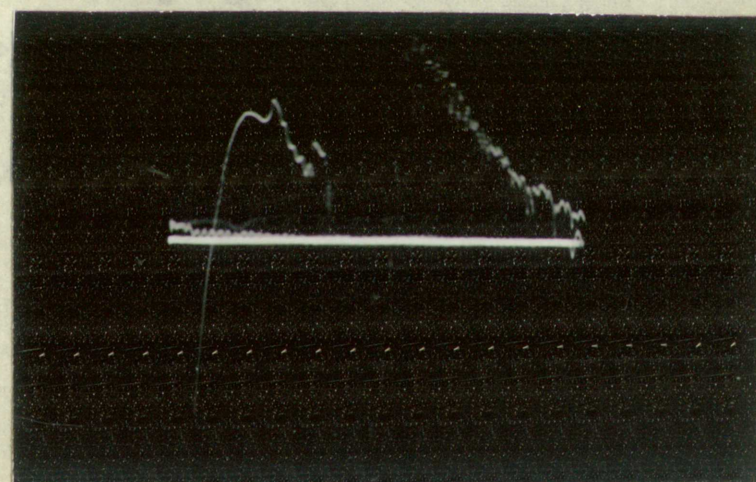
XIII 25-26

XIII 26-27

XIII 27-28



8:1 Compression Ratio

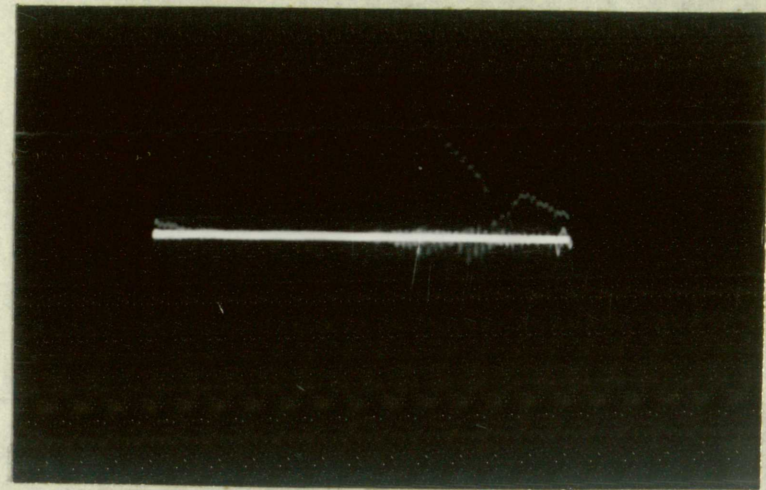


8.5:1 Compression Ratio

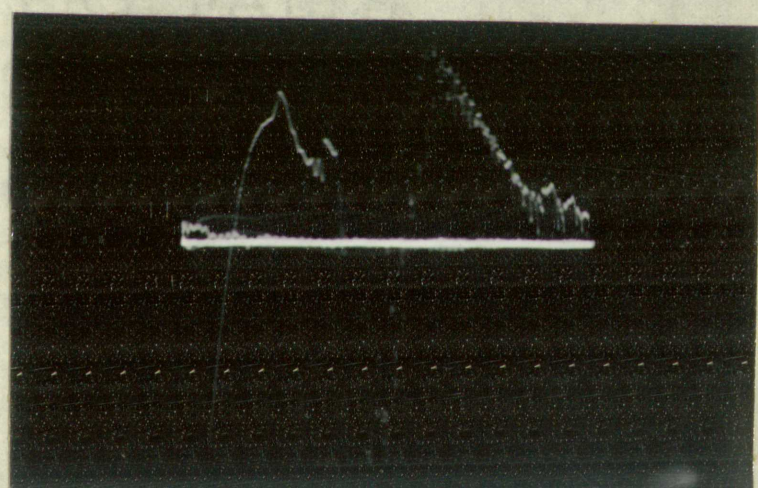
Figure XIV H-Regular Gasoline-Pressure Wave Forms

XIV 12-13

XIV 13-14



6:1 Compression Ratio



6.5:1 Compression Ratio

Figure XV 65 Octane-Pressure Wave Forms

XV 14-15

18

XV 15 16

The knockmeter was very erratic, and much time was consumed in waiting for the instrument to reach equilibrium. The standard procedure specifies a time interval of at least one minute for the engine and knockmeter to reach equilibrium, but extending this interval to approximately five minutes was necessary for most readings. The complete test procedure, during which only two gasolines were satisfactorily rated, required approximately seven hours, exclusive of initial engine setup.

Accuracy of New Method

Reproducibility of results by the New Method is exceptionally good. A comparison of the results obtained during one month of preliminary testing with those of the final calibration and testing showed excellent reproducibility of results.

The accuracy of the New Method cannot be definitely determined without a long range test program combining the CFR Method and the New Method on a comparative basis. If some of the Cooperative Fuel Research member committees would join in a cooperative test program utilizing both the CFR Method and the New Method, the accuracy of the New Method could be conclusively established. This could be accomplished easily by comparing the octane ratings of fixed test samples as determined by the two test methods.

The knockmeter was very sensitive, and much time was consumed in waiting for the instrument to reach equilibrium. The standard procedure specifies a time interval of at least one minute for the engine and knockmeter to reach equilibrium, but extending this interval to approximately five minutes was necessary for most readings. The complete test procedure, during which only two gasolines were completely rated, required approximately seven hours, exclusive of initial engine setup.

Accuracy of New Method

Reproducibility of results by the New Method is exceptionally good. A comparison of the results obtained during one month of preliminary testing with those of the final calibration and testing showed excellent reproducibility of results.

The accuracy of the New Method cannot be definitely determined without a long range test program utilizing the CFR Method and the New Method on a comparative basis. If some of the Cooperative Fuel Research member committees would join in a cooperative test program utilizing both the CFR Method and the New Method, the accuracy of the New Method could be conclusively established. This could be accomplished easily by comparing the octane ratings of fixed test samples as determined by the two test methods.

The octane ratings for the two gasolines, K-Premium and J-Premium, were 78 and 78 respectively as determined by the New Method and 77 and 77.5 respectively as determined by the CFR Method. While this comparison does not establish the accuracy of the New Method, it does, to one familiar with the CFR Method, indicate the accuracy.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Recommended Test Procedure

To clearly define the test procedure for the New Method, a Recommended Test Procedure, which includes standard engine operating conditions, equipment adjustments, suggestions on fuel changing and suggestions on operating technique, is presented.

A. Standard Engine Operating Conditions

1. Engine Speed ----------- 900 r.p.m. ± 9 r.p.m.
2. Oil Pressure ----------- 25 to 30 p.s.i. under operating conditions.
3. Valve Clearances -------- Intake 0.008 inch cold. Exhaust 0.010 inch cold.
4. Spark Advance ---------- Automatically controlled, 19.0 degrees at 7:1 compression ratio.
5. Throttle Opening -------- 75 degrees on the throttle quadrant.
6. Carburetor Adjustment -- Maximum knock for initial setting with 85 octane reference fuel, constant thereafter.
7. Mixture Temperature ---- 300°F. ± 2°F.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Recommended Test Procedure

To clearly define the test procedure for the [illegible] Method, a Recommended Test Procedure, which includes standard engine operating conditions, equipment adjustments, suggestions on fuel changing and suggestions on operating technique, is presented.

A. Standard Engine Operating Conditions

1. Engine Speed ---------- 900 r.p.m. ± [illegible] r.p.m.

2. Oil Pressure ---------- 25 to 35 p.s.i. under operating conditions.

3. Valve Clearances ------- Intake 0.[illegible] inch cold. Exhaust 0.010 inch cold.

4. Spark Advance ----------- Automatically controlled, 19.8 degrees at 7:1 compression ratio.

5. Throttle Opening ------- 7 degrees on the throttle quadrant.

6. Carburetor Adjustment -- Maximum knock for initial setting with [illegible] reference fuel, constant thereafter.

7. Mixture Temperature ---- 300°F. ± [illegible]°F.

B. Equipment Adjustments

1. Voltage Amplifier -- The gain control on the voltage amplifier shall be maintained at its lower limit for vacuum tube voltmeter operation and shall be variable for oscilloscope operation.

2. Vacuum Tube Voltmeter -- The vacuum tube voltmeter shall be set for AC volts on the 15v scale for the entire test procedure.

C. Suggestions on Fuel Changing

1. Carburetor Condition -- If any doubt exists as to the proper functioning of the carburetor and specimen tanks, confine the operation to a single carburetor bowl and specimen tank. This procedure reduces the possibility of fuel mixtures caused by leaking valves.

2. Fuel Changing -- When changing fuels, drain the specimen tank and carburetor bowl by opening the proper drain cocks and allow a small portion of the new fuel to flow through the lines before closing the drain cocks. This purging operation helps prevent fuel mixtures. Do not rush the fuel changing process. It is better to let the engine motor a few seconds without fuel than to rush the process and mix the fuels. However, the engine should not be allowed to motor more than a few seconds because the mixture temperature will rise rapidly in the absence of fuel vaporization.

3. Equilibrium Period -- When changing from one fuel to another, allow a time interval of from one to two minutes for the engine and test equipment to reach equilibrium before readings are taken.

D. Procedure

1. Standard Operating Conditions -- When the test equipment is connected as shown in Figure I, operate the engine on any suitable fuel at a compression ratio of approximately 6:1 until standard operating conditions are reached. A 6:1 compression ratio is recommended for the warm-up period as this will permit smooth engine operation and a steady approach to standard operating conditions.

2. Compression Ratio -- When standard operating conditions have been reached, change the fuel to 85 octane reference fuel and change the compression ratio to 10:1 by lowering the cylinder head until a reading of zero is reached on the micrometer attached to the cylinder head. Micrometer readings can be readily converted to compression ratios by using the conversion scale shown in Figure VI. The combustion chamber height referred to on the conversion scale is equal to the micrometer reading plus one-half inch.

3. Maximum Knock -- When the engine is operating on a reference fuel of 85 octane, check that equipment is

adjusted correctly; then set the air-bleed adjustment B, Figure VII, for maximum knock. Maximum knock is determined by turning the air-bleed adjustment to the right as far as it will go, then slowly opening it and observing the voltmeter reading. As the air-bleed adjustment is opened, the knock will approach a maximum and begin to decrease, as will be shown by the voltmeter reading. After the knock passes a maximum value, reverse the air-bleed adjustment and observe the voltmeter reading until maximum knock, as registered on the voltmeter, is again passed. Repeat this operation several times until a maximum voltmeter reading is determined; this is maximum knock. The air-bleed adjustment for maximum knock will remain constant for the entire test procedure.

4. Calibration -- The voltmeter reading for maximum knock is the 85 octane calibration. Maintain the 10:1 compression ratio and change the fuel to 90 octane reference fuel, following the fuel changing procedure prescribed in C. 2. and C. 3. The voltmeter reading is the 90 octane calibration. The calibration procedure is continued for the following groups of reference fuels, and their respective compression ratios are expressed as micrometer readings: 80 octane, 82.5 octane, and 85 octane at a micrometer reading of 0.059 inch; 75

adjusted correctly; then set the air-bleed adjustment 3, Figure VII, for maximum knock. Maximum knock is determined by turning the air-bleed adjustment to the right as far as it will go, then slowly opening it and observing the voltmeter reading. As the air-bleed adjustment is opened, the knock will approach a maximum and begin to decrease, as will be shown by the voltmeter reading. After the knock passes a maximum value, reverse the air-bleed adjustment and observe the voltmeter reading until maximum knock, as registered on the voltmeter, is again passed. Repeat this operation several times until a maximum voltmeter reading is determined; this is maximum knock. The air-bleed adjustment for maximum knock will remain constant for the entire test procedure.

4. Calibration - The voltmeter reading for maximum knock is the 90 octane calibration. Retain the 1:1 [illegible] compression ratio and change the fuel to 90 octane reference fuel, following the fuel changing procedure described in C. 2. and C. 3. The voltmeter reading is the 90 octane calibration. The calibration procedure is continued for the following groups of reference fuels and their respective compression ratios are expressed as micrometer readings: 80 octane, 82.5 octane, and 85 octane at a micrometer reading of 0.0[illegible] inch; 75 [illegible]

octane, 77.5 octane, and 80 octane at a micrometer reading of 0.170 inch; 70 octane, 72.5 octane, and 75 octane at a micrometer reading of 0.237 inch; 65 octane and 70 octane at a micrometer reading of 0.279 inch. The recommended calibration from 65 octane to 90 octane will encompass the existing commercial grades of gasolines.

5. Gasoline Rating -- Unknown gasolines are rated by operating the engine on each of the unknown gasolines and varying the compression ratio in accordance with the prescribed calibration settings expressed as micrometer readings. The compression ratio is varied until a prescribed setting is reached which produces a voltmeter reading that matches a calibration or falls between two calibrations at the same compression ratio. The octane rating of the unknown gasoline is then determined by interpolation. If doubt exists concerning an octane rating, the gasoline in question may be checked at any time during the test procedure.

6. Checks -- After the unknown gasolines have been rated, check the calibration by changing the fuel to 85 octane reference fuel, setting the compression ratio at 10:1 and checking the voltmeter reading against the initial calibration. Continue this check method for 90 octane, 80 octane, 75 octane, 70 octane, and 65 octane.

octane, 77.5 octane, and 80 octane at a micrometer reading of 0.170 inch; 70 octane, 72.5 octane, and 75 octane at a micrometer reading of 0.237 inch; 65 octane and 70 octane at a micrometer reading of 0.279 inch. The recommended calibration from 65 octane to 90 octane will encompass the existing commercial grades of gasolines.

5. Gasoline Rating -- Unknown gasolines are rated by operating the engine on each of the unknown gasolines and varying the compression ratio in accordance with the prescribed calibration settings expressed as micrometer readings. The compression is set in turn until a prescribed setting is reached which gives a voltmeter reading that matches a calibration or falls between two calibrations at the same compression ratio. The octane rating of the unknown gasoline is then determined by interpolation. If doubt exists concerning an octane rating, the gasoline in question may be checked at any time during the test procedure.

6. Checks -- After the unknown gasolines have been rated, check the calibration by changing the fuel to 85 octane reference fuel, setting the compression ratio at 10:1 and checking the voltmeter reading against the initial calibration. Continue this check method for 90 octane, 80 octane, 75 octane, 70 octane, and 65 octane.

General Conclusions and Recommendations

The writer believes that the New Method presents a reliable and expedient method for the determination of octane ratings of gasolines. Extensive developmental testing using commercial gasolines and standard reference fuels has shown the New Method to possess very good reproducibility of results and suggests good possibilities for the New Method in the field of fuel research.

The electro-mechanical equipment as developed and operated at the present time is satisfactory, but certain modifications would improve the overall performance.

The present quartz pressure element, with its ignition electrode feature, was intended as a combination spark plug and pressure pickup, but the lack of a suitable location in the cylinder head for both ignition and pressure response purposes confined its use to that of pressure pickup. It is recommended that the pressure element now in use be replaced with one more suitable for the present application. The quartz crystal arrangement in the present pressure element is far removed from the cylinder head opening, and the complicated piston arrangement necessary to transfer cylinder pressure variations to the quartz crystals is subject to corrosion and subsequent erratic performance. A pressure element similar to the Type 3 Cox Quartz Pressure

Element is recommended as a replacement since the quartz crystals and related piston depend only upon the deflection of a sealed diaphragm for the transfer of the cylinder pressure variations.

Another type pressure element, which should surpass the performance of the quartz crystal element, is the liquid-cooled condenser type.[9] This type pressure element offers excellent response and stability characteristics.

The study of pressure wave forms on the oscilloscope, or from photographs, would be simplified if a synchronizing device were installed which would provide a time axis. This synchronizing device could be a voltage-impulse arrangement operated from the crankshaft. The device could be either a battery and contactor arrangement or a magnetic impulse generator. Variations of these devices appear in the material listed in the Bibliography.

A very useful device, both from the standpoint of pressure wave form study and octane rating of gasoline, would be a triggering or switching arrangement for selecting only that portion of the engine cycle under study. This device could be operated from the crankshaft and could be so

---

[9] C. E. Grinsted, R. N. Frawley, F. W. Chapman and H. F. Schultz, "An Improved Indicator for Measuring Static and Dynamic Pressures," SAE Journal (Transactions), 52:534-56, November, 1944.

arranged as not to interfere with the snychronizing device, if both were desired. The device would consist of a contactor-cam arrangement on the crankshaft. The cam position is adjustable to eliminate that portion of the engine cycle not under study.

Perhaps the most important modification to the existing equipment would be the modernization of the CFR Fuel Research Engine. This modification would be expensive, but the benefits to be realized from such an undertaking would more than outweigh the initial cost. A modern carburetor system alone would increase the reliability and expediency of the testing procedure as set forth by the New Method.

The writer believes the New Method to be equal to the CFR Method with respect to reliability and superior to the CFR Method with respect to simplicity and expediency. With a few modifications and additions, the existing electromechanical equipment can be adapted to numerous projects in the fields of fuel research and combustion chamber design. It is hoped that the present project will become the basis of an extensive fuel study program.

BIBLIOGRAPHY

ASTM-CFR Knock Testing Unit. Ninth edition; Waukesha, Wisconsin: Waukesha Motor Company, 1932. 47 pp.

Ebacher, R. W., "Development of Electro-Mechanical Equipment for the Measurement of Knock Characteristics of Gasolines." Unpublished Master's thesis, The University of New Mexico, Albuquerque, 1952. 37 pp.

Grinsted, C. E., and others, "An Improved Indicator for Measuring Static and Dynamic Pressure," SAE Journal (Transactions), 52:534-56, November, 1944.

Krebs, R. P., and Thomas Dallas, "Constant-Gain Knock Pickup Amplifier," Electronics, 20:87-89, January, 1947.

Lichty, L. C., Internal Combustion Engines. Fifth edition; New York: McGraw-Hill Book Company, Inc., 1939. 603 pp.

Schrader, H. J., "Cathode-Ray Engine-Pressure Measuring Equipment," RCA Review, 2:202-12, October, 1937.

Standard Method of Test for Knock Characteristics of Motor Fuels. (In A.S.T.M. Standards on petroleum products and lubricants. Annual, 1944. pp. 250-66)

Type 4 Cox Ignition Quartz Pressure Element. Detroit, Michigan: Commercial Research Laboratories, Inc., n.d. 2 pp.

Type 3 Cox Quartz Pressure Element. Detroit, Michigan: Commercial Research Laboratories, Inc., n.d. 16 pp.

APPENDIX A

NEW METHOD

Final Calibration and Gasoline Rating Data

Vacuum tube voltmeter (VTVM): Set for AC volts on 15v scale

Calibration data:

Reference Fuel	Micrometer Reading	Compression Ratio	VTVM Indication
85.0 Octane	0.000	10:1	11.5 ± 1/2 volts
90.0 Octane	0.000	10:1	6.0 ± 1/4
85.0 Octane	0.000	10:1	11.5 ± 1/2
80.0 Octane	0.059	9:1	14.00 ± 3/4
82.5 Octane	0.059	9:1	9.75 ± 1/2
85.0 Octane	0.059	9:1	8.25 ± 1/2
82.5 Octane	0.059	9:1	9.75 ± 1/2
80.0 Octane	0.059	9:1	14.00 ± 3/4
75.0 Octane	0.170	7.7:1	14.00 ± 3/4
77.5 Octane	0.170	7.7:1	11.25 ± 1/2
80.0 Octane	0.170	7.7:1	8.00 ± 1/2
77.5 Octane	0.170	7.7:1	11.25 ± 1/2
75.0 Octane	0.170	7.7:1	14.00 ± 3/4
70.0 Octane	0.237	7.1:1	14.00 ± 3/4
72.5 Octane	0.237	7.1:1	11.50 ± 1/2
75.0 Octane	0.237	7.1:1	9.50 ± 1/2
72.5 Octane	0.237	7.1:1	11.50 ± 1/2
70.0 Octane	0.237	7.1:1	14.00 ± 3/4
65.0 Octane	0.279	6.8:1	14.00 ± 3/4
70.0 Octane	0.279	6.8:1	11.00 ± 1/2
65.0 Octane	0.279	6.8:1	14.00 ± 3/4
70.0 Octane	0.279	6.8:1	11.00 ± 1/2

Commercial gasoline rating data:

Gasoline	Micrometer Reading	Compression Ratio	VTVM Indication	Octane
A-Regular	0.237	7.1:1	9.75 ±1/4 Volts	75
B-Regular	0.237	7.1:1	10.00 ±1/4	74
C-Regular	0.237	7.1:1	9.25 ±1/4	75
D-Regular	0.237	7.1:1	8.50 ±1/2	76
E-Regular	0.237	7.1:1	11.25 ±1/2	73
F-Regular	0.237	7.1:1	9.75 ±1/4	75
G-Regular	0.237	7.1:1	9.50 ±1/4	75
H-Regular	0.170	7.7:1	10.75 ±1/4	78
J-Premium	0.170	7.7:1	10.25 ±1/2	78
K-Premium	0.170	7.7:1	12.00 ±1/2	77
L-Premium	0.170	7.7:1	10.25 ±1/2	78
M-Premium	0.059	9:1	10.75 ±1/4	82
N-Premium	0.059	9:1	9.00 ±1/4	84
O-Premium	0.059	9:1	12.50 ±1/2	81
P-Premium	0.059	9:1	12.00 ±1.0	81
Q-Premium	0.000	10:1	9.50 ±1/2	87

APPENDIIX B

CFR METHOD

Gasoline Ratting Data

Run	Fuel	Micrometer Setting	Knockmeter Reading
	H-Regular		50
1	70.0 Octane	.550	38
	72.5 Octane		35
	H-Regular		52
2	70.0 Octane		43
	65.0 Octane	.492	45
	H-Regular		50
3	65.0 Octane	.492	45
	60.0 Octane		70
	H-Regular		29
4	65.0 Octane	.492	40
	77.5 Octane		12
	H-Regular		16
5	75.0 Octane	.492	17
	70.0 Octane		20

NOTE: Supply of H-Regular gasoline was exhausted; readings were too erratic for rating purposes. New test was planned with K-Premium gasoline.

Run	Fuel	Micrometer Setting	Knockmeter Reading
	K-Premium		35
1	70.0 Octane	.385	50
	77.5 Octane		33
	K-Premium		36
2	75.0 Octane	.385	28
	77.5 Octane		28
	K-Premium		29
3	75.0 Octane	.385	20
	77.5 Octane		22
	K-Premium		24
4	75.0 Octane	.385	20
	77.5 Octane		20

NOTE: Readings were unsatisfactory; knockmeter was adjusted to reading of 50 with 75 octane for new test.

Run	Fuel	Micrometer Setting	Knockmeter Reading
	K-Premium		46
1	75.0 Octane	.296	50
	77.5 Octane		42
	K-Premium		45
2	75.0 Octane	.296	54
	77.5 Octane		47
	K-Premium		42
3	75.0 Octane	.296	50
	77.5 Octane		43
	K-Premium		43
4	75.0 Octane	.296	51
	77.5 Octane		41

NOTE: Knockmeter was adjusted to reading of 50 with 75 octane for test with J-Premium gasoline.

Run	Fuel	Micrometer Setting	Knockmeter Reading
	J-Premium		42
1	75.0 Octane	.296	50
	77.5 Octane		42
	J-Premium		43
2	75.0 Octane	.296	50
	77.5 Octane		39
	J-Premium		41
3	75.0 Octane	.296	48
	77.5 Octane		43
	J-Premium		42
4	75.0 Octane	.296	49
	77.5 Octane		44

Results of tests with K-Premium and J-Premium gasolines:

	K-Premium Results			J-Premium Results		
	K	75	77.5	J	75	77.5
	46	50	42	42	50	42
	45	54	47	43	50	39
	42	50	43	41	48	43
	43	51	41	42	49	44
	176	205	173	168	197	168
Avg.	44	51.2	43.2	42	49.2	42

K-Premium gasoline . . . 77.00 Octane

J-Premium gasoline . . . 77.50 Octane