

Summer 6-2-1952

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

Charles B. Gangwer

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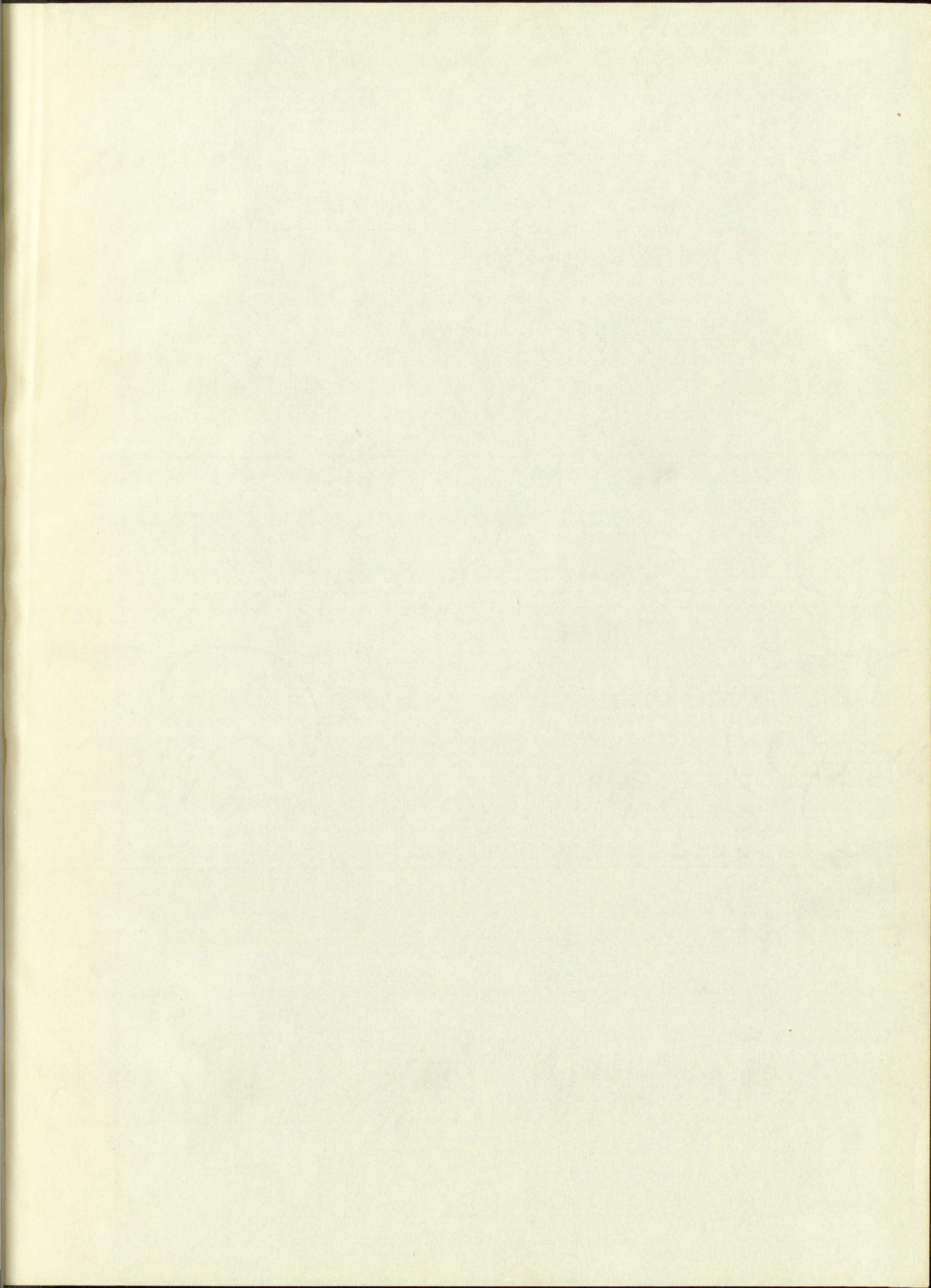
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DEVELOPMENT OF A TEST METHOD FOR RAPID DETERMINATION
OF
OCTANE RATINGS OF GASOLINES

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

DEVELOPMENT OF A TEST METHOD FOR RAPID DETERMINATION

OF

OCCUPATIONAL RISK OF ACCIDENTS



BY

Charles E. Garwood

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ALBUQUERQUE, N.M.

A Thesis

In partial fulfillment of the

Requirements for the Degree of

Master of Science in Mechanical Engineering

The University of New Mexico
1972

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

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DATE

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University of New Mexico in partial fulfillment of the require-
ments for the degree of

MASTER OF SCIENCE

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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

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COTTON CONTENT

A summary of the results of the analysis of the cotton content of the various samples of cotton lint and seed cotton, as well as of the cotton content of the various samples of cotton linters and cotton seed, is given in the following table. The results are given in percentages of cotton content, based on the weight of the sample.

ANALYSIS OF COTTON LINT AND SEED COTTON

The following table gives the results of the analysis of the cotton content of the various samples of cotton lint and seed cotton, as well as of the cotton content of the various samples of cotton linters and cotton seed, in percentages of cotton content, based on the weight of the sample.

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. 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 discussed three recommendations were essential to the progress of a comprehensive motor fuel research: (1) a standardized engine and accessories; (2) a common reference fuel and mixing ratio; (3) a uniform testing procedure. All three of these essential requirements were met by 1931. The Research Motor Company had developed a fuel testing engine which had the approval of the Cooperative Fuel Research Committee. The octane and normal heptane, both stable hydrocarbons, were adopted as reference fuels at the suggestion of Dr. Graham Edgar of 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.

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 by Chrysler, Plymouth, and
Corvair of these cars, and later by the Bureau of Motor
Vehicles, it was found that the Corvair had the best
mileage of the standard testing mile and the Chrysler car
had the best mileage of the two cars.

MILLERS FALLS

ERASE

COFFIN CONTENT

and to see whether the coffin is in fact a coffin
and whether it is a coffin. The coffin was found
under the name "Coffin" in the Miller's Fall
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found the coffin of the Miller's Fall.
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The Miller's Fall

The Miller's Fall, and the Miller's Fall, and the Miller's Fall
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(Coffin Miller's Fall) provides a coffin, and the Miller's Fall
method for the Miller's Fall, and the Miller's Fall, and the Miller's Fall.

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 following requirements prescribed by the test plan are not included here as they are readily available in the books, ASTM specifications, and various other Company publications on the test plan Research Unit and the test plan. However, the description of the bearing pin device and knocker and a brief summary of the test procedure prescribed by the test plan are included for comparison with similar tests of the test plan. The bearing pin device consists of a cylindrical steel pin with a knocker attached to one end of the pin. The pin is maintained in a vertical position on the engine by two bearings in a hollow barrel. The bottom end of the pin rests on a hardened steel standard which is locked in the lower end of the barrel with a hollow lock nut. Attached to the head of the barrel, and extending inwards, are two flat spring plates against which immediately above the bearing pin. Attached to the top of the barrel is the bearing pin support which is provided for the adjustment of the bearing pin sensitivity and gap clearance. The bearing pin device is located at the top of the cylinder head in a standard hole opposite the spark plug location. Adjustment of the bearing pin depends upon the location of the standard which is fixed 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 actuates 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

The knockmeter is a device for indicating the effective current which flows in the bounding air circuit when the contacts are closed by the upward movement of the piston pin that results from knock. Current is supplied from a small direct-current generator which is belt-driven from the power-shafting unit. The current flow is regulated from a variable resistor in series with the contacts. A variable resistance heating element, located near a thermocouple, the potential produced by the thermocouple is used to heat the element through the heating element. The element is connected to the generator and produces a continuous indication of knock intensity. The C.R. 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 knock meter reading at standard knock intensity is 75 to 60. It may be necessary to alter the bounding air 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 knock meter reading of 75 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 obtained 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 standard pin-in-disk test in conjunction with the knockmeter.

The CIP method requires that the average 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.

Illustration of Improved CIP Method

The CIP 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 fluctuation. 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.

in ambient temperature can result in completely unreliable
knockmeter readings, and a single reading per hour cannot be
tolerated if reasonably accurate results are to be expected.
The CWR Method for determining octane ratings of gasoline

MILLER TEST
E Z E R A S E

COTTON COTTON

provides reliable results, but the very slight variation in
method leaves much to be desired with respect to simplicity,
accuracy, and expediency.
The purpose of the proposed test method is to present a simple, ac-
curate, and expedient test method, which requires a minimum
of adjustments to equipment, which is relatively insensitive
to variations in ambient temperature and to ignition inter-
ruption, and which provides results well within the accuracy
of the CWR Method. A comparison of actual test results from
both the CWR 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.

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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.

A. Knock intensity for each fuel run under identical test

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2. Knock intensity by blow struck on diaphragm in

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3. Knock intensity from temperature of plug in compression

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c. Spark advance

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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 characteris-

tics. Also assume B is a knock suppressor and I is a

knock inducer. Then the ratings may be made as follows:

a. Amount of B 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."

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, 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 watching the knock intensity of the unknown fuel eliminates 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 gasoline 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.

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The proposed test method, hereafter referred to as "The New Method," utilizes the electro-mechanical equipment developed by Mr. R. W. Boscher.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 pressure to electrical energy and is used in conjunction with an amplifier and an instrument for measuring the magnitude of the mechanical pressure in terms of the electrical energy output of the pressure-sensitive device.

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⁴ Type J 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.

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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.

CHAPTER III

EQUIPMENT

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

Type 4 Cox Ignition Quartz Pressure Element (Detroit, Michigan: General Motors Research Laboratories, Inc., n.d.), 2 pp.

Figure I Electro-Mechanical Equipment

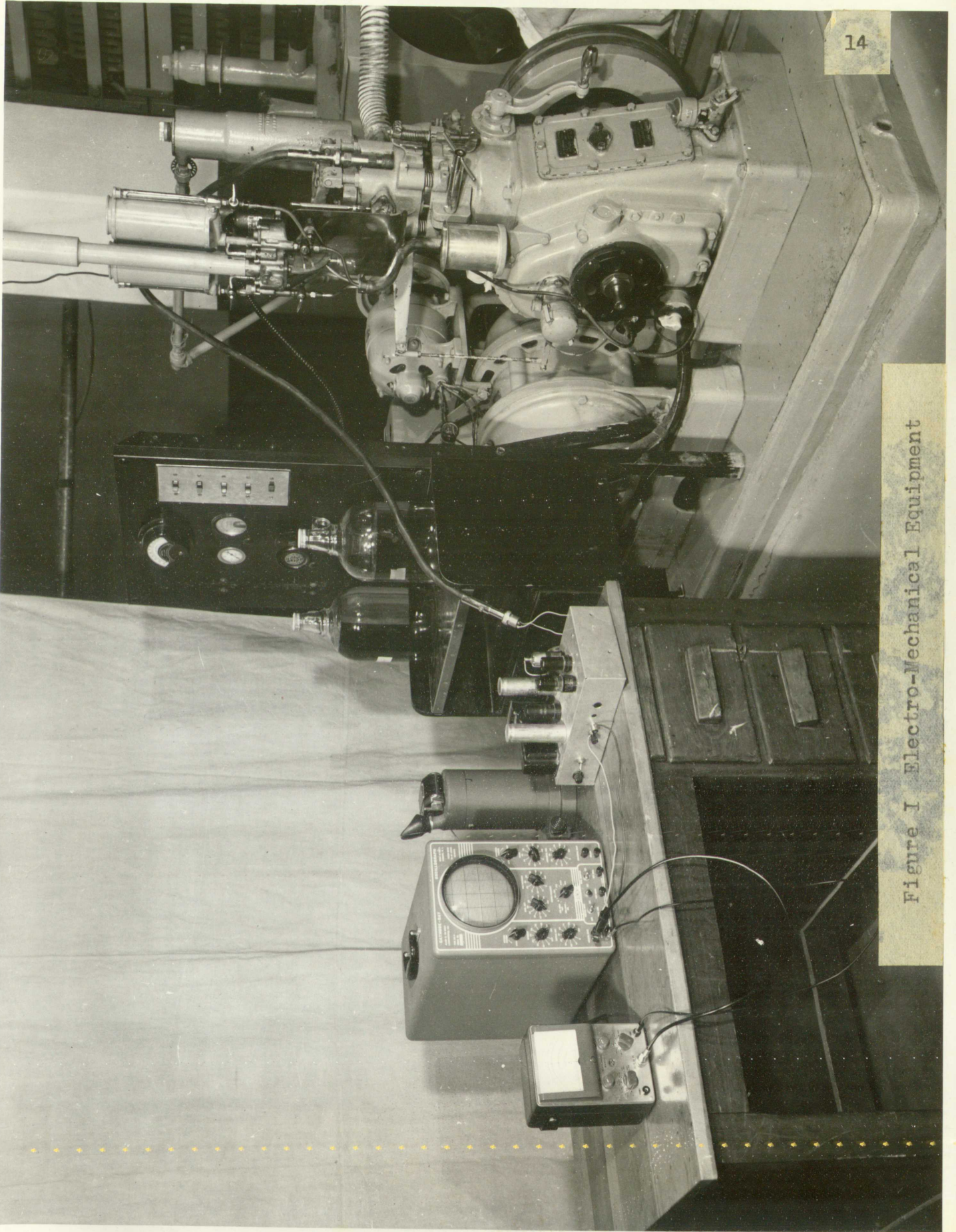
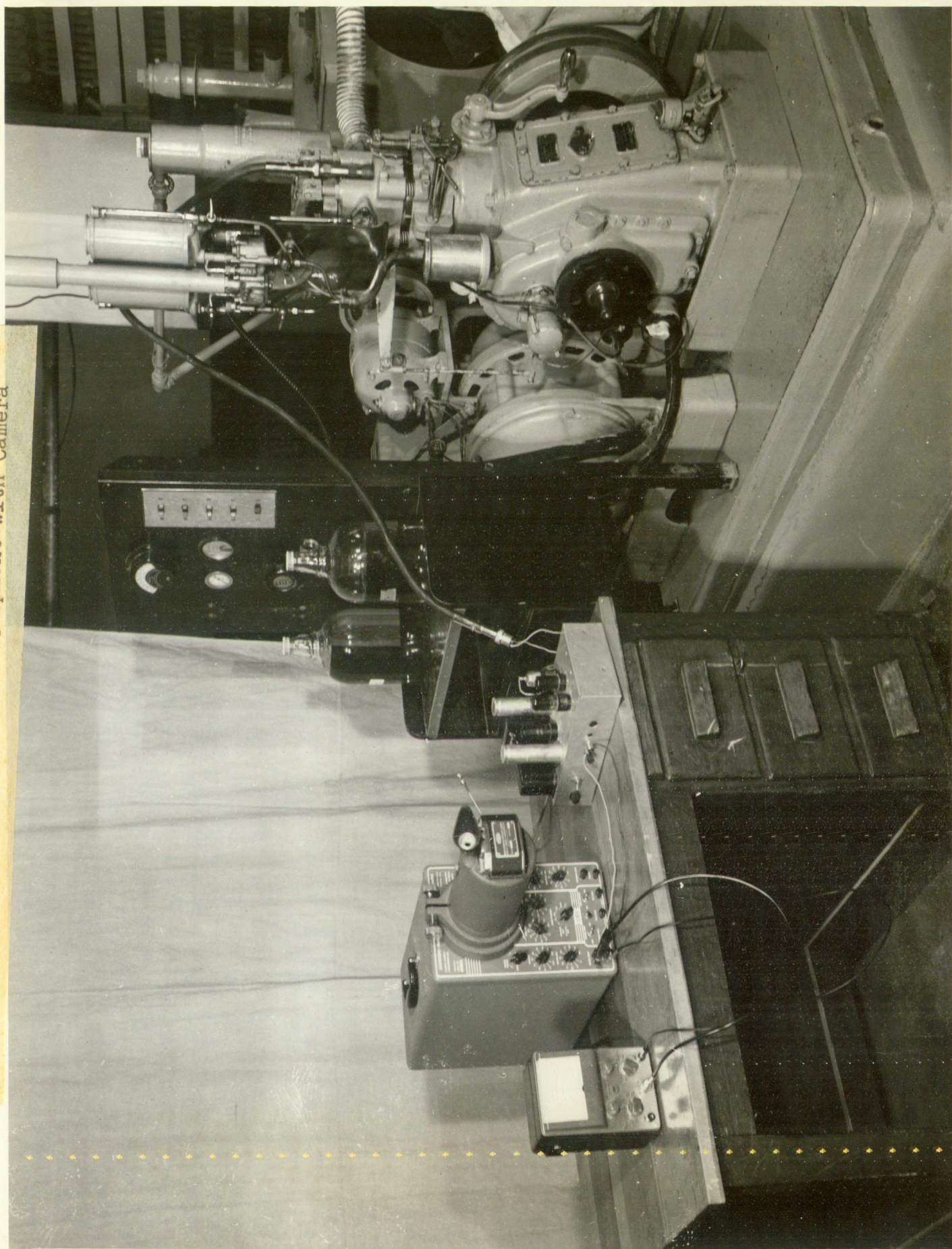


Figure 11 Electro-Mechanical Equipment with Camera



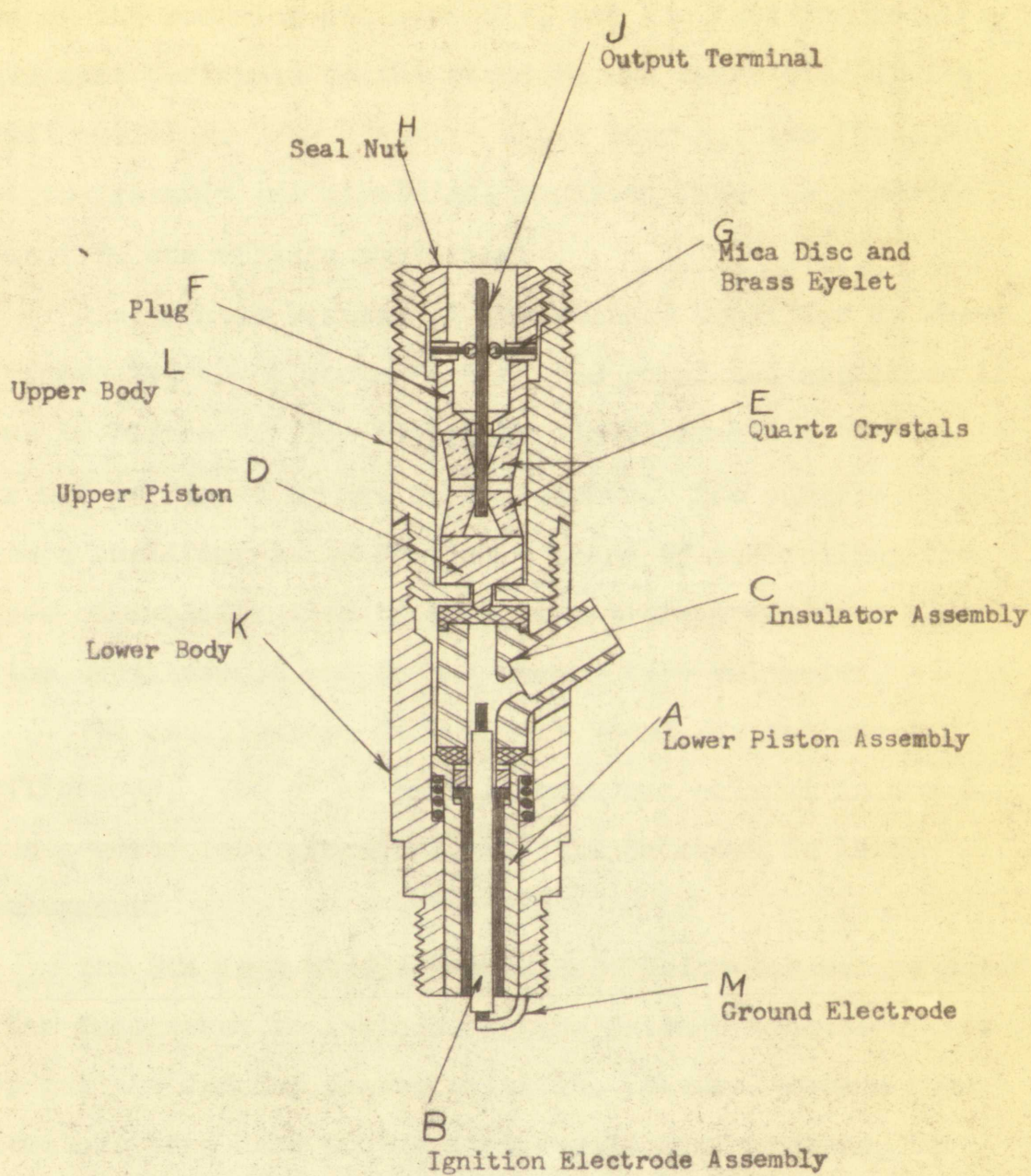
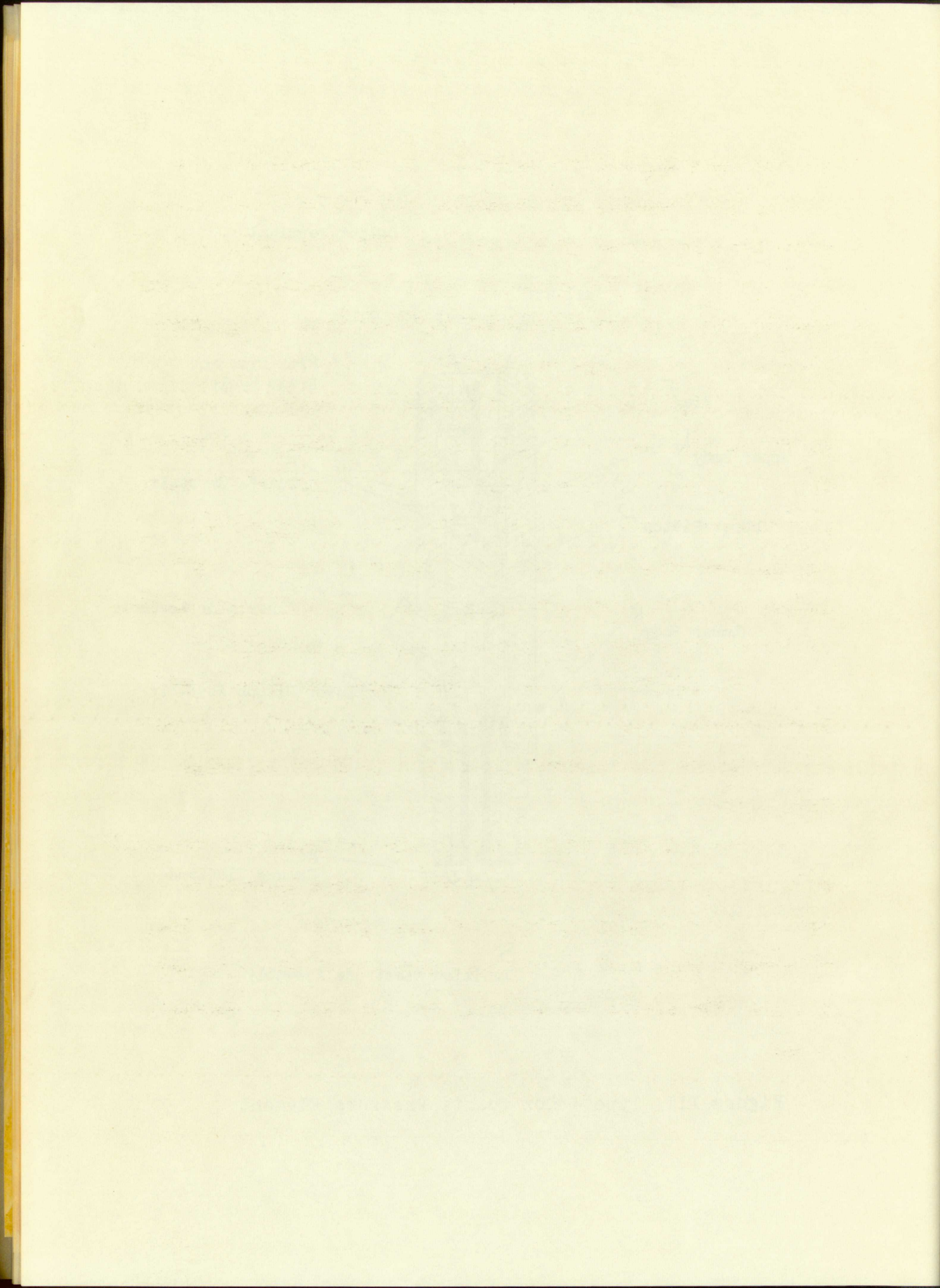


Figure III Type 4 Cox Quartz Pressure Element



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.

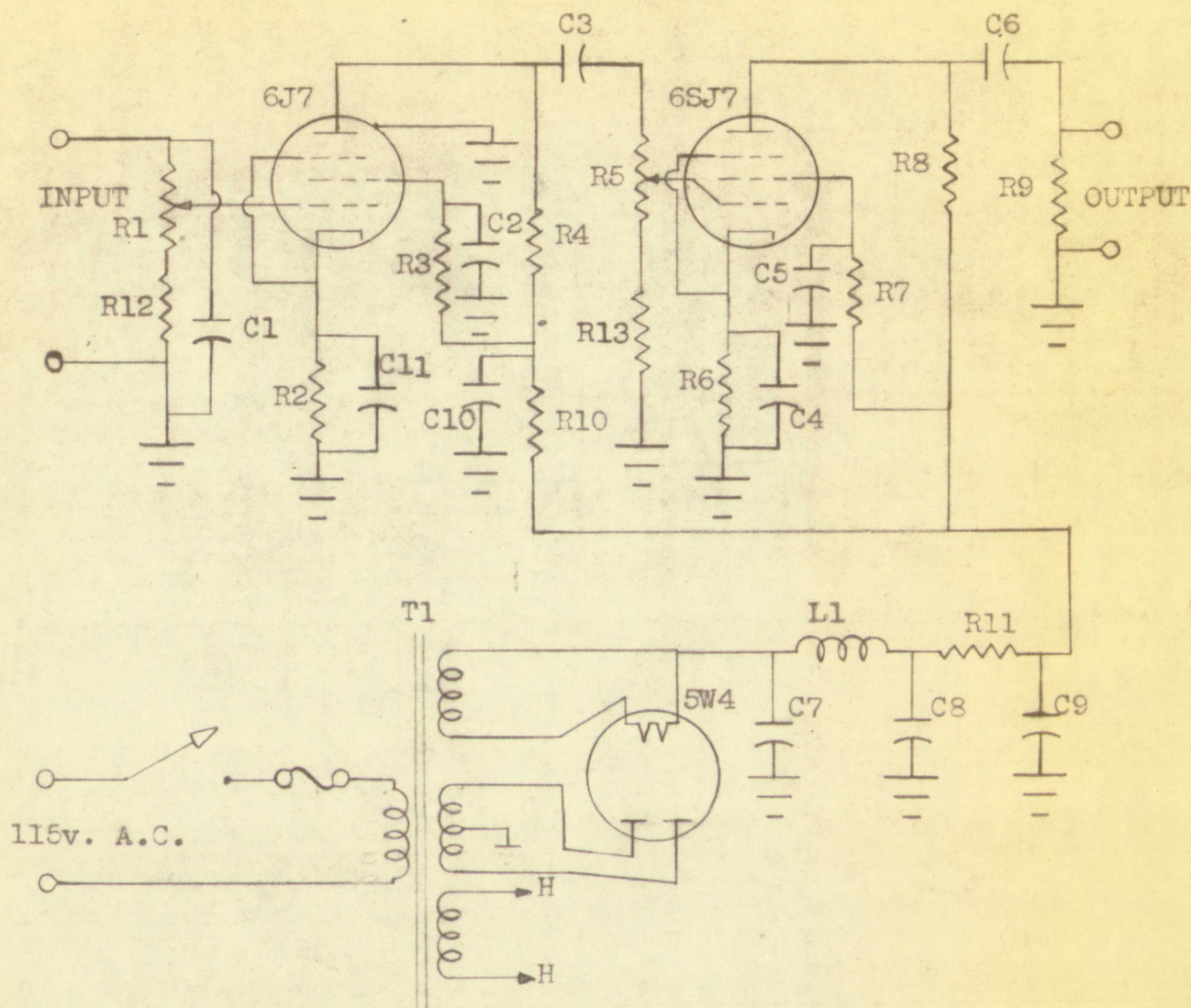
The oscilloscope is a Dumont Model 274 Cathode-Ray Oscilloscope. Use of an oscilloscope was helpful in developing a sound test procedure, as will be shown in later development.

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 bonding pin assembly, and the ignition experiments were performed by the standard EFM 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. Eberhart. 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 WU-97A Vacuum Tube Voltmeter was selected as the instrument to indicate output voltage because of its response and damping characteristics. Several vacuum tube voltmeters were used in the test development process, but the RCA Type WU-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.

C1,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

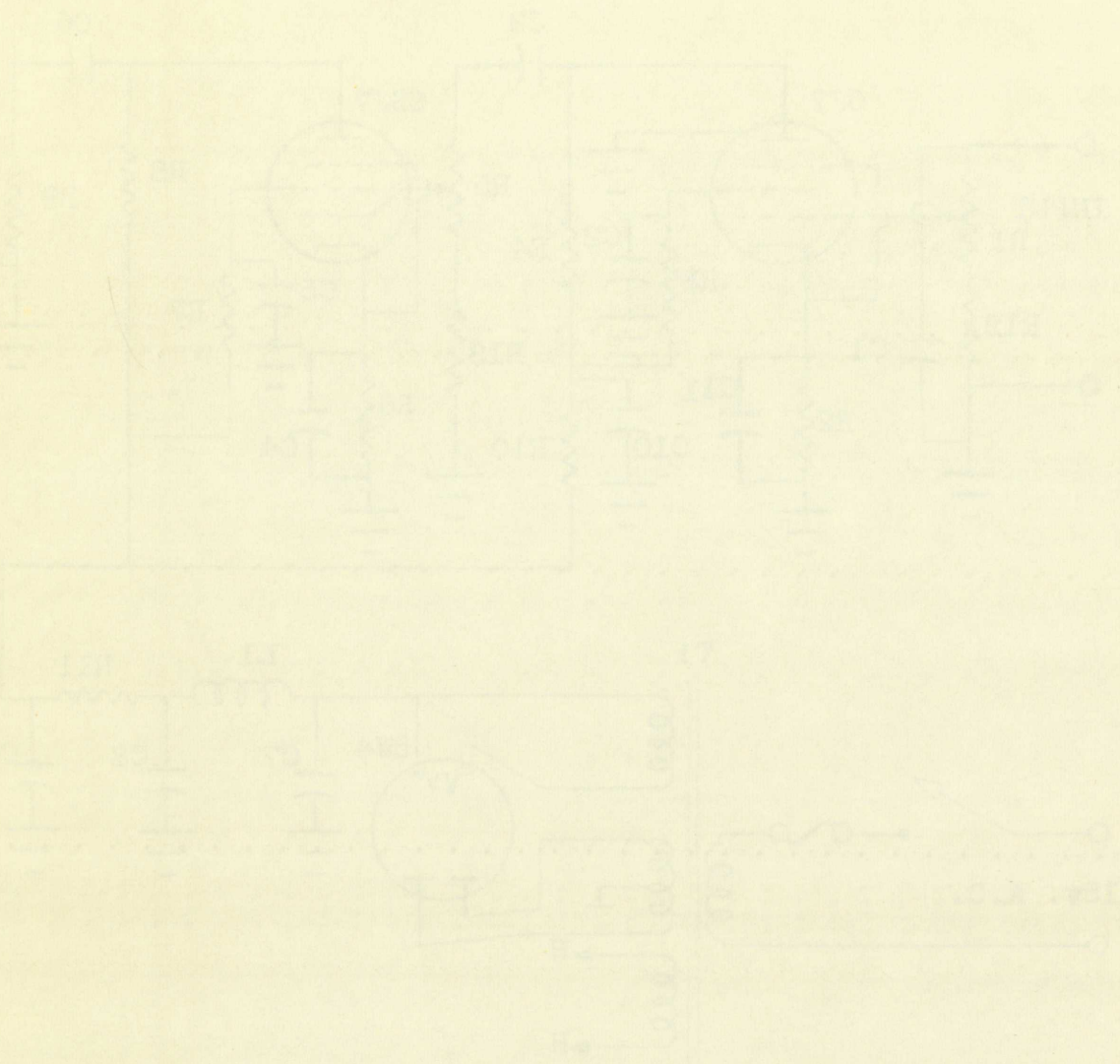
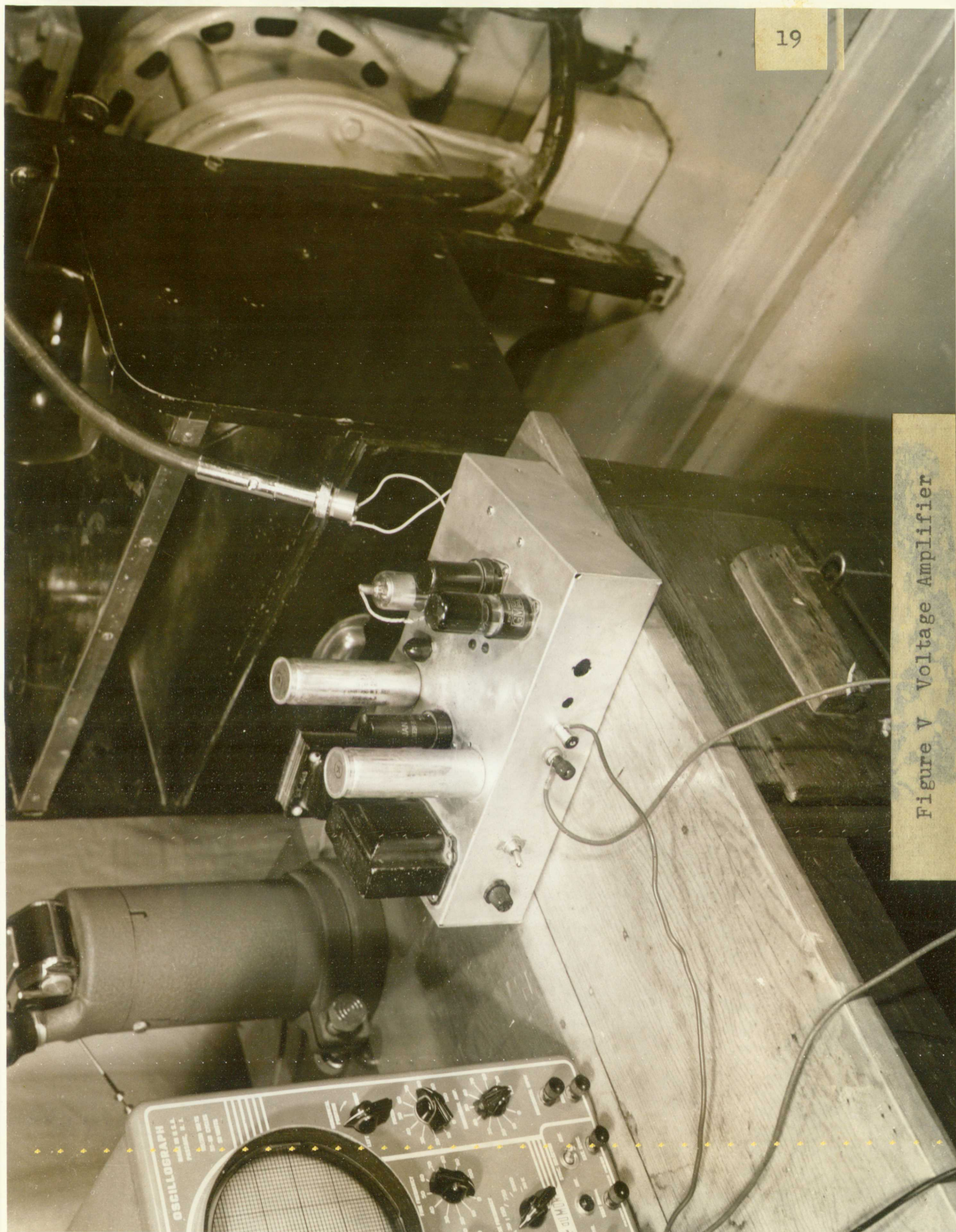


Figure IV. Schematic Diagram of Voltage Amplifier

Figure V Voltage Amplifier



MIL
E 24
CO

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 $\pm 5\%$ 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 Characteristic of Test Equipment

The characteristics and limitations of the various pieces of equipment used in the New Method for determining octane ratings of gasoline are summarized here. The Type 4 Cox Ignition Control Pressure Element has an average voltage response of 1.0 volt 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. The voltage amplifier has a voltage gain of 9000 with good linear response between 0 cycle per second and 10,000 cycles per second. The oscilloscope is a standard commercial Dumont Model 274. The RCA Type W-7A vacuum tube voltmeter has a full scale sensitivity of 1.5 with a frequency response of 30 cycles per second to 3 megacycles on the full 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. Fischer.

Type 4 Cox Ignition Control Pressure Element, loc. cit.

Fischer, 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

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The oscilloscope provided an excellent observation of the pressure wave forms of gasolines; but the fuel 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

effective or root-mean-square (RMS) of the voltage output of the quartz pressure element and the various gas lines and reference leads being tested. A vacuum tube voltmeter having suitable response and damping characteristics was needed to provide an accurate reading of the voltage output. The instrument was constructed using all the vacuum tube voltmeters immediately available. The RCA Type 6X4 tube was the best available and was installed as the output stage of the instrument. Numerous tests were performed to determine the correlation between the pressure wave form and the voltage output indicated on the vacuum tube voltmeter. Several alternative tests, using reference leads varying from 1/16 inch to 1/2 inch, were performed to provide data to establish the validity of the octane rating indicated on the vacuum tube voltmeter. The range of comparison tests was established for the various reference leads to provide indication of adequate amplification on the same scale as the indicating instrument. The comparison of octane ratings at each of the range to a single scale on the indicating instrument was considered a major accomplishment. In conducting the series of octane ratings to a single scale, the resulting instruments to the test equipment, after initial adjustments, were reduced to only one - varying the comparison ratio. More than thirty ratings 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. \pm 9 r.p.m.; (2) Oil pressure--25 to 30 pounds per square inch under operating conditions; (3) Valve clearances--intake 0.003 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. \pm 2°F. as indicated on the mercury stem thermometer.

fifteen gallons of refrigerant fluid were contained in the
 mental testing before the new method was considered practical.
 One of the prime considerations about the new method was
 the reproducibility of results. The reproducibility as-
 spect of the new method was tested by performing a series
 of tests under identical conditions. The first series was
 from 24 to 30 pounds. Since the results were not reproducible
 this development was not continued. The second series was
 initial engine and evaporator at 100 degrees for the complete
 series of reproducibility tests. The reproducibility of re-
 sults obtained under these conditions was exceptionally good,
 as witnessed on numerous occasions by the following:
 A set of standard operating conditions similar to
 those of the CBR Method was applied for the first test and
 is as follows: (1) Engine speed--1000 r.p.m. (2) Oil pressure--25 to 30 pounds (3) Valve clearance--.005 inch cold
 conditions; (4) Valve clearance--.005 inch cold; (5) Throttle opening--75 degrees (6) Evaporator pressure--10.0 degrees at 7.5 r.p.m. (7) Compressor adjustment--standard space for initial setting with
 85 octane reference fuel, constant (8) Mixture temperature--maintained at 80°F. (9) Initial setting 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 Testing 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 equipment, is presented here. This is the collation used in the 1934 edition which are discussed in Chapter 7, "Reference Gasolines".

During the entire test there is no gas in contact with the voltage amplifier is maintained at the lower limit, and the vacuum tube is set at 100% 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 evaporator bowl, confirm the operation by a standard bowl and specimen tank. This procedure reduces the possibility of fuel mixture caused by leaked vapors. When changing fuels, drain the specimen tank and evaporator bowl by opening the proper drain cocks and allow a small portion of the new fuel to flow through the lines before draining the drain cocks. This purging operation helps prevent fuel mixture. Do not rush the fuel changing process. It is better to let the engine motor a few seconds at low fuel than to rush the process and risk the fuel. 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.

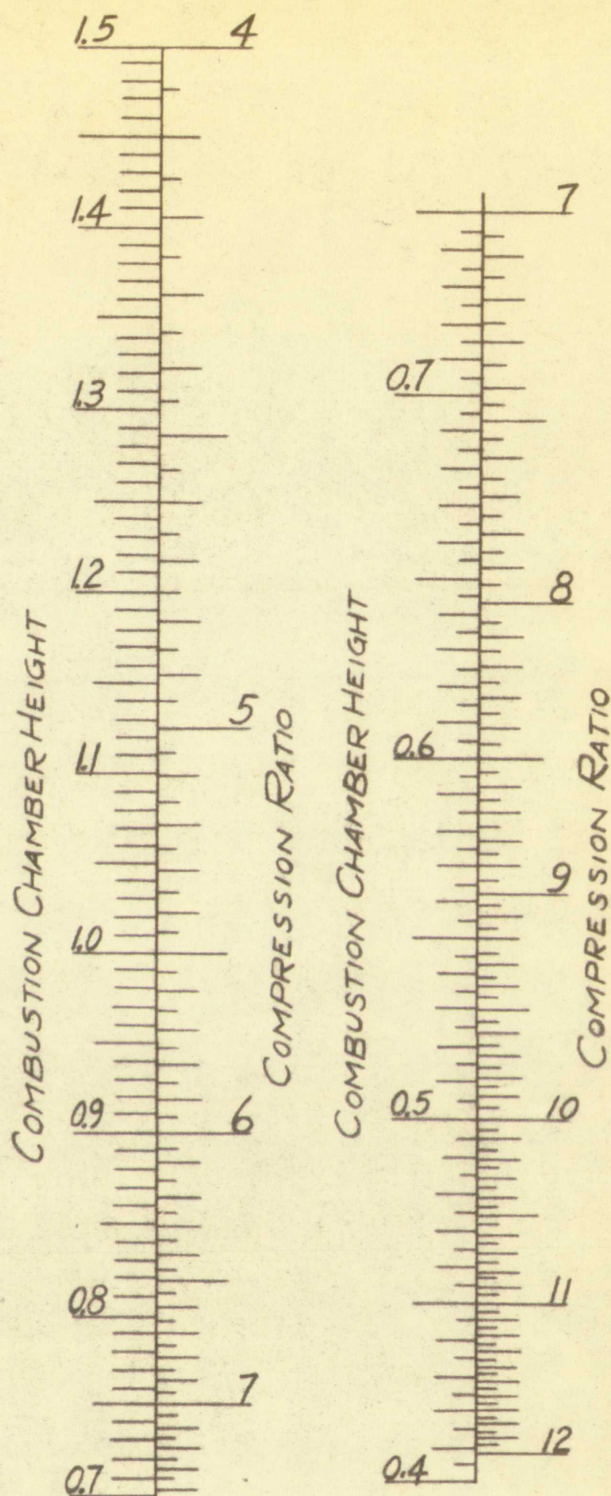
When the test equipment is connected as shown in Figure I and the engine is operating at standard operating conditions, perform the calibration procedure. The octane-rating scale is calibrated for octane ratings ranging from 65 octane to 90 octane, for this calibration encompasses the existing commercial 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 also result in the presence of fuel vaporization. When changing from one fuel to another, allow a time interval of 100 sec. to 120 minutes for the engine and test equipment to reach equilibrium before readings are taken.

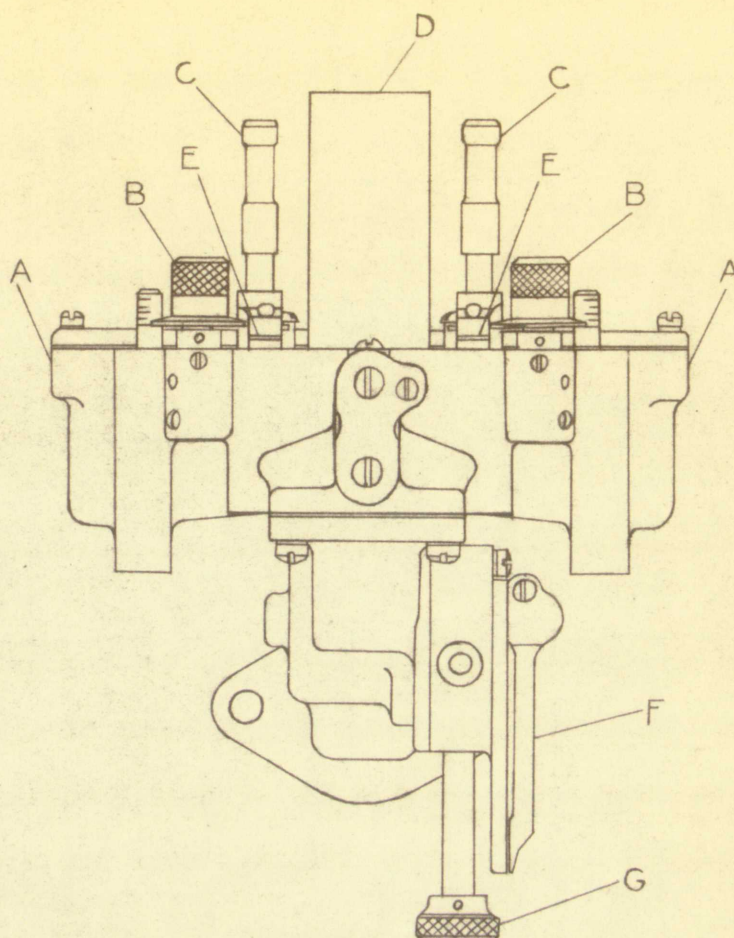
When the test equipment is connected as shown in Figure 1 and the engine is operating at constant operating conditions, perform the calibration procedure. The constant rating scale is calibrated for octane values ranging from 85 octane to 90 octane. For this calibration, approximate the existing commercial grades of gasoline.

When the engine is operating at a reference level of 85 octane, set the compression ratio to 10:1 by lowering the cylinder head until a reading of zero is reached on the indicator fitted to the cylinder. When the readings are converted to octane values by using the conversion scale shown in Figure VI. Set the air-fuel adjustment, 8, Figure VII, to the normal mode. This setting of the air-fuel 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. 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,



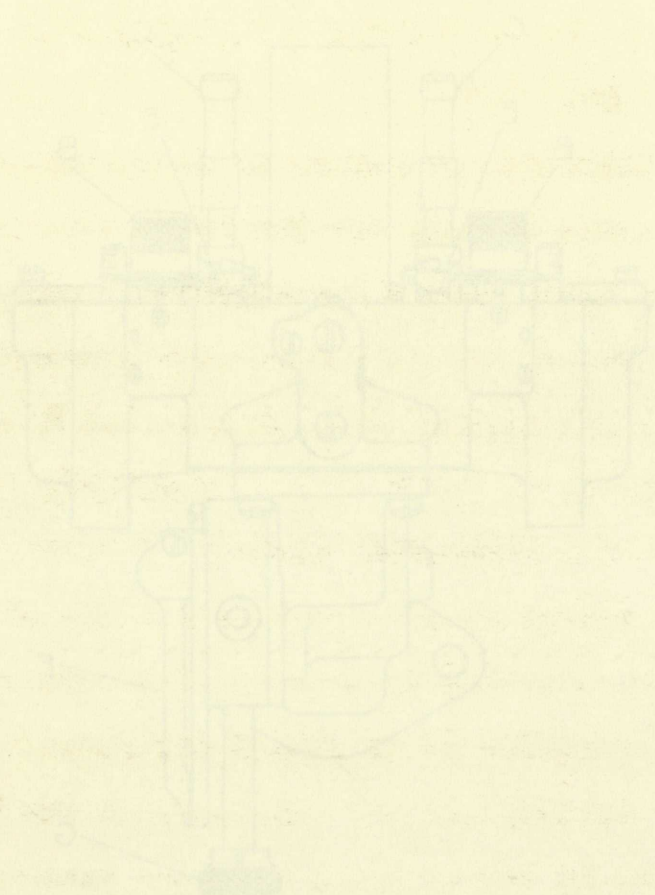
COMBUSTION CHAMBER HEIGHT = MICROMETER READING + 0.500"

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



- 1. Piston
- 2. Air Valve
- 3. Piston
- 4. Piston
- 5. Piston
- 6. Piston
- 7. Piston
- 8. Piston
- 9. Piston
- 10. Piston

Figure VII. Two-Port Component

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

The calibration procedure is constant, in accordance with the preceding method, for the following series of octane fuels and their respective micro-reading values:

octane, 82.5 octane, and 85 octane at a micro-reading value of 0.059 inch; 75 octane, 77.5 octane, and 80 octane at a micro-reading value of 0.170 inch; 70 octane, 72.5 octane, and 75 octane at a micro-reading value of 0.279 inch.

Complete calibration data for the reference fuels in the range of 65 octane to 90 octane is shown in Table VII.

The preceding calibration was performed as the final calibration for use in rating the commercial gasoline as discussed in Chapter V, Results of Tests.

Comparison with the New Method

To emphasize the simplicity and expediency of the new Method, a comparison of the requirements of the C.F. method and the New Method is presented.

Data provided by the C.F. method are largely dependent from a reliability standpoint, on a constant ambient temperature as well as the uniformity of the mixture composition at 300 \pm 2 $^{\circ}$ 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 $300^{\circ}\text{F.} \pm 2^{\circ}\text{F.}$

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 the relative humidity of a mixture is relatively insensitive to variations in mixture temperature; the only close temperature requirement being the maintenance of the mixture temperature at 300-325°F.

The GWR Method cannot operate at temperatures that fluctuate once an hour, while the two Method systems only a

time interval of five or ten minutes is required.

Each equilibrium after an initial period of five or ten minutes

activity of the GWR Method to maintain a constant level of

strict requirements upon the GWR Method.

The GWR Method requires that the test sample be

bracketed at least three times between two periods of testing.

Since these which differ by no more than two hours between

The constant rating of the test sample is obtained by inference

from the averages of the bracketed readings of the

test sample and the two reference levels. A test sample is

tested by the New Method by selective predetermined comparison

at intervals until the test sample reaches a reference level

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 selective comparison with

corresponding to the previous rating and checking for response

effectivity of results. The GWR 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.

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

MILLERS FALLS
EZE RASE
COTTON CONTENT

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

RESULTS

Pressure Wave Form

Figure 1 shows the pressure wave form as recorded by the piezoelectric method, using the final calibration described in Chapter IV and illustrated in Figure VIII. A typical example of the wave form of the reference valve and a typical example of the wave form for the final calibration are shown in Figure IX. The individual wave forms recorded are shown graphically in Figure X. The final calibration shown above and the original wave form for the reference valve are also shown. The wave forms were obtained by averaging 100 wave forms. This included several cycles of the reference valve and a final check on the initial wave form. The initial wave form was checked for reproducibility as well as for the reproducibility of the reference valve setting. This time element was checked with the time required for the reference valve to be closed which is presented later in this chapter. For reference purposes, the final calibration and the wave form for the reference valve are tabulated in Appendix A.

In order to present data in the various forms of the pressure wave form of the reference valve and the wave form of the

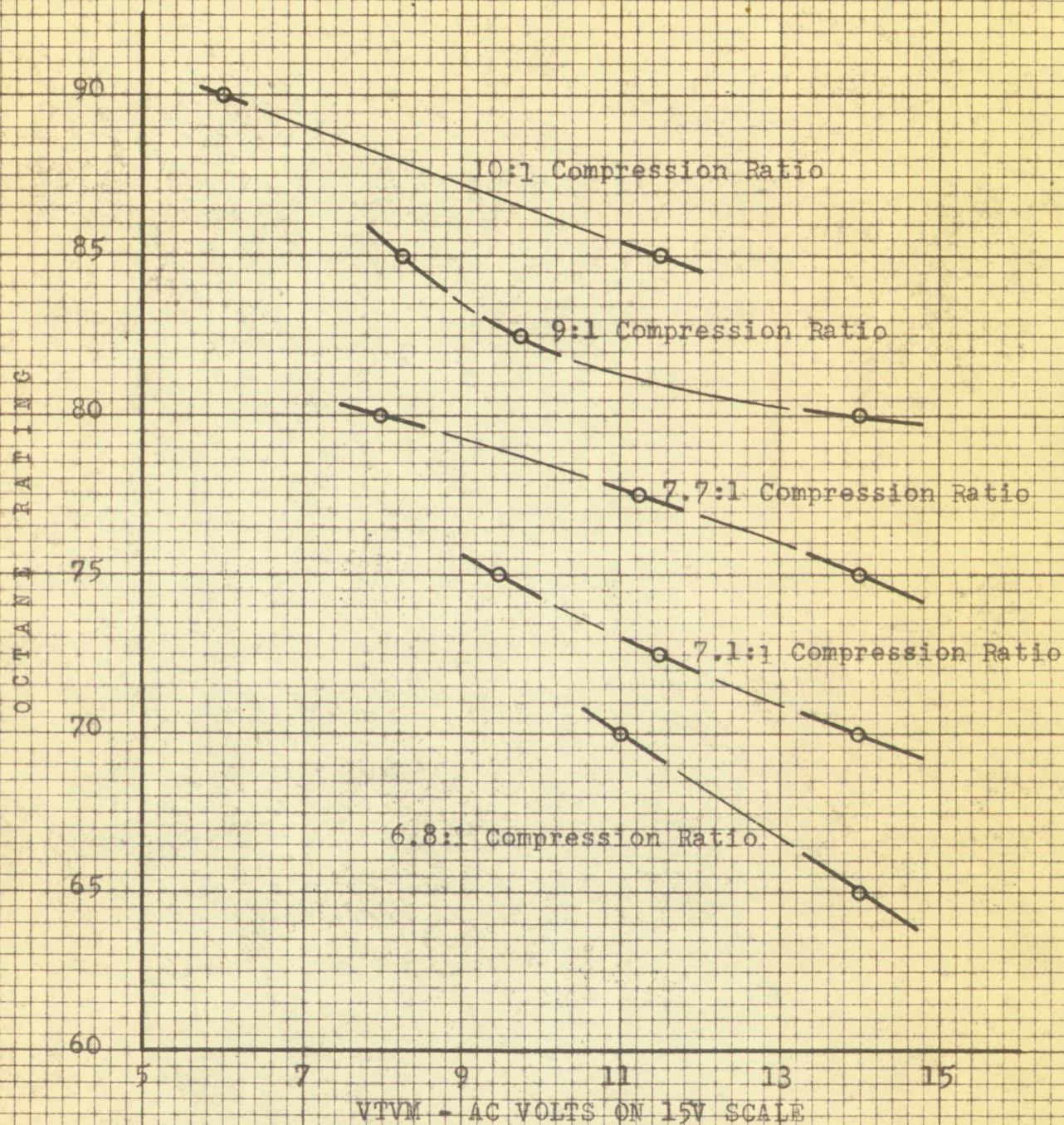


Figure VIII Calibration Curves - 65 to 90 Octane

Figure IX Reference Fuels and Commercial Gasolines



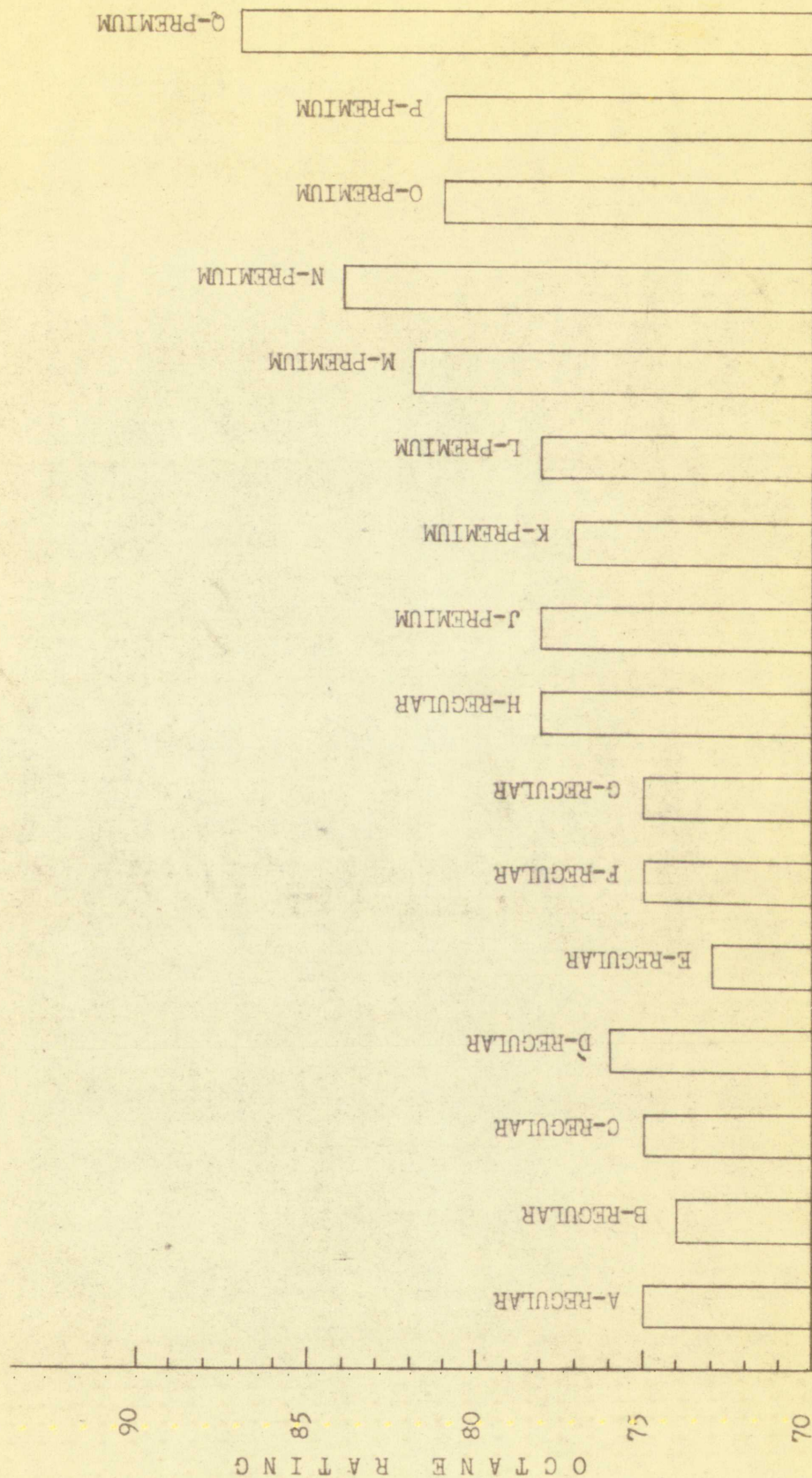
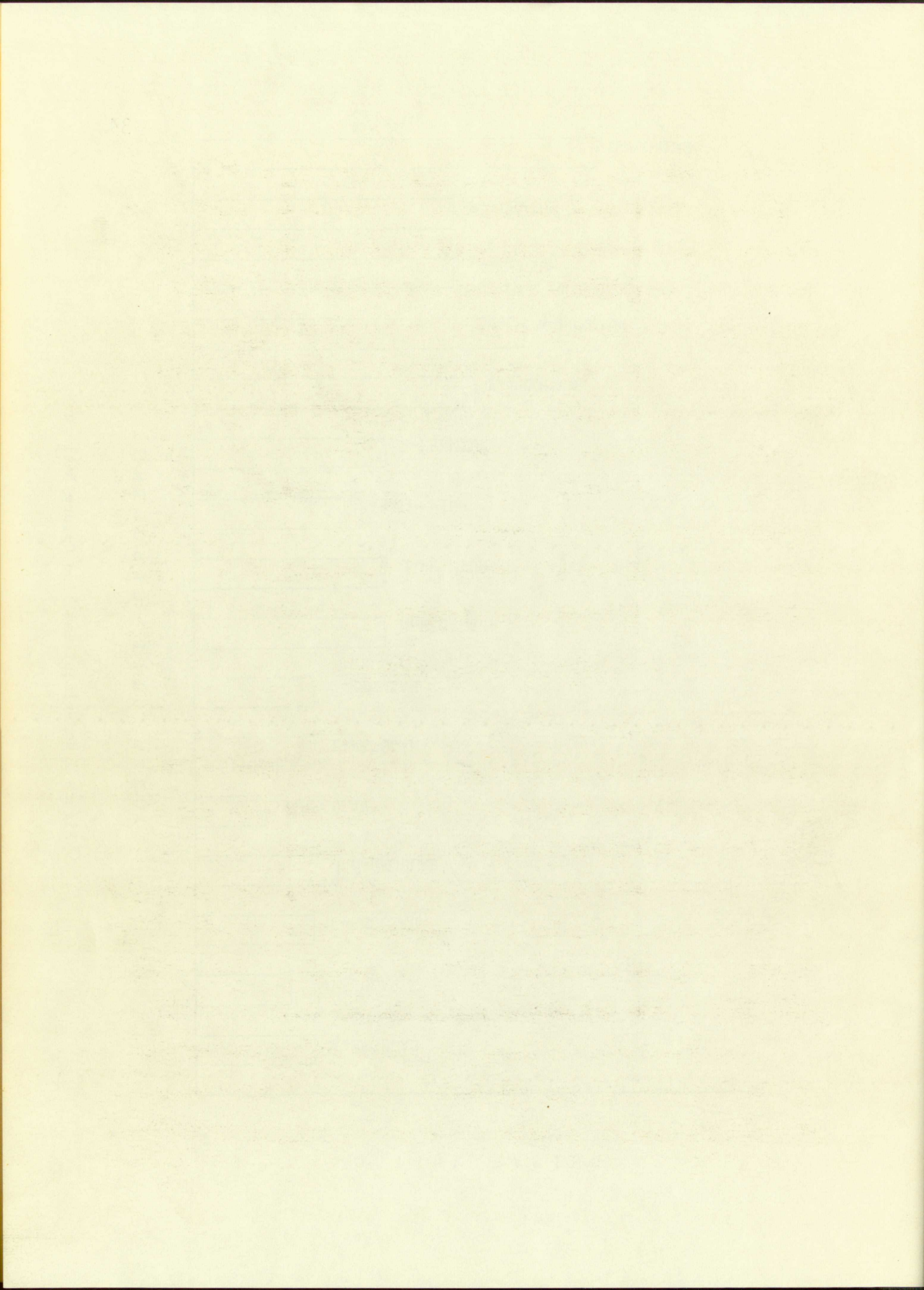


Figure X Commercial Gasoline Octane Ratings



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

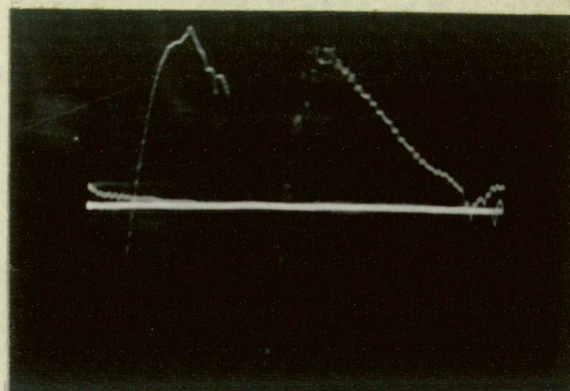
For comparative purposes, the octane ratings of two commercial gasolines, previously rated by the New Method, were determined by the CFR Method. These gasolines carry the code designations K-Premium and J-Premium. Three gasolines were actually tested in this procedure, but the supply of one of them, 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.

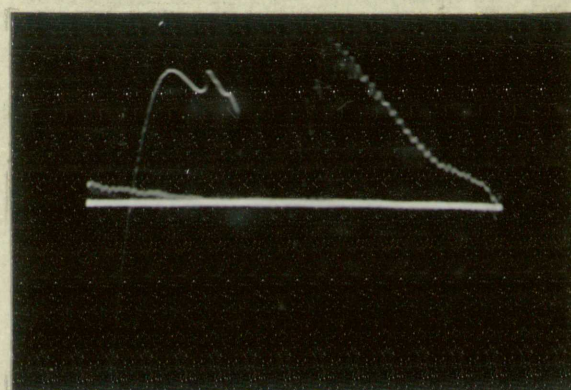
different compression ratios, the pressure wave forms of five known fuels were investigated at different compression ratios. These photographs, with respective, etc. in common, and compression ratios, are presented in Figures XII, XIII, XIV, and XV. A definite relation exists between the frequency wave-form of the pressure wave form and the variations in intensity of the oscillations. The pressure wave forms. The intensity of the oscillations. The frequency wave forms have been shown to vary with the frequency wave-form of the wave form. This relationship is clearly shown by the photographs of the oscillations for the respective fuels and compression ratios.

RELATION OF THE METHOD

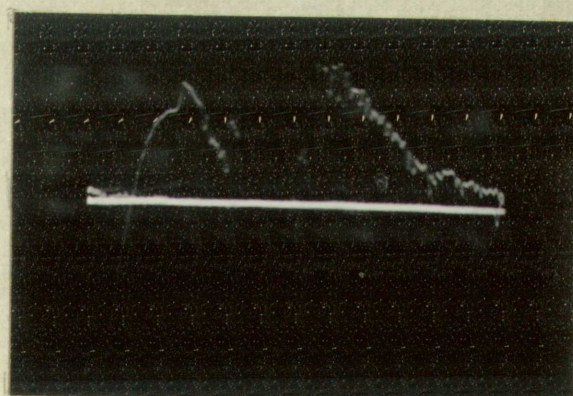
For comparative purposes, the same method of common gasolines, previously tested by the test method, were determined by the test method. These gasolines, the code designations 1-10 and 1-11, were tested. These were actually tested under identical conditions, but the only one of them, M-10, was tested before and after the results could be obtained. Data and results on the test procedure by the test method are presented in Appendix I. Considerable difficulty was encountered when using the test procedure by the test method because of varying ambient temperature and blowing dust in the compressed circuit.



7:1 Compression Ratio

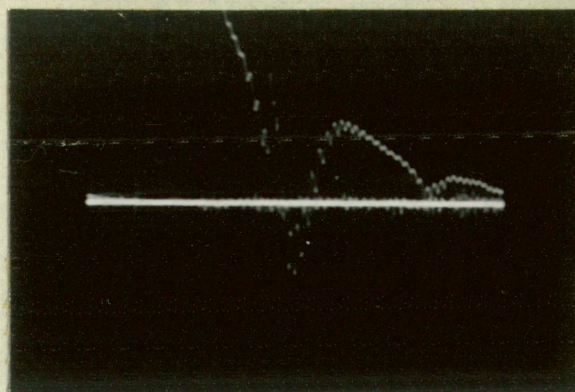


8:1 Compression Ratio

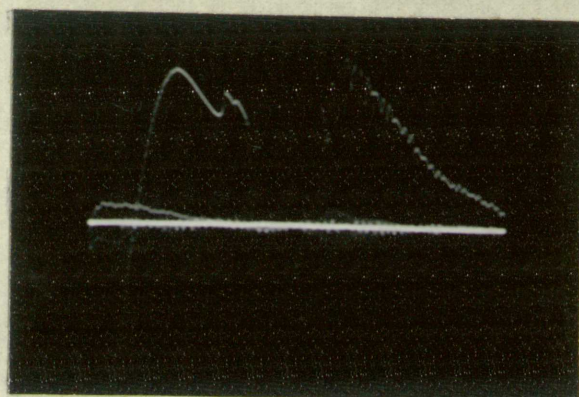


9:1 Compression Ratio

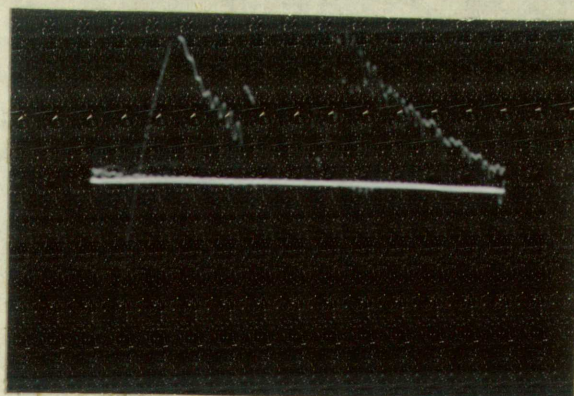
Figure XI O-Premium Gasoline-Pressure Wave Forms



7:1 Compression Ratio



8:1 Compression Ratio



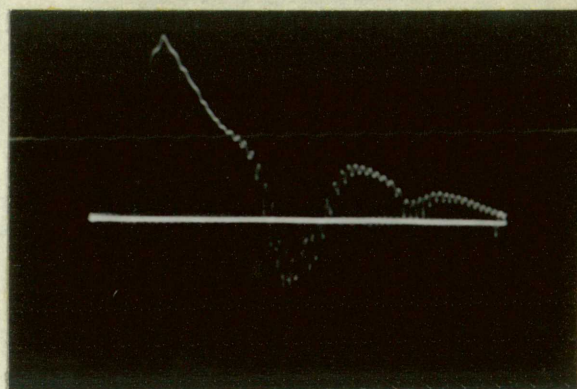
9:1 Compression Ratio

Figure XII K-Premium Gasoline-Pressure Wave Forms

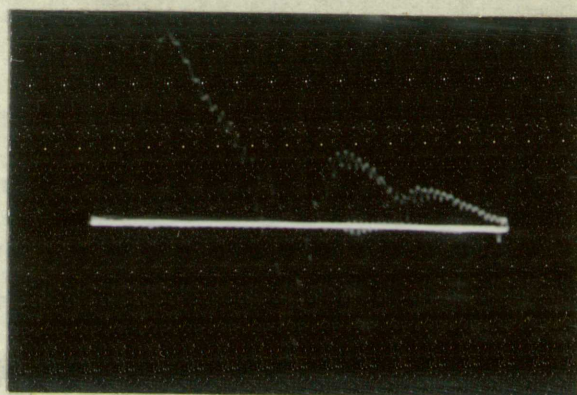
IX 18-19

XII 19-20

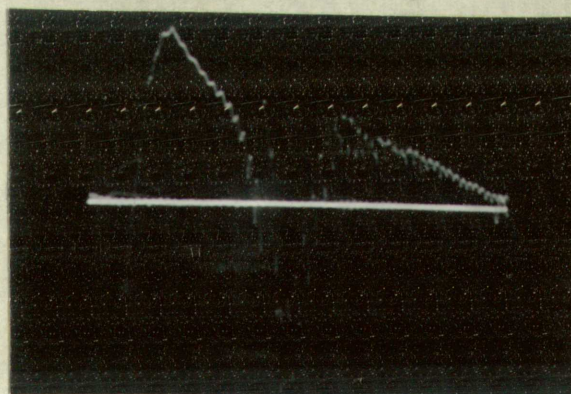
XI 21-22



7:1 Compression Ratio

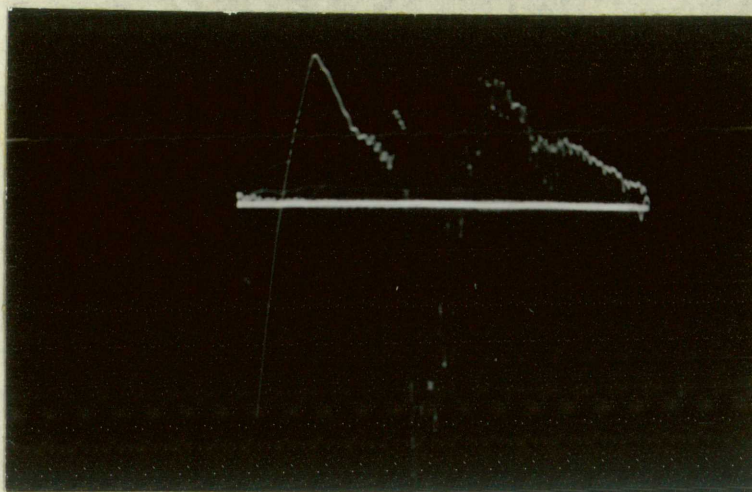


8:1 Compression Ratio

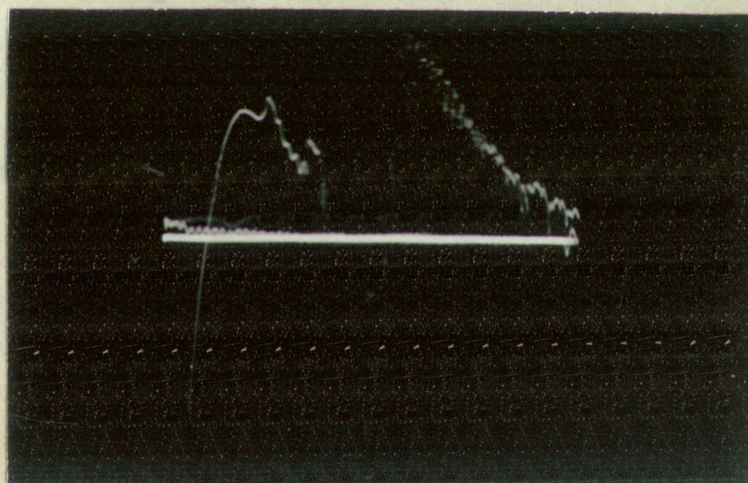


9:1 Compression Ratio

Figure XIII 85 Octane-Pressure Wave Forms

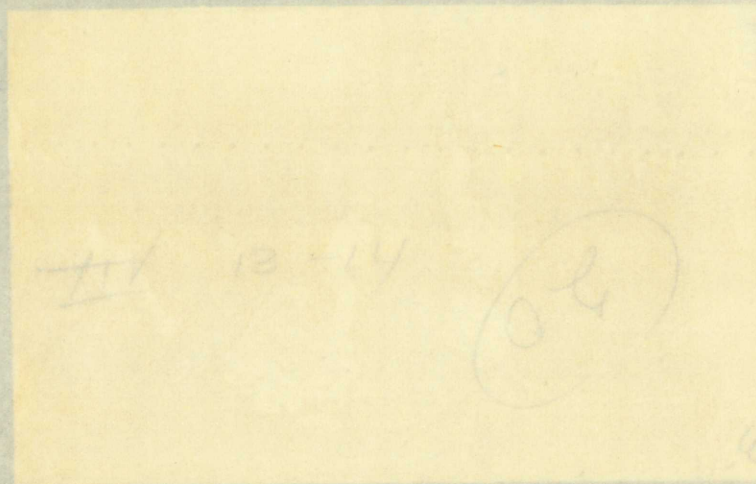
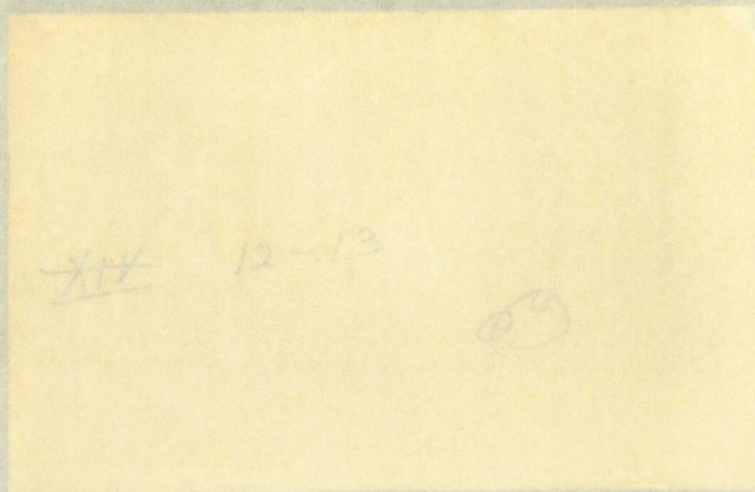


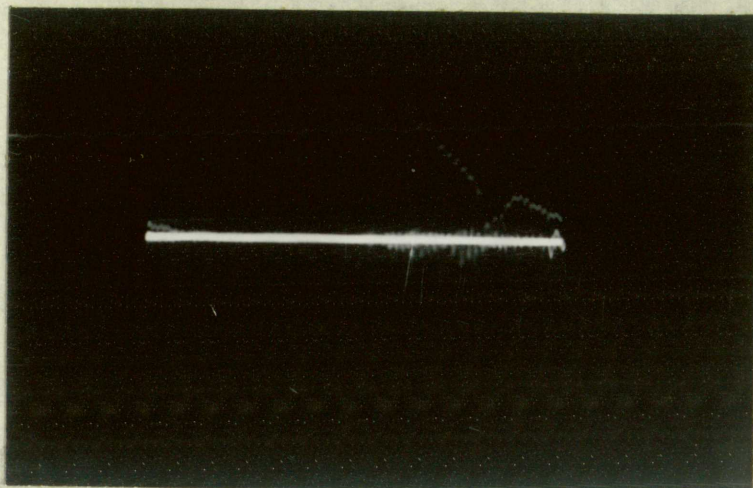
8:1 Compression Ratio



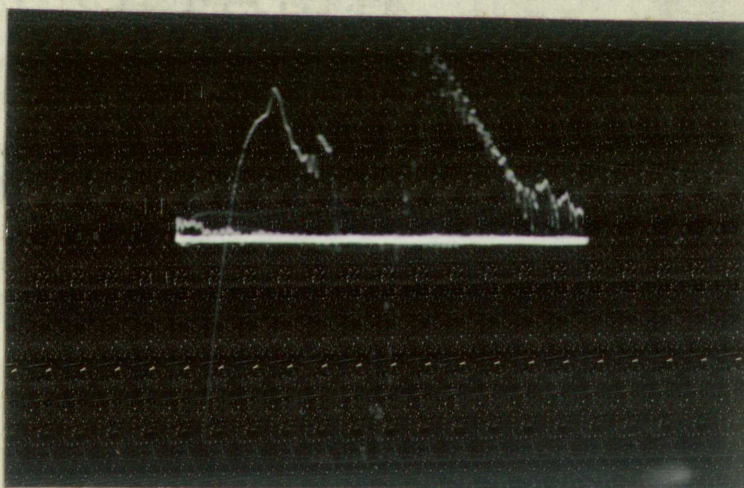
8.5:1 Compression Ratio

Figure XIV H-Regular Gasoline-Pressure Wave Forms





6:1 Compression Ratio



6.5:1 Compression Ratio

Figure XV 65 Octane-Pressure Wave Forms

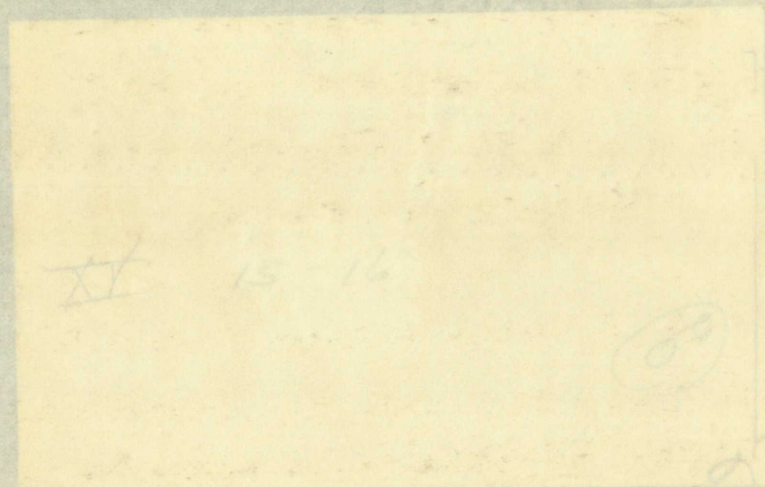
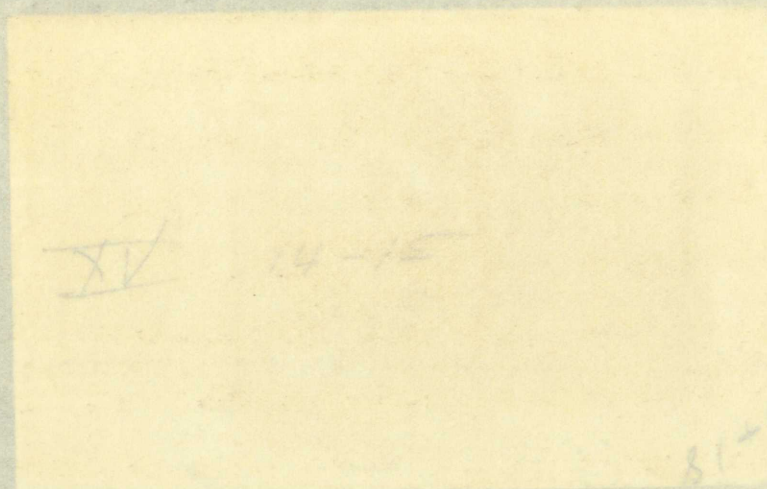


Figure XV. 65 Octane-Pressure Wave Forms

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 accurate, and was used in waiting for the instrument to reach equilibrium. The standard procedure specified a time interval of 10 minutes for the engine and knockmeter to reach equilibrium, but extending this interval to 15 minutes was necessary for most readings. The engine was run during, during which only two readings were taken. The first, recorded approximately 10 minutes after starting, and the second, recorded approximately 15 minutes after starting.

Accuracy of the Method

Representative of results of the New Method is conditionally good. A comparison of the results obtained in one month of preliminary testing with those of the Old Method and testing of one month of preliminary testing results.

The accuracy of the New Method cannot be accurately determined without a long series of comparative tests. The Old Method and the New Method on a comparative basis. Some of the comparative test results are shown in Table I. The Old Method and the New Method, the results of the New Method could be considerably improved. This could be accomplished easily by comparing the results of the Old Method and the New Method.

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.

The results for the two methods, 1-2-3-4-5
and 1-2-3-4-5, were 78 and 78 respectively as determined by
the New Method and 77 and 77 respectively as determined by
the Old Method. While this comparison does not establish
the accuracy of the New Method, it does, to one familiar
with the Old Method, indicate the accuracy.

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CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Recommended Test Procedure

To clearly define the test procedure for the Nev 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. \pm 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. \pm 2°F.

CONCLUSION AND RECOMMENDATIONS

Recommended Test Procedure

To clearly define the test procedure for the test method, a recommended test procedure, which includes engine operating conditions, adjustment instructions, and instructions on fuel charging and adjustment on constant speed, is presented.

A. Standard Test Conditions

1. Engine Speed - 1500 r.p.m.
2. Oil Pressure - 10 to 15 p.s.i. (gauge)
3. Valve Clearance - Intake 0.005 inch, Exhaust 0.010 inch
4. Spark Advance - Automatically controlled, 15.0 degrees at 750 r.p.m. (crankshaft position)
5. Throttle Opening - 75 percent on the throttle
6. Carburetor Adjustment - Adjusted for best fuel economy at 1500 r.p.m. and 75 percent throttle opening
7. Mixture Temperature - 70 to 80 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.

B. Equipment Adjustment

1. Voltage Amplifier -- The gain control on the voltage amplifier shall be maintained at a low setting so vacuum tube voltmeter operation shall be verified for oscilloscope operation.

2. Vacuum Tube Voltmeter -- The vacuum tube voltmeter shall be set for 40 volts on the 150 scale for the entire test procedure.

C. Specifications on Fuel Character

1. Carburetor Condition -- If any doubt exists as to the proper functioning of the carburetor and associated tanks, continue the operation to a safe condition before and after each test. This procedure reduces the possibility of fuel mixture caused by jamming.

2. Fuel Changing -- When changing fuels, drain the fuel 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 air current. Do not turn the fuel change process. It is better to let the engine idle a few seconds before fuel than to rush the process and mix the fuels. However, the engine should not be allowed to idle more than a few seconds because the mixture becomes too rich and will rise rapidly in the absence of fuel supply.

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

3. Reestablishment Period -- When changing from one level 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 1, 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 the 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 conversion scale 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 equilibrium 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

adjustment correctly; then set the air-flow to the
B, Figure VII, for maximum knock. Maximum knock is
determined by turning the air-flow adjustment to the
right as far as it will go, then slowly backing it
observing the voltmeter reading. As the air-flow
adjustment is opened, the knock will increase and
will begin to become irregular, as will be shown by the
voltmeter reading. After the knock passes a certain
value, reverse the air-flow adjustment and the
the voltmeter reading will again increase, as will
be shown on the voltmeter. As soon as the knock is
operation several times until a maximum voltmeter
reading is obtained; this is maximum knock. The
air-flow adjustment for maximum knock will be
correct for the entire test procedure.

4. Calibration of the voltmeter for maximum knock
is the same as for the test in the 100 octane
compression ratio and change the fuel to 90 octane as
soon as the following and then change the procedure as
described in 1, 2, and 3. The voltmeter reading is
90 octane calibration. The calibration procedure is
continued for the following groups of reference fuels,
and their respective compression ratios are expressed
as voltmeter readings: 80 octane, 12.5:1 compression,
85 octane at a voltmeter reading of 0.025, 12.5:1

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 gasoline 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 distance of 0.170 inch; 70 octane, 77.5 octane, and 80 octane at a distance of 0.237 inch; 70 octane and 75 octane at a distance of 0.237 inch. The recommended calibration from 0 octane to 80 octane will encompass the existing compression grades of gasoline.

5. Gasoline Rating - Unknown Gasoline will be tested by creating the engine on each of the known gasoline and varying the compression ratio in accordance with the prescribed calibration setting expressed as meter readings. The compression ratio will be varied until a prescribed setting is reached which will give a voltmeter reading that matches a calibration setting between two calibrations at the same compression ratio. The octane rating of the unknown gasoline is then determined by interpolation. It should be noted concerning an octane rating, the gasoline is measured may be checked at any time during the test procedure.

6. Checks - After the unknown gasoline has been tested, check the calibration by changing the fuel to 80 octane reference fuel, setting the compression ratio at 12.1 and checking the voltmeter reading against the initial calibration. Continue this check method for 80 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

General Description of the Apparatus

The first part of the apparatus is the pressure-measuring

reliable and efficient method for the determination of
certain values of pressure. The apparatus is designed for
the measurement of pressure in a closed system. The
has shown the new method to be accurate and reliable.
The method is the first of its kind.

The electro-mechanical apparatus is designed for
operation at the pressure range in which the
modifications would improve the overall
The present design is based on the
tion electrode system, which is based on
plus and pressure signal, but the use of a
tion in the cylinder head for both the
response purposes confined the use of the
up. It is suggested that the pressure element
be replaced with one that is suitable for the
tion. The present design is based on the
sure element is for removal from the cylinder head
and the simplified design arrangement necessary for
cylinder pressure variations to the pressure
foot to corrosion and subsequent waste of
pressure element similar to the Type 3 Cox

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.

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

Another type pressure element, which shows a marked improvement in the performance of the quartz crystal element, is the liquid-cooled condenser type. This type pressure element offers excellent response and stability characteristics.

The study of pressure wave form on the oscilloscope, or from photostats, would be simplified if a synchronizing device were installed which would provide a time axis. This synchronizing device could be a voltage-regulator arrangement operated from the crankshaft. The device could be either a battery and contactor arrangement or a magnetic timing error. Variations of these devices appear in the literature listed in the bibliography.

A very useful device, both from the standpoint of pressure wave form study and engine timing 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. G. A. Kistner, E. F. Newley, W. E. Chapman and H. P. Schmitt, "An Improved Indicator for Measuring Static and Dynamic Pressure," *SAE Journal* (Transactions), 52:534-56, November, 1944.

arranged as not to interfere with the synchronizing 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 electro-mechanical 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.

arranged as not to interfere with the engine's operation.

It has been found that the device would consist of a
contact-arm arrangement of the contact type. The device
then is adjustable to eliminate the possibility of the
cycle not under study.

Because the most important consideration for the
ing equipment would be the location of the engine.

Research Engine. This engine is a model of a
the benefits to be realized from a study of the engine
more than outweigh the initial cost. The engine
system alone would improve the reliability and
of the testing procedure as well as the engine.

The writer believes the new method to be a
CPS Method with respect to reliability and superior to the
CPS Method with respect to simplicity and expediency. With
a few modifications and additions, the existing method
mechanical equipment can be adapted to many of the
the field of fuel research and combustion engine testing.
It is hoped that the present project will become the basis
of an extensive fuel study program.

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APPENDIX A

NEW METHOD

Final Calibration and Gasoline Rating Data

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

Calibration data:

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

APPENDIX A

NEW METHOD

Typical Calibration and Analysis Results

Vacuum tube voltmeter (VTVM): 100, 20, 40 volts on 100 scale

Calibration Data

Reference Input	Microammeter Reading	Calibration Factor	VTVM Reading
85.0 Octane	0.000	100.1	81.5 ± 1.5 volts
90.0 Octane	0.000	100.1	80.0 ± 1.5
85.0 Octane	0.000	100.1	78.5 ± 1.5
80.0 Octane	0.000	99.9	77.0 ± 1.5
82.5 Octane	0.000	99.9	75.5 ± 1.5
85.0 Octane	0.000	99.9	74.0 ± 1.5
87.5 Octane	0.000	99.9	72.5 ± 1.5
90.0 Octane	0.000	99.9	71.0 ± 1.5
75.0 Octane	0.170	99.9	69.5 ± 1.5
77.5 Octane	0.170	99.9	68.0 ± 1.5
80.0 Octane	0.170	99.9	66.5 ± 1.5
82.5 Octane	0.170	99.9	65.0 ± 1.5
85.0 Octane	0.170	99.9	63.5 ± 1.5
87.5 Octane	0.170	99.9	62.0 ± 1.5
90.0 Octane	0.170	99.9	60.5 ± 1.5
70.0 Octane	0.330	99.9	59.0 ± 1.5
72.5 Octane	0.330	99.9	57.5 ± 1.5
75.0 Octane	0.330	99.9	56.0 ± 1.5
77.5 Octane	0.330	99.9	54.5 ± 1.5
80.0 Octane	0.330	99.9	53.0 ± 1.5
82.5 Octane	0.330	99.9	51.5 ± 1.5
85.0 Octane	0.330	99.9	50.0 ± 1.5
87.5 Octane	0.330	99.9	48.5 ± 1.5
90.0 Octane	0.330	99.9	47.0 ± 1.5
70.0 Octane	0.500	99.9	45.5 ± 1.5
72.5 Octane	0.500	99.9	44.0 ± 1.5
75.0 Octane	0.500	99.9	42.5 ± 1.5
77.5 Octane	0.500	99.9	41.0 ± 1.5
80.0 Octane	0.500	99.9	39.5 ± 1.5
82.5 Octane	0.500	99.9	38.0 ± 1.5
85.0 Octane	0.500	99.9	36.5 ± 1.5
87.5 Octane	0.500	99.9	35.0 ± 1.5
90.0 Octane	0.500	99.9	33.5 ± 1.5

Commercial gasoline rating data:

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

Commercial gasoline ratings table :

Gasoline	Motor Octane	Research Octane	Motor Octane	Research Octane
A-Regulus	87.0	91.0	87.0	91.0
B-Regulus	86.0	90.0	86.0	90.0
C-Regulus	85.0	89.0	85.0	89.0
D-Regulus	84.0	88.0	84.0	88.0
E-Regulus	83.0	87.0	83.0	87.0
F-Regulus	82.0	86.0	82.0	86.0
G-Regulus	81.0	85.0	81.0	85.0
H-Regulus	80.0	84.0	80.0	84.0
I-Regulus	79.0	83.0	79.0	83.0
J-Regulus	78.0	82.0	78.0	82.0
K-Regulus	77.0	81.0	77.0	81.0
L-Regulus	76.0	80.0	76.0	80.0
M-Regulus	75.0	79.0	75.0	79.0
N-Regulus	74.0	78.0	74.0	78.0
O-Regulus	73.0	77.0	73.0	77.0
P-Regulus	72.0	76.0	72.0	76.0
Q-Regulus	71.0	75.0	71.0	75.0

APPENDIX B

CFR METHOD

Gasoline Rating Data

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

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

APPENDIX B

TEST RESULTS

Results of tests on

Test	Material	Result
1	70.0 Octane	40.0
2	70.0 Octane	40.0
3	70.0 Octane	40.0
4	70.0 Octane	40.0
5	70.0 Octane	40.0

NOTE: Copy of E-regular results are enclosed; results are too small for better picture. See test 10.

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

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

1	K-Premium	.296	46
	75.0 Octane		50
	77.5 Octane		42
2	K-Premium	.296	45
	75.0 Octane		54
	77.5 Octane		47
3	K-Premium	.296	42
	75.0 Octane		50
	77.5 Octane		43
4	K-Premium	.296	43
	75.0 Octane		51
	77.5 Octane		41

Grade	Weight	Length	Width	Area
1	77.5	77.5	77.5	77.5
2	77.5	77.5	77.5	77.5
3	77.5	77.5	77.5	77.5
4	77.5	77.5	77.5	77.5

MILLERS FALLS
ERASE
COTTON CONTENT

NOTE: Headings were unclassified by Knudsen and adjusted to reading of 50 with 75 degree for new test.

1	77.5	77.5	77.5	77.5
2	77.5	77.5	77.5	77.5
3	77.5	77.5	77.5	77.5
4	77.5	77.5	77.5	77.5

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

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

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

<u>K-Premium Results</u>			<u>J-Premium Results</u>		
<u>K</u>	<u>25</u>	<u>77.5</u>	<u>J</u>	<u>25</u>	<u>77.5</u>
46	50	42	42	50	42
45	54	47	43	50	39
42	50	43	41	48	43
43	51	41	42	49	44
<u>176</u>	<u>205</u>	<u>173</u>	<u>168</u>	<u>197</u>	<u>168</u>
Avg.	44	51.2	42	49.2	42

K-Premium gasoline . . . 77.00 Octane

J-Premium gasoline . . . 77.50 Octane

NOTE: Proportion may be varied to suit the
 octane for each class of gasoline.

Run Fuel Motorist Motorist



COT 10

1	77.5 Octane	77.5 Octane	77.5 Octane
2	77.5 Octane	77.5 Octane	77.5 Octane
3	77.5 Octane	77.5 Octane	77.5 Octane
4	77.5 Octane	77.5 Octane	77.5 Octane

Results of tests with E-Prerim and 1-Prerim gasoline

E-Prerim Results				1-Prerim Results			
40	50	45	12.1	40	50	45	12.1
45	55	47		45	55	47	
47	57	49		47	57	49	
49	59	51		49	59	51	
51	61	53		51	61	53	
53	63	55		53	63	55	
55	65	57		55	65	57	
57	67	59		57	67	59	
59	69	61		59	69	61	
61	71	63		61	71	63	
63	73	65		63	73	65	
65	75	67		65	75	67	
67	77	69		67	77	69	
69	79	71		69	79	71	
71	81	73		71	81	73	
73	83	75		73	83	75	
75	85	77		75	85	77	
77	87	79		77	87	79	
79	89	81		79	89	81	
81	91	83		81	91	83	
83	93	85		83	93	85	
85	95	87		85	95	87	
87	97	89		87	97	89	
89	99	91		89	99	91	
91	100	93		91	100	93	
93		95		93		95	
95		97		95		97	
97		99		97		99	
99		100		99		100	
100				100			
Avg.	40	50	45	Avg.	40	50	45

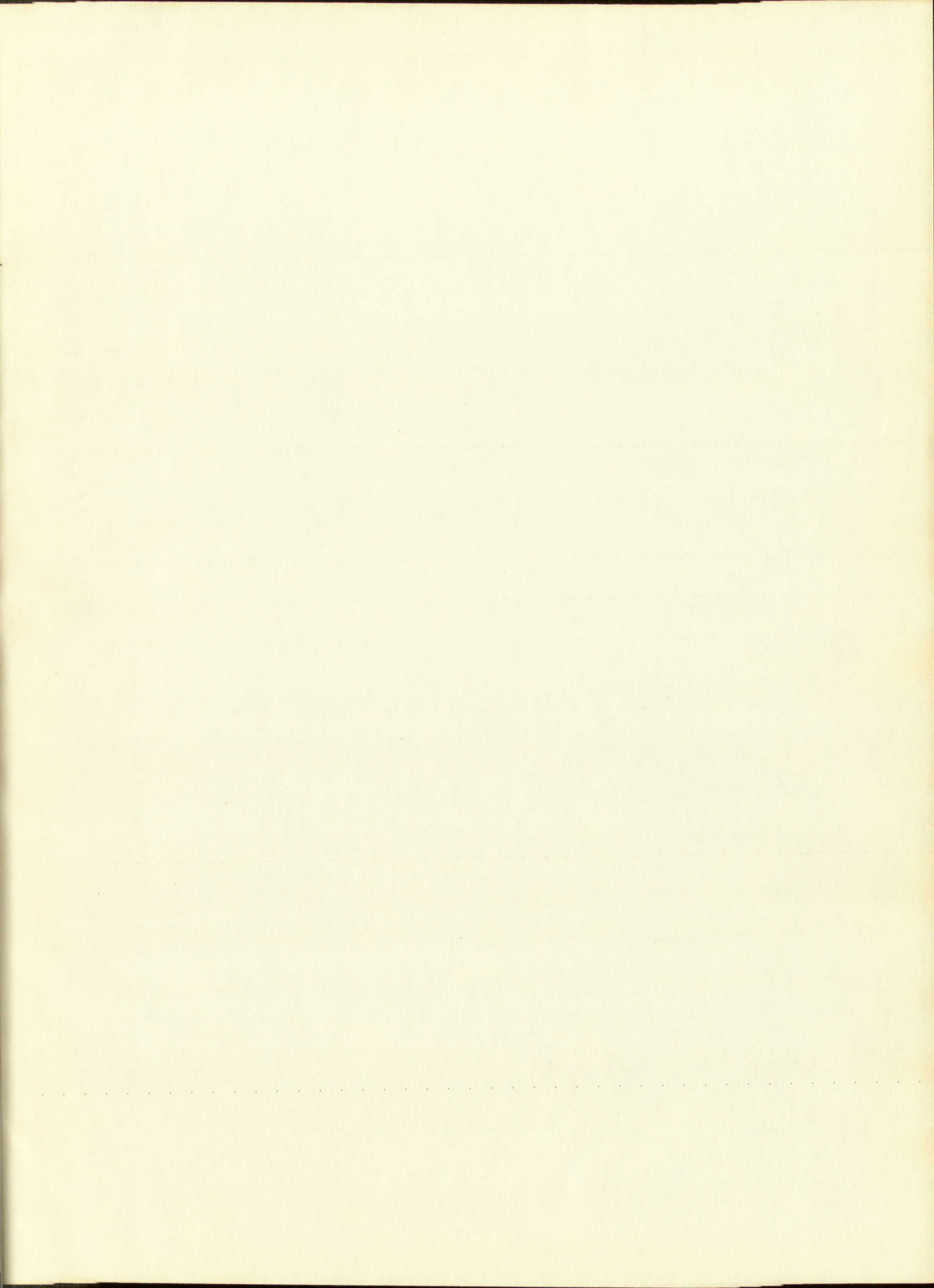
1-Prerim gasoline . . . 77.5 Octane
 E-Prerim gasoline . . . 77.5 Octane

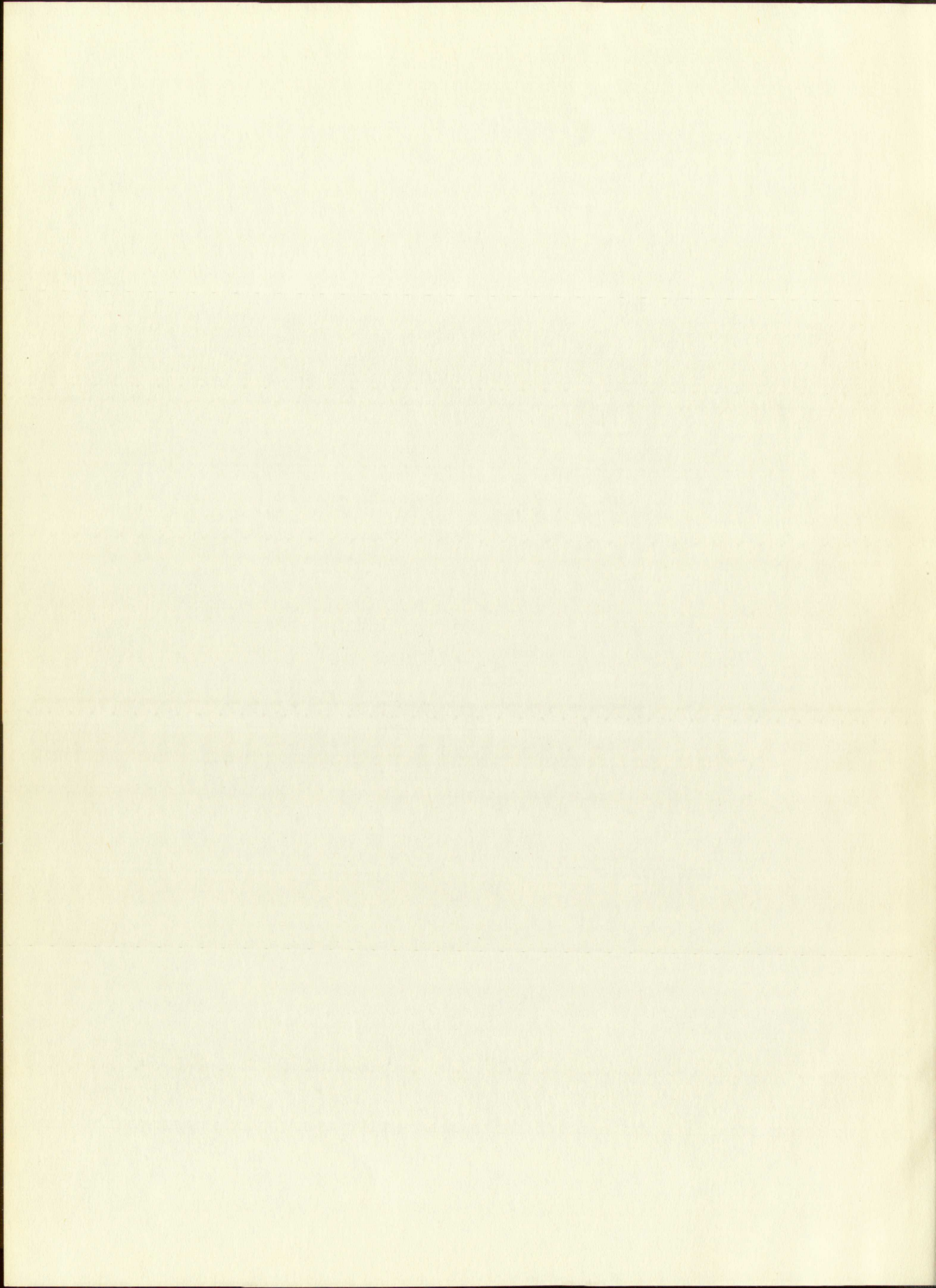
MILLERS FALLS
ERASE
COTTON CONTENT

MILLERS FALLS

EVERETT

COTTON CONTENT





IMPORTANT!

Special care should be taken to prevent loss or damage of this volume. If lost or damaged, it must be paid for at the current rate of typing.

[illegible]

