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Development of Electro-Mechanical Equipment for the Measurement of Knock Characteristics of Gasolines

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Ebacher — Development of Electro-Mechanical Equipment

NAME AND ADDRESS	DATE

DEVELOPMENT OF ELECTRO-MECHANICAL EQUIPMENT FOR THE MEASUREMENT OF KNOCK CHARACTERISTICS OF GASOLINES

A Thesis
Presented to
the Faculty of the College of Engineering
University of New Mexico

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Mechanical Engineering

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by
Rudolph W. Ebacher
April 1952

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

MASTER OF SCIENCE

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DATE

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Many people have attempted to develop electro-mechanical equipment for the measurement of knock characteristics of gasolines. In spite of much effort in this direction, the ASTM - CFR testing equipment has not been displaced from use. This apparently indicates that results of the above-mentioned investigation have not produced superior equipment.

The ASTM - CFR equipment presently specified involves the use of a bouncing pin and a knockmeter in the determination of octane ratings of gasolines. The closure of the contact points, as the bouncing pin responds to pressure changes, allows current to flow through a resistance heater located in the knockmeter. This heater is surrounded by a thermocouple, which is a part of the knock intensity meter circuit.[1,2] Because this unit operates on slight changes in the heater temperature, it has been extremely difficult to maintain ambient temperatures constant enough to allow measurement. It has been shown that the hand, if close but

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[1] E. F. Obert, Internal Combustion Engines (Scranton, Pennsylvania: International Textbook Company, 1951), p. 277.

[2] Waukesha Motor Company, General Instructions For The Care And Operation Of The ASTM - CFR Fuel Research Engine, (Waukesha, Wisconsin: 1932), p. 22.

CHAPTER I

INTRODUCTION

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not in contact with the knockmeter, could cause inaccuracies in the testing data obtained.

The ASTM - CFR Test Method requires excessive time to determine the octane rating of a gasoline (approximately 3 - 4 hours).

Accuracy of results obtained from the ASTM - CFR Method is questionable inasmuch as no guarantee can be made that reproducibility of results at subsequent tests can be obtained. This has been the writer's experience. General inquiry of persons experienced in the ASTM - CFR Test Method substantiates this conclusion.

Using the above-mentioned undesirable aspects as guides, this investigation aimed to develop equipment that could be used to determine the octane ratings of gasolines and still not include the aforementioned adverse conditions.

The object was to develop a better device than the "CFR knockmeter" for indicating relative knock intensities in engines.

If this aim were realized, then the equipment developed might be the forerunner of further refined equipment which could be used, after much field testing to prove its worth, as the standard equipment for the determination of octane ratings of gasolines.

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CHAPTER II

DEVELOPMENT OF THE EQUIPMENT

It was considered by the writer that characteristics of oscilloscope wave forms representing the varying pressures taking place in the CFR engine cylinder might provide an index to octane ratings of gasolines.

Obtaining pressure wave forms on the oscilloscope required some medium for providing an electrical signal in response to engine cylinder pressures. A quartz pressure element was considered as the item that could fulfill this requirement.

The quartz pressure element will yield an electrical potential when pressure is subjected to surfaces properly oriented to its electrical axis. This potential, fortunately, is proportional to the pressure - thus providing a direct index of pressure. "This electrical charge, besides being in exact proportion to the pressure exerted, varies instantly with changes of pressure."[1]

The quartz pressure element will indicate potential according to pressure, but this is only three millivolts (approx.) per one hundred pounds per square inch. Electrical

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[1] Commercial Research Laboratories, Inc., _The Cox Quartz Pressure Element, Handbook of Instructions_ (Detroit, Michigan), p. 7.

equipment to measure these minute potential changes, which are caused by pressure fluctuations, was not available; therefore, an amplifier to magnify these small pressure changes would be necessary.

When an amplifier adequate to do this job could be developed, it was intended to feed output of the amplifier into a cathode ray oscilloscope and visibly observe the pressure variations taking place in the engine cylinder.

equipment to record these rapid potential changes, which are caused by pressure fluctuations, may not be [illegible]; therefore, an amplifier to magnify these small pressure changes would be necessary.

When an amplifier adequate for this purpose could be developed, it was intended to feed output of the amplifier into a cathode ray oscillograph and thereby observe the pressure variations taking place in the engine cylinders.

CHAPTER III

SELECTION OF QUARTZ PRESSURE ELEMENT AND DEVELOPMENT OF AMPLIFIER

I

SELECTION OF A QUARTZ PRESSURE ELEMENT

The selection of the quartz pressure element was determined largely by the equipment available in the Mechanical Engineering Laboratory. A Cox quartz pressure element, Type 4, was used and is shown in Figure 1. A threaded reducer was machined to permit installation of the Cox element to the engine cylinder. This was mounted to one of the two cylinder access holes. The spark plug was mounted on the alternate opening.

II

DEVELOPMENT OF THE AMPLIFIER

The amplifier was the greatest source of trouble. Four amplifiers were constructed. A brief description of the steps taken during the amplifier development is given in the succeeding paragraphs of this chapter. Details of the development may be found in Chapter IV.

The first amplifier constructed was a two-channel amplifier with crossover at approximately 1000 cycles per

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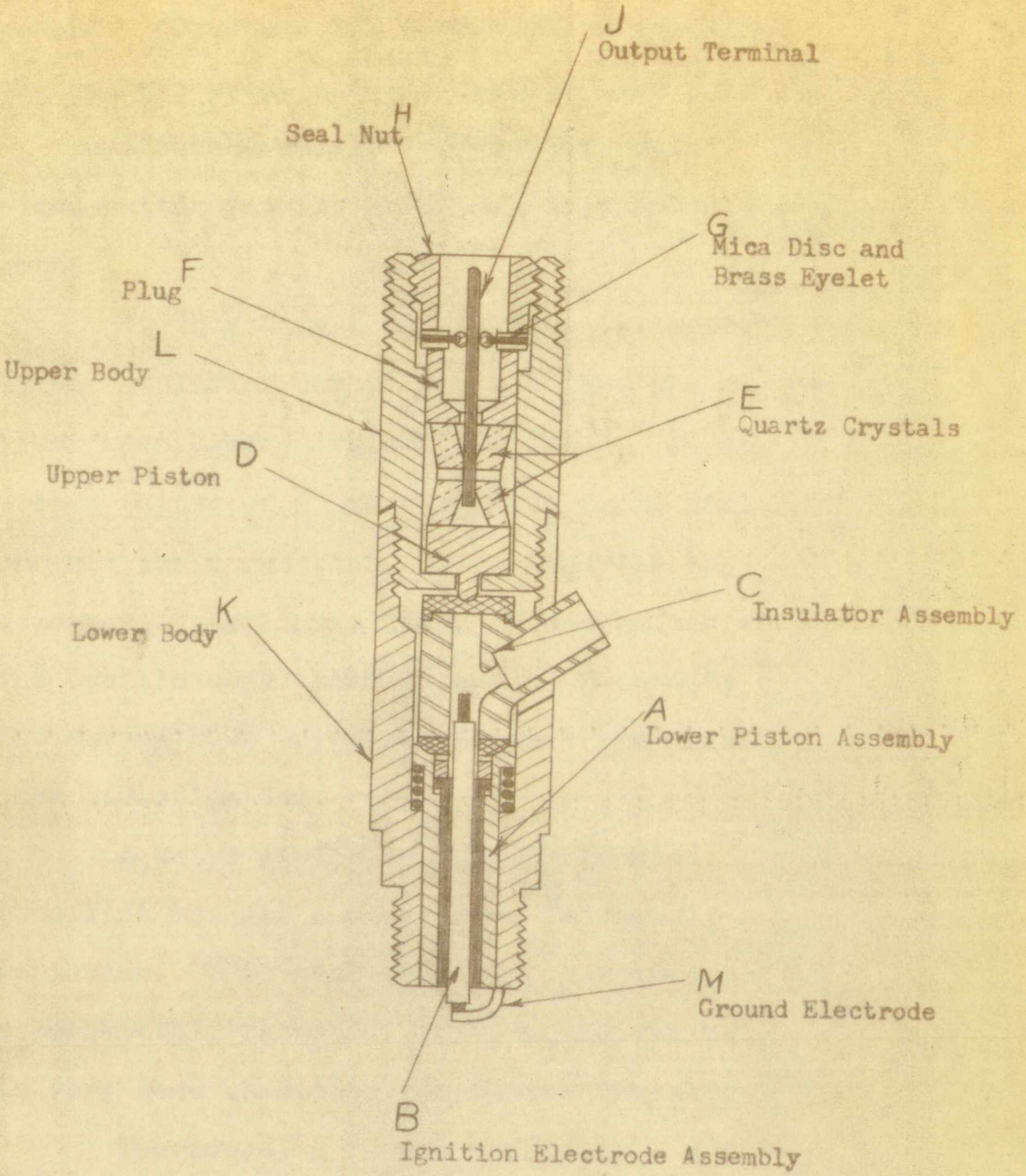

FIGURE 1: COX QUARTZ PRESSURE ELEMENT, TYPE 4

second. (See page 10, paragraph on Amplifier No. 1) Each channel was used, and the results were poor.

A second amplifier was constructed. This unit provided better results than the first but did not satisfy the author.

At this time a vacuum tube voltmeter was used - whereby the amplifier output was fed into the meter and the RMS (root mean square) values indicated. It was discovered that octane values of known reference fuels could be calibrated on this scale and that, by running the engine on unrated commercial gasolines, their octane values could be determined. The oscilloscope approach became secondary at this point, and the vacuum tube voltmeter assumed the prime position for further investigation.

A third amplifier was constructed. This unit gave excellent results and was used for nearly a year in experimentation. This amplifier was, however, constructed in an experimental, makeshift fashion and was not considered to be in very good condition for future investigations.

Therefore, a fourth amplifier - a final, refined version of amplifier Number 3 - was constructed which also gives excellent results. This amplifier is to be left with the Mechanical Engineering Department of the University of New Mexico.

CHAPTER IV

DESCRIPTION AND OPERATION OR EQUIPMENT

The author wishes to establish that the development of the amplifier for this project was started without the full electrical background that would have been advantageous. The initial step was a general study of amplification. The construction and testing of the amplifiers followed. This study, accompanied by experimentation and consultations with electrical experts advising in the more technical aspects of the electrical problems, led through a series of developments that produced the desired results as obtained by amplifiers Numbers 3 and 4.

A suitable amplifier required a unit that would receive the signals as produced by the quartz pressure element and amplify these signals. These signals in turn would be fed into the oscilloscope and duplicate the curves obtained by Professor E. F. Smelley who used Mr. Emswiler's indicator. This indicator had the same CFR engine which was used in this project. This latter setup was not suitable for octane rating determination but gave good pressure diagrams. These diagrams can be found in the University of New Mexico Mechanical Engineering Department files.

Inasmuch as amplifiers Numbers 1 and 2 did not provide the results sought, their electrical characteristics will not

be discussed in detail.

I. DESCRIPTION OF EQUIPMENT

Pressure Element. The Cox quartz pressure element, Type 4 (Figure 1), which was selected, is a unit that develops a 3.6 millivolt potential per 100 pounds per square inch pressure exerted on the element. The element is capable of operating under a range of 25 psi to 2000 psi. This range was used in operation. A thicker diaphragm will, however, allow readings to be taken up to and above 5000 psi.[1]

The Cox pressure element will accurately record frequencies from 10 cps and upward.[2]

The sensitivity of the pressure element is unaffected by temperatures up to 350° C. The sensitivity drops rapidly above this temperature, and at about 573° C it is zero.[3]

At the latter temperature, the quartz changes from Alpha to Beta quartz and loses the characteristics of lower temperatures.[4]

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[1] Commercial Research Laboratories, Inc., The Cox Quartz Pressure Element, Handbook of Instructions (Detroit, Michigan), p. 8.

[2] Ibid., p. 8.

[3] Ibid., p. 8.

[4] Ibid., p. 8.

The pressure element should be inserted into the explosion chamber until the end of the piston is flush with the inner wall of the chamber. The clamp nut should then be drawn tight. When installed as prescribed, the volumetric capacity of the chamber remains practically unchanged.

The pressure element has a coaxial cable which supplies the amplifier with the pressure signal. The center conductor carries the positive signal, and the outer conductor is fixed to ground. The cable should be placed as far as possible from ignition circuits as pickup from these circuits will result in inaccurate pressure signals.

Amplifier. Amplifier Number 1. The first amplifier constructed was a two-channel amplifier with crossover at approximately 1000 cycles per second. This actually means that each channel was an amplifier. One channel ranged from 20 to 1000 cycles, and the other channel from 1000 to 20,000 cycles per second. This amplifier had voltage amplification in the initial stages and power amplification in the last stages, making amplifier Number 1 essentially a power amplifier without high gain characteristics. This amplifier did have nearly flat response over the 20 to 20,000 cps range. Modification of the power supply to produce a higher voltage was effected; however, this did not have any noticeable effect in raising the gain of the amplifier. After this

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attempt to render the amplifier suitable to use for the project, it was discarded. A second attempt was made in the construction of another amplifier which was thought to incorporate adequate gain. This unit is pictured in Figures 2 and 3, and its schematic is shown in Figure 4.

Amplifier Number 2. The second amplifier made use of two, beam-power amplifier tubes which were connected for push-pull operation. This unit was an improvement when compared to the first amplifier; however, results were far from those desired as this amplifier also did not have adequate gain. The amplifier is pictured in Figure 5, and the schematic for this is shown in Figure 6. Modification of the power supply to produce a higher voltage also proved futile in raising the gain characteristics, and this amplifier was discarded also.

Amplifier Number 3. Further study in amplification brought forth a simple but very effective unit as represented by Figures 7 and 8 and its schematic in Figure 9.

This voltage amplifier incorporated a feature that was determined in this development to be very important. The voltage gain of 9000 in this amplifier made it possible to obtain a workable signal. With a good power supply (containing condenser input followed by choke, condenser, resistance, and a condenser as the last stage of the filter) the

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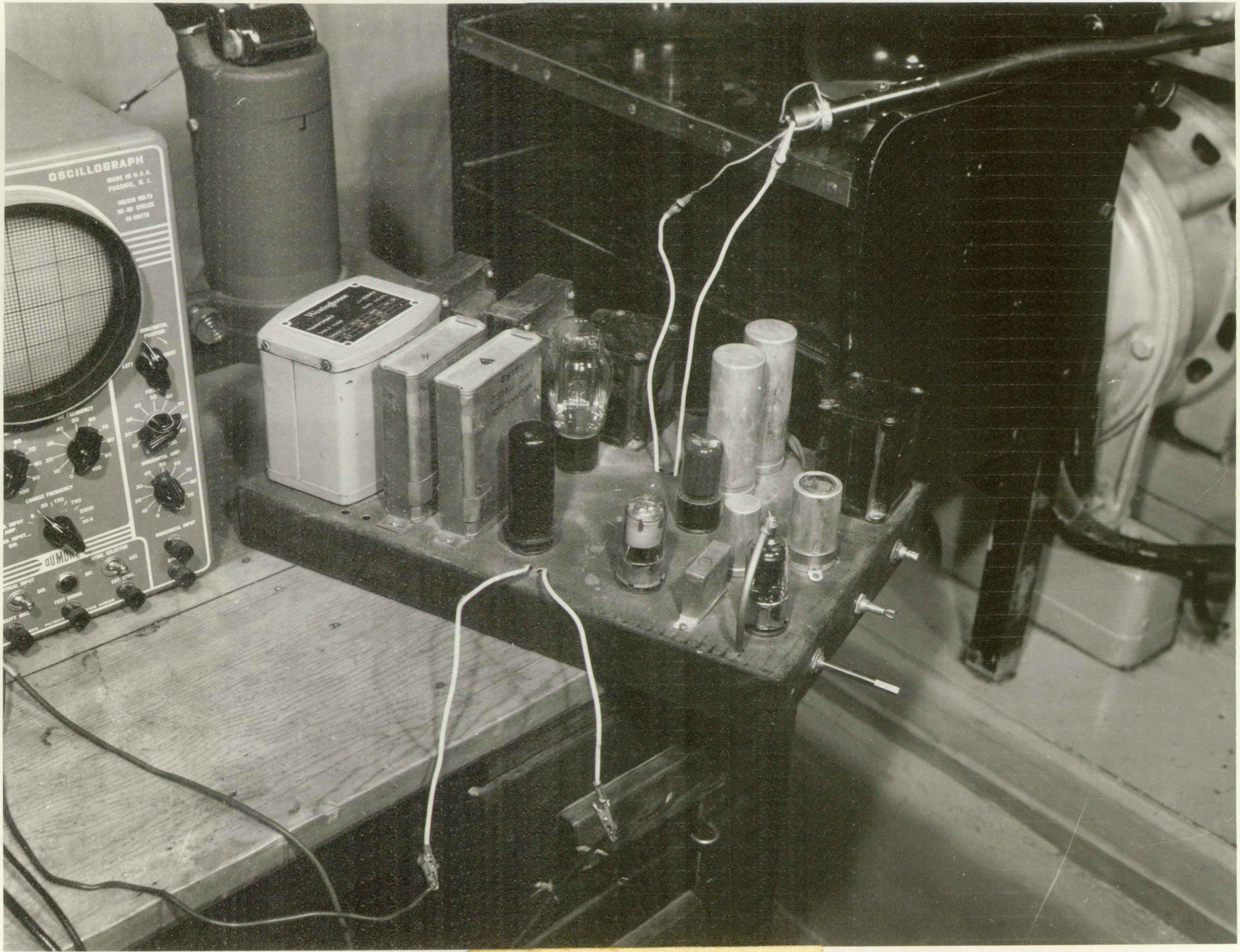


FIGURE 2: AMPLIFIER NO. 1

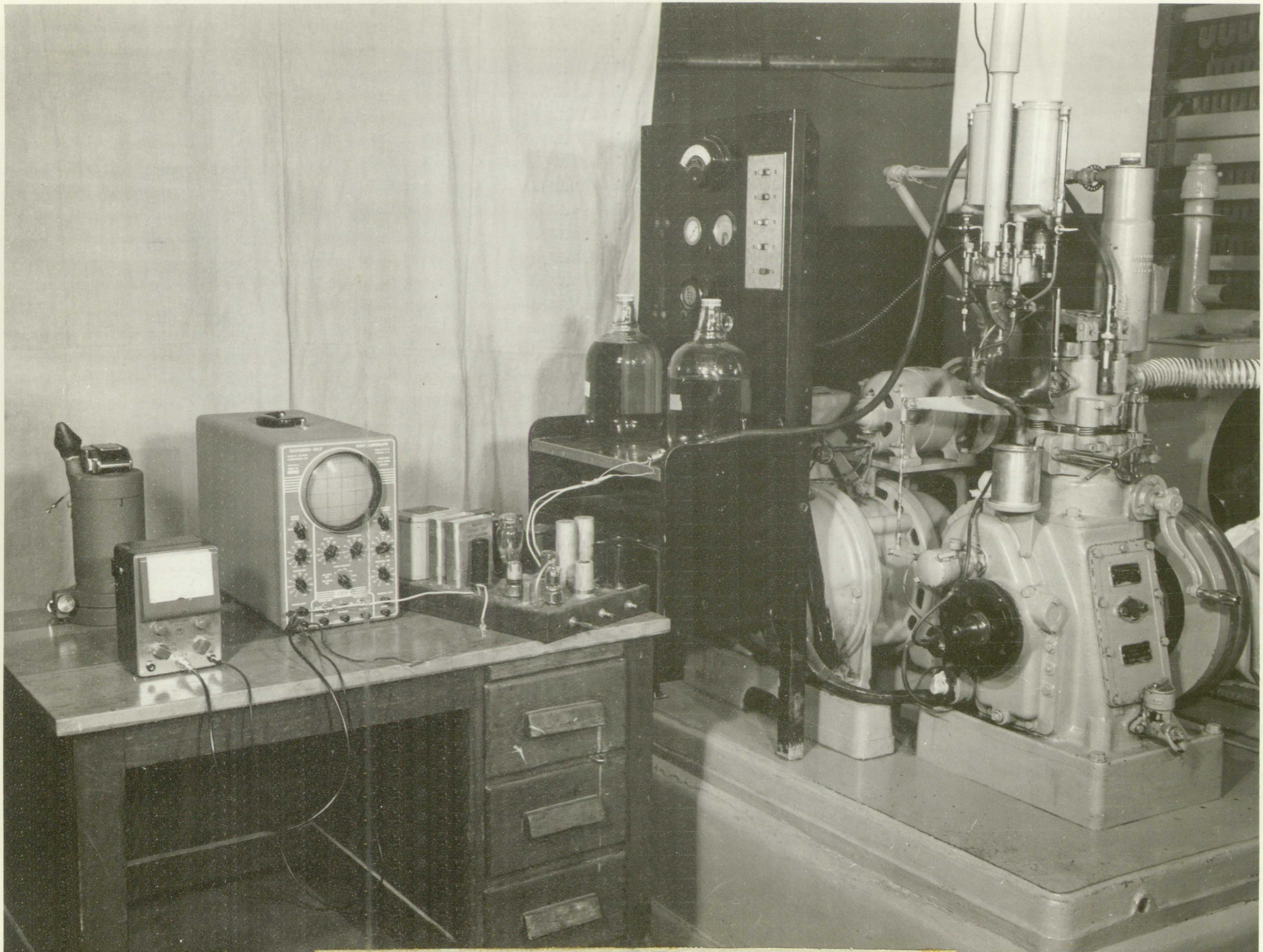
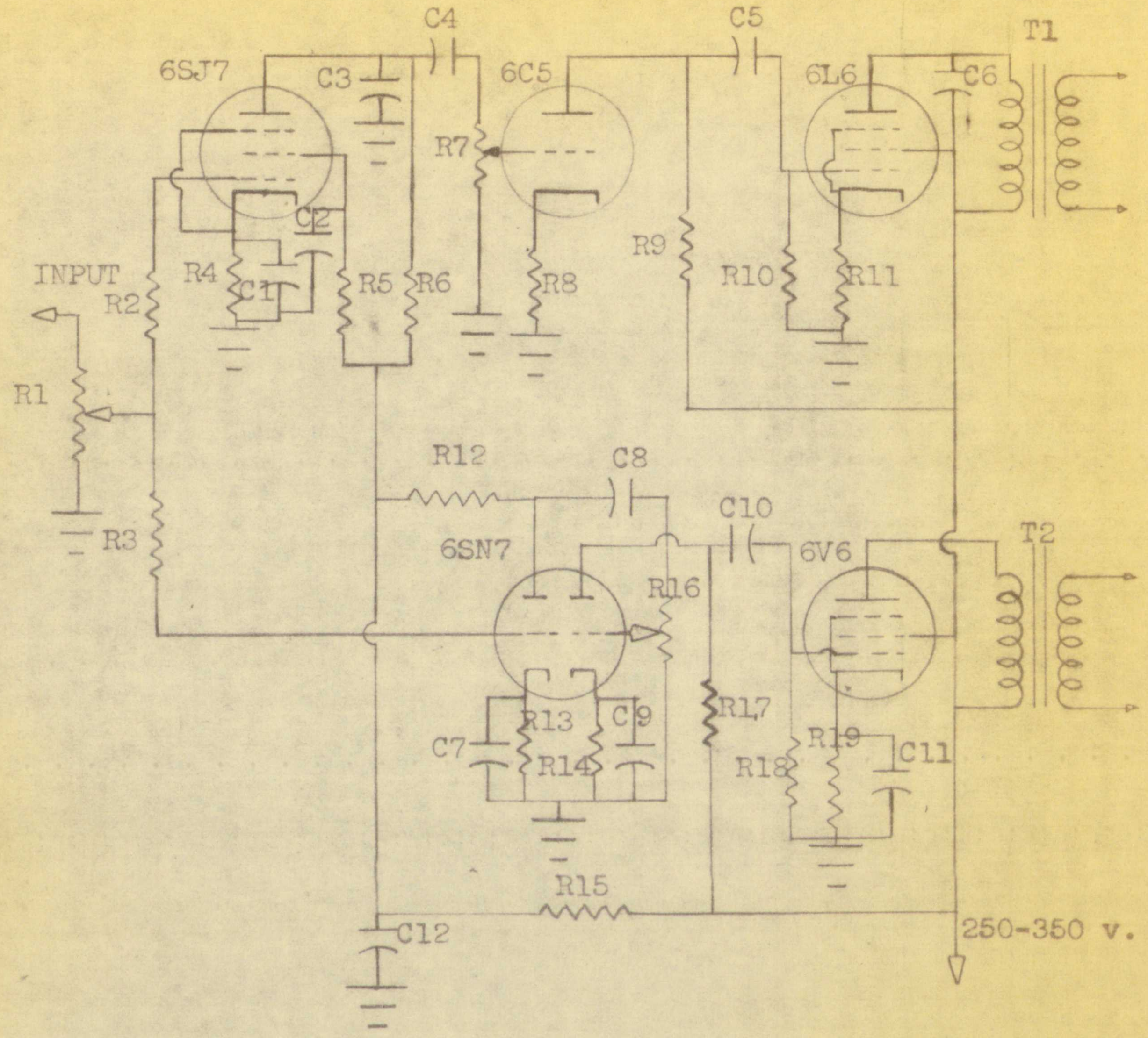


FIGURE 3: COMPLETE ELECTRO-MECHANICAL EQUIPMENT
AMPLIFIER NO. 1



R1-10,000 ohm pot.	C1-50 mfd., 25 v., elec.
R2, R3-1 megohm, $\frac{1}{2}$ w. res.	C2,C4,C5-.1 mfd., 400 v.
R4,R8,R13,R14-1000 ohms, 1 w.	C3,C8,C10-.01 mfd., 400 v.
R5,R10,R18-500,000 ohms, $\frac{1}{2}$ w.	C6-.05 mfd., 400 v.
R6-100,000 ohm, $\frac{1}{2}$ w.	C7,C9-.1 mfd., 200 v.
R7,R16-500,000 ohm pot.	C11-.25 mfd., 200 v.
R9,R12,R15,R17-50,000 ohms, $\frac{1}{2}$ w.	C12-10 mfd., 450 v. elec.
R11-250 ohm, 1 w.	T1-A. Trans., 4500 ohms to c.
R19-400 ohm, 1 w.	T2-A. Trans., 5000 ohms to c.

FIGURE 4: SCHEMATIC DIAGRAM OF AMPLIFIER NO. 1

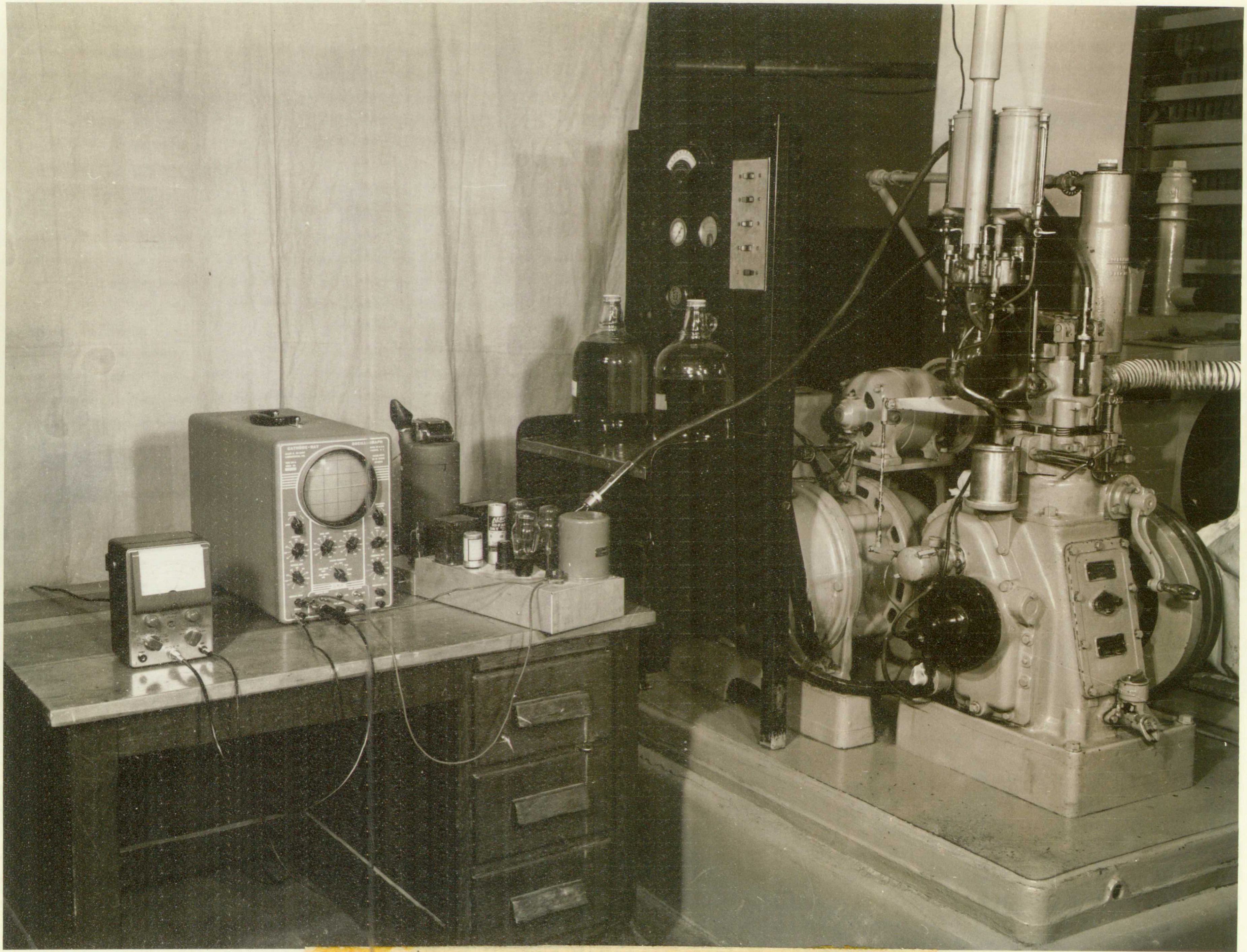
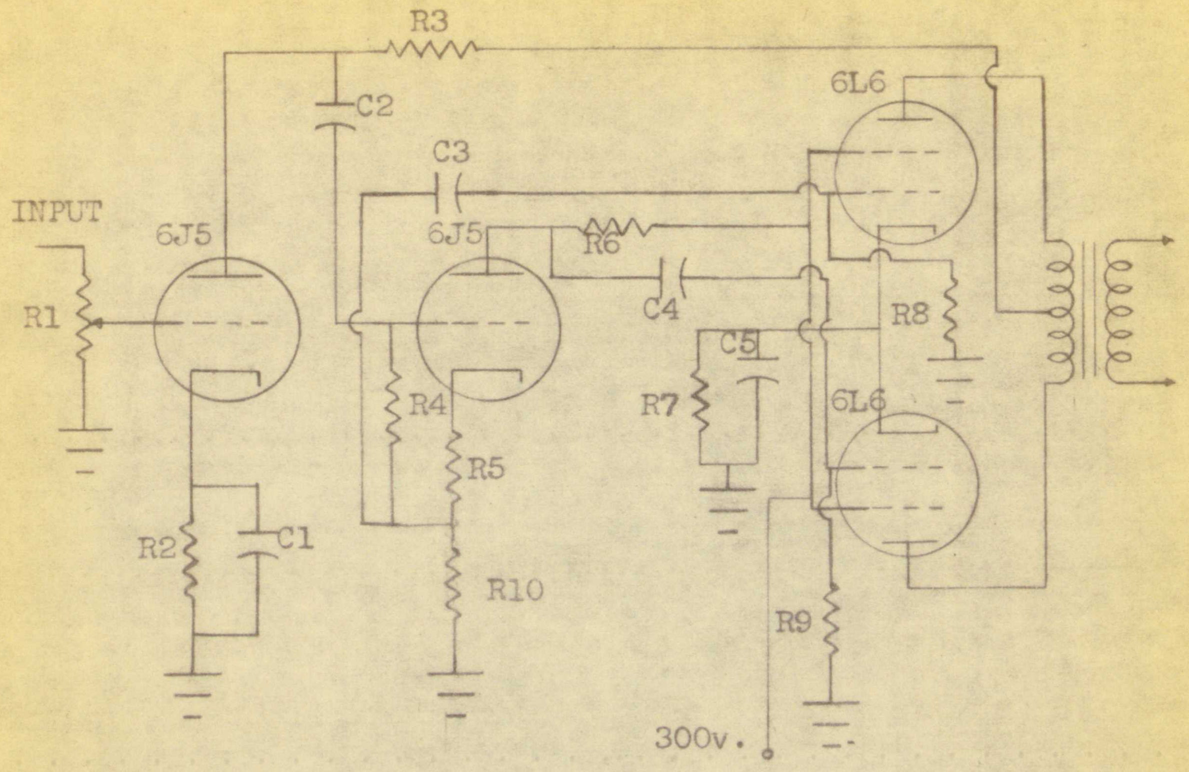


FIGURE 5: COMPLETE ELECTRO-MECHANICAL EQUIPMENT
AMPLIFIER NO. 2



R1-250,000 ohm pot.
R2-1800 ohm,1 w.
R3-10,000 ohm, $\frac{1}{2}$ w.
R4,R8,R9-470,000 ohm,1 w.
R5,R6-47,000 ohm, $\frac{1}{2}$ w.
R7-270 ohm, $\frac{1}{2}$ w.
R10-2700 ohm, 1 w.

C1-100 mfd., 50 v., elec.
C2,C4-.25 mfd., 600 v.
C3-.25 mfd., 600 v.
C5-100 mfd., 50 v.

FIGURE 6: SCHEMATIC DIAGRAM OF AMPLIFIER NO. 2

FIGURE 7: AMPLIFIER NO. 3

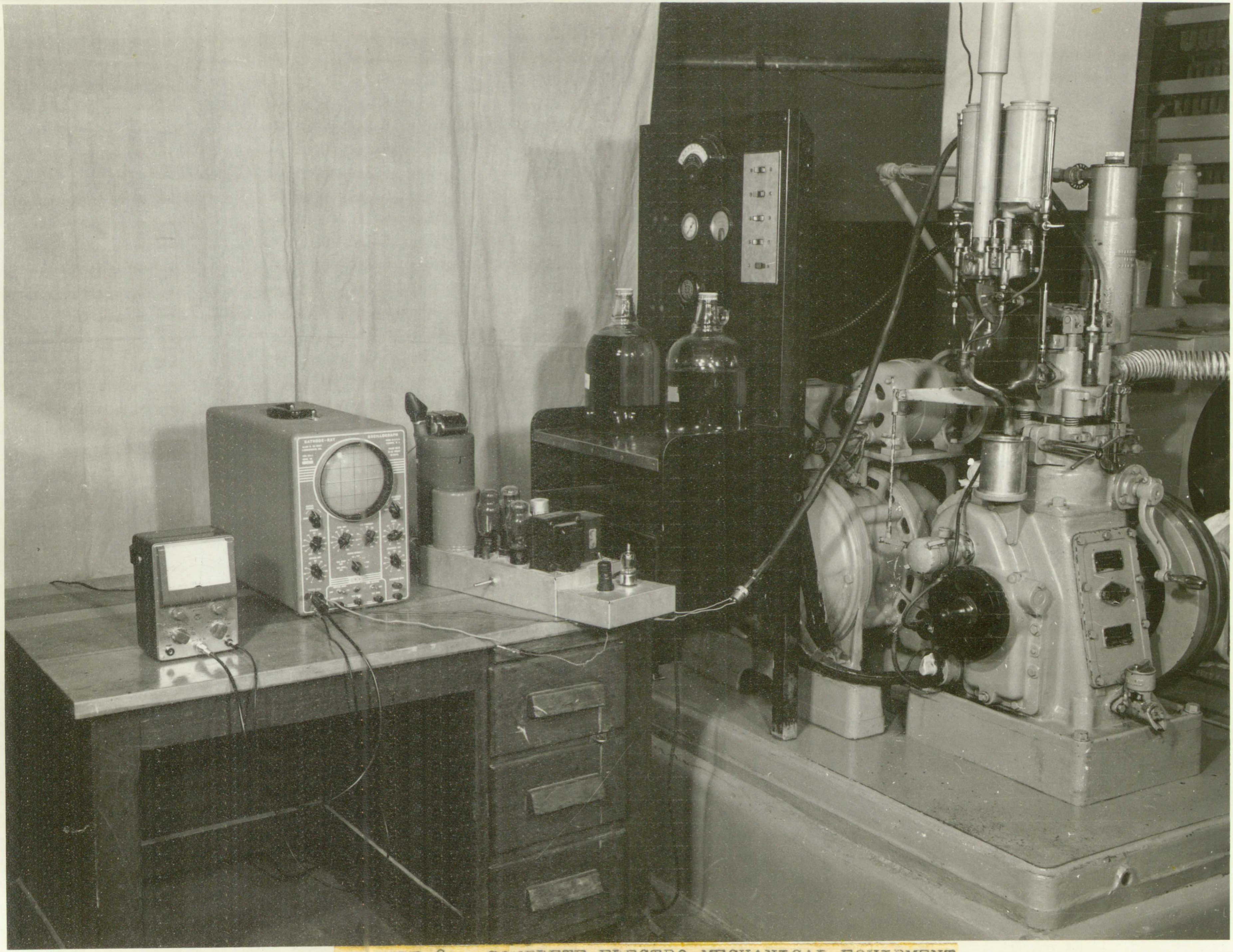
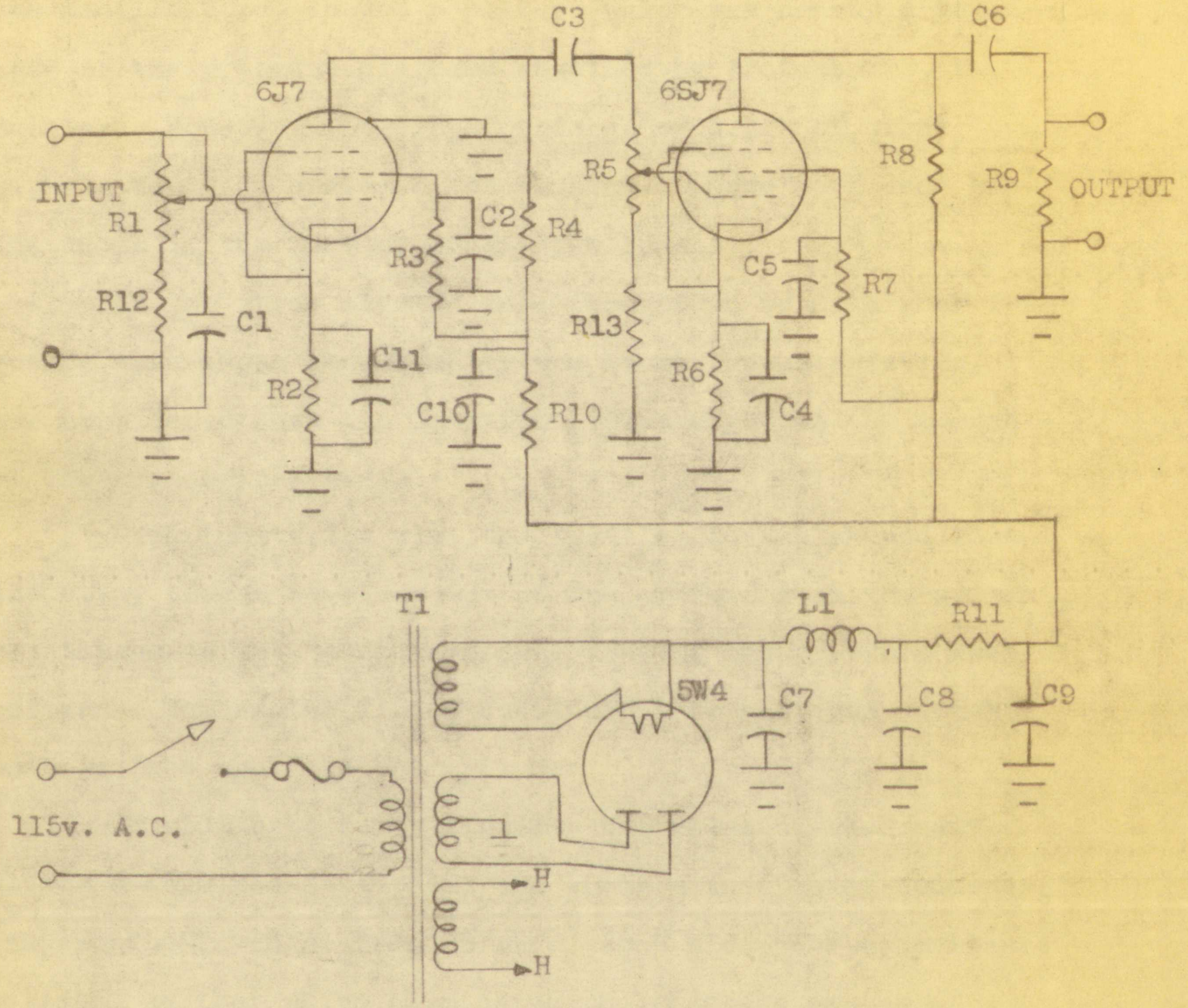


FIGURE 8: COMPLETE ELECTRO-MECHANICAL EQUIPMENT
AMPLIFIER NO. 3



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, lw.

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

FIGURE 9: SCHEMATIC DIAGRAM OF AMPLIFIERS NO. 3 AND NO. 4

470,000 ohms was selected. A fixed resistor of this value was installed in the amplifier.

When C1 = .002 mfd., C10 = 5 mfd., and R10 = 470,000 ohms were used, the resulting patterns were considered by the writer to be very satisfactory and nearly free of stray signals.

An electrical laboratory check indicated that the amplifier had a flat response between 20 and 9000 cps which includes the operating range used.

The coaxial cable between the quartz pressure element and the amplifier was removed as far from the ignition system as possible in order to reduce pickup of stray signals.

The author believes that all the aforementioned steps taken to reduce stray signals produced satisfactory results. Therefore, amplifier Number 3 was considered suitable.

Amplifier Number 4. Amplifier Number 3, as mentioned in Chapter 3, was rebuilt in a more permanent construction. This amplifier is shown in Figures 10, 11 and 12, and its schematic is shown in Figure 9.

Oscilloscope and Voltmeter. The oscilloscope used in the experimentation was a standard, commercial Dumont Oscilloscope, Model 274. The oscilloscope was outfitted

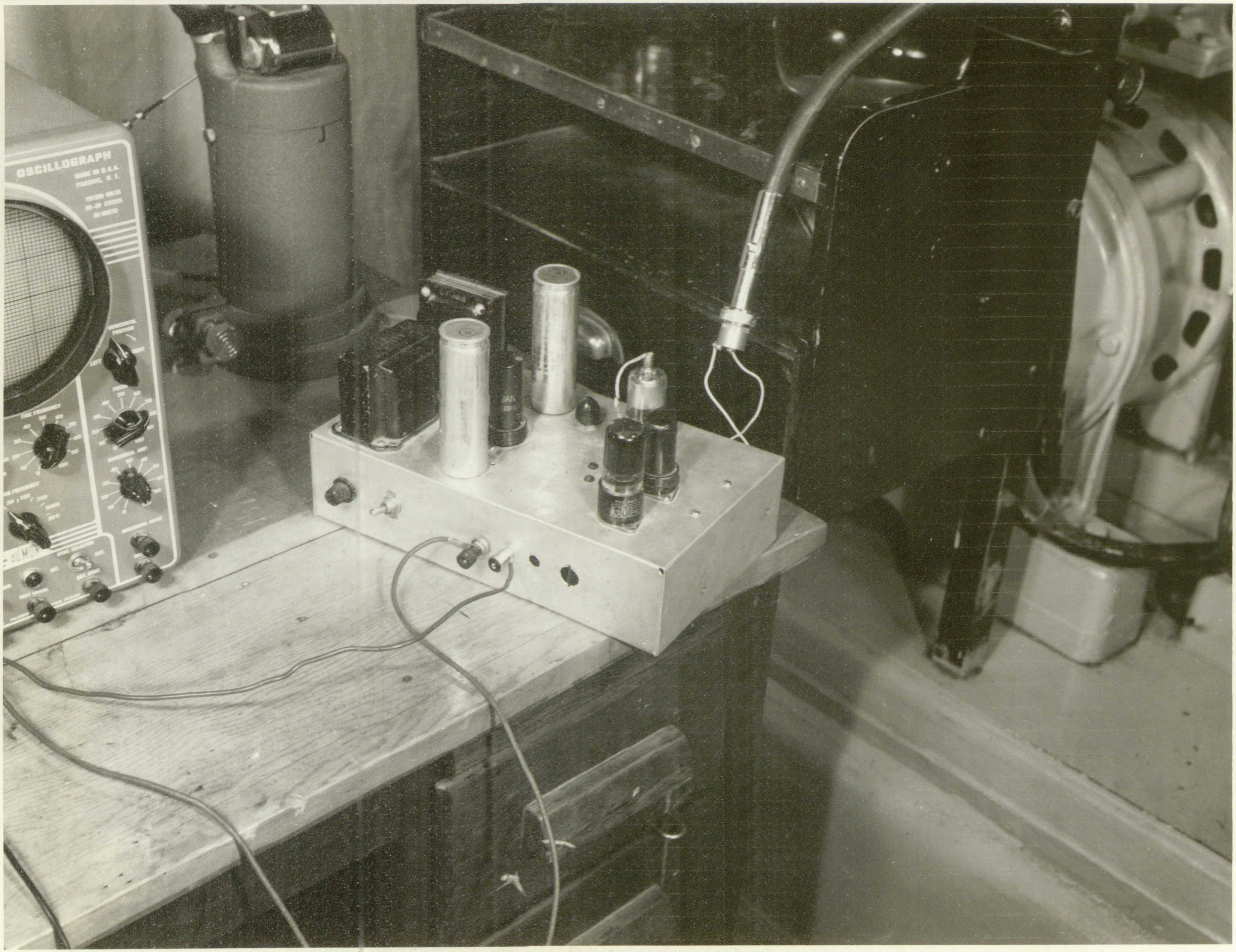


FIGURE 10: AMPLIFIER NO. 4

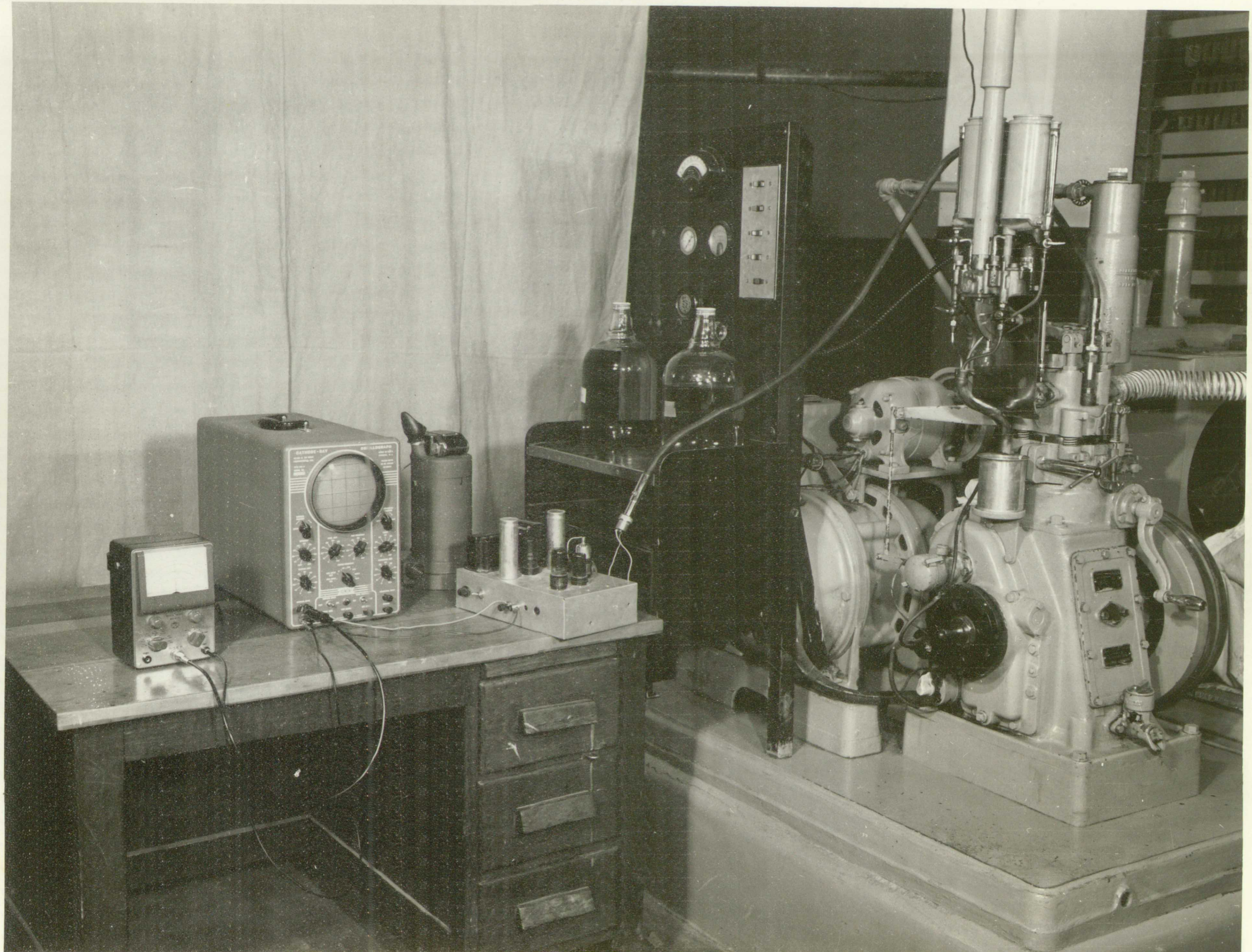


FIGURE 11: COMPLETE ELECTRO-MECHANICAL EQUIPMENT AMPLIFIER NO. 4

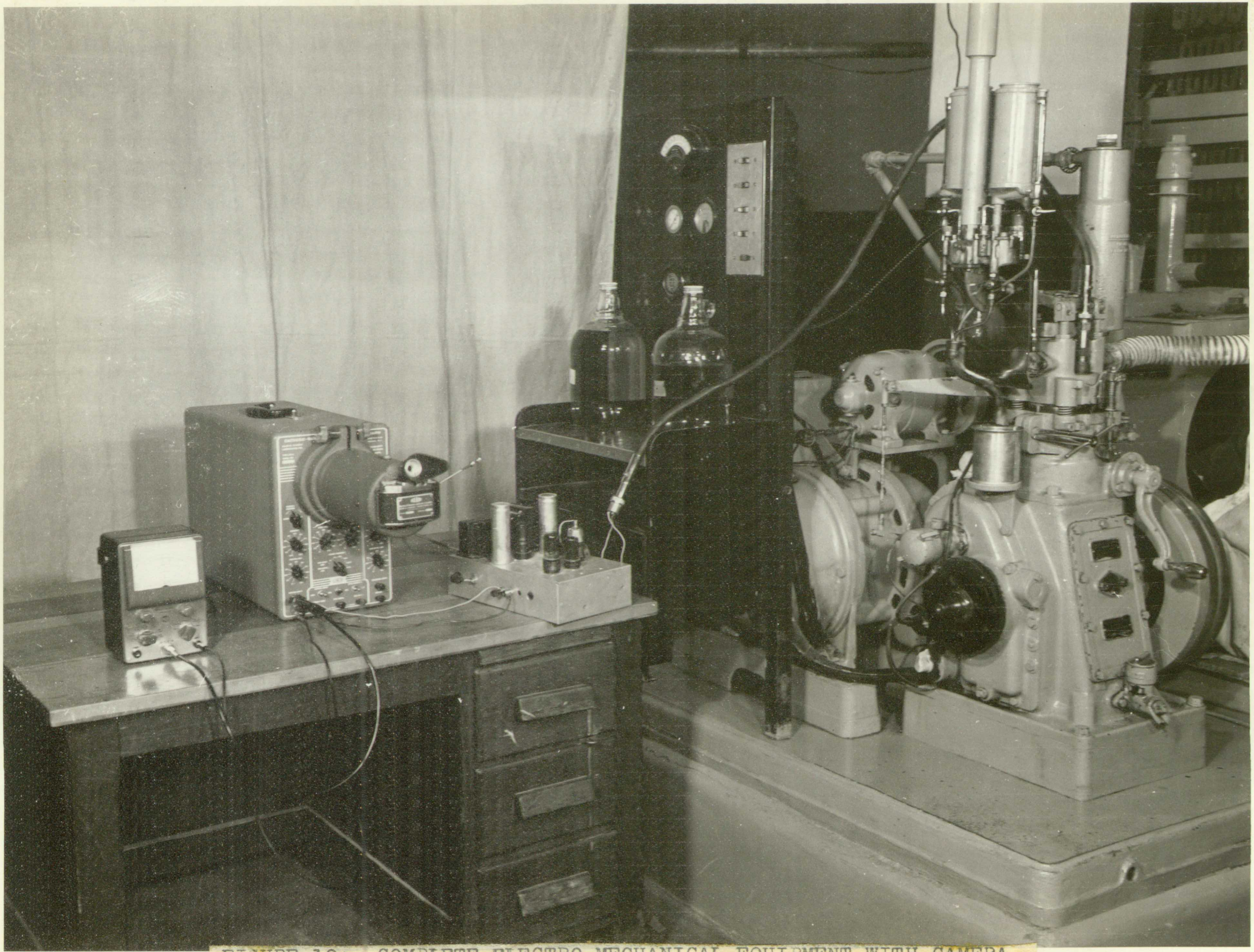


FIGURE 12: COMPLETE ELECTRO-MECHANICAL EQUIPMENT WITH CAMERA AMPLIFIER NO. 4

with an oscillograph record camera, Dumont, Type 296.

The vacuum tube voltmeter selected was an RCA, commercial type, Model WV-97A.

The RMS scale was used on this instrument. The output of the amplifier was fed into the voltmeter leads, and the readings on the upper RMS scale were noted.

II. CHARACTERISTICS OF COMPONENTS

Pressure Element. The characteristics[5] of the Cox, Type 4, pressure element used are as follows:

Output per 100 psi	3.6 m.v.
Maximum operating temperature	350° C.
Minimum frequency response . . approx.	10 cps.
Length	$4\frac{1}{4}$ ins.
Thread	14-1-$\frac{1}{4}$ mm.
Weight	8 oz.
Coaxial cable length	5 ft.

Amplifier Number 4. This amplifier has advantage of a voltage gain of 9000 and a good linear response between 20 cps and 9000 cps. The latter characteristic, however, is not particularly critical in this instance, for the testing required only a small portion of the curve. The amplifier is

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[5] Ibid, p. 12.

with an oscillograph record camera, Dumont, Type 27.

The vacuum tube voltmeter selected was an R.C.A. commercial type, Model WV-27A.

The RMS scale was used on this instrument. The output of the amplifier was fed into the voltmeter leads and the readings on the upper RMS scale were noted.

II. CHARACTERISTICS OF COMPONENTS

Pressure Element. The characteristics[5] of the Cox, Type 4, pressure element used are as follows:

Output per 100 psi . . . . 3.0 m.v.

Maximum operating temperature . . [illegible]

Minimum frequency response . . approx. 10 [illegible]

Length . . . . 1½ in.

Thread . . . . 3/8-24-(unf) [illegible]

Weight . . . . 4 oz.

Coaxial cable length . . . . 5 ft.

Amplifier Number 4. This amplifier was given specs of a voltage gain of 9000 and a flat frequency response between 20 cps and 9000 cps. The latter characteristic, however, is not particularly critical in this instance, for the test required only a small portion of the curve. The amplifier is

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[5] Ibid. p. 12.

of simple construction and should require little maintenance.

Voltmeter. The characteristics of the 15V-RMS scale used on the RCA voltmeter are as follows:[6]

Overall accuracy . . . . ± 5% of full scale

Input resistance and capacitance

(When used with direct probe and cable WG-218):

1.5, 5, 50, 150-V ranges . . 0.83 meg. shunted by 70 uuf.

Frequency response

(When used with direct probe and cable WG-218):

. . . . 30 cps to 3 Mc.

The characteristics of the power supply for the voltmeter are as follows:[7]

Voltage rating . . . . 105-115 Volts

Frequency rating . . . . 50/60 cps

Power consumption . . . . approx. 6 Watts

Battery . . . . 1.5-Volt Cell

The voltmeter used has many applications; however, as the RMS scale was the only scale used, any meter having this scale might be used.

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[6] Radio Corporation of America, RCA Senior Voltohmyst (Harrison, N. J.), p. 5.

[7] Ibid, p. 7.

III. ADVANTAGES AND LIMITATIONS OF FINAL EQUIPMENT

The advantages, in the writer's opinion, of the final equipment which was developed during this study are many compared to the present ASTM - CFR knockmeter equipment. The data listed on the following page illustrates the benefits of adopting the final equipment, or improved models, as the future standard for knock characteristic measurement of gasolines. However, extensive testing would be necessary before such an adoption.

It is desired to stress, at this point, the fact that the developed equipment has rendered a high rate of reproducibility of octane rating of fuels over a period of many months. The same fuels were tested at many sessions over a long time, always reproducing results within close limits. The ASTM - CFR Test Method has not reproduced with this reliability.

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FACTORS	KNOCKMETER		PROPOSED EQUIPMENT
Time	2 unknown fuels/8 hrs.	. . .	16 unknown fuels/3 hrs.
Repetitive confirmation	Fair	. . .	Good to excellent
Effect of unstable ambient conditions	Affected by drafts and small temp. changes	. . .	Unaffected by drafts and small temp. changes
Readings	Erratic	. . .	Steady
	Indicator often drifts wildly; when steady-state conditions seem apparent, indicator may act erratically		Superior to knockmeter characteristics

The installation of the proposed equipment must be carefully executed. Ignition conductors and circuits should be isolated and shielded. The coaxial cable from the pressure element to the amplifier must be kept from vibrating. These precautions, if observed, will permit proper functioning of the proposed equipment. To fail to do this will cause pickup of voltages and signals not intended for reckoning in the final results.

IV. OPERATING INSTRUCTIONS

This section will explain the steps that were taken in setting up the equipment developed for the measurement of octane ratings of gasolines.

The quartz pressure element was installed in the CFR engine cylinder access hole. The coaxial cable had one end attached to the pressure element and the other end to the amplifier. The center conductor was fed to the jack marked "input," and the outer conductor was connected to the ground jack.

To the output jack of the amplifier was attached an electrical lead which was fed into the RCA voltmeter. The selector switches of the voltmeter were set on the AC and RMS 15-V. scale, using the WG-218 probe.

At this point, the CFR engine was prepared for normal operation in the following manner:

1. The unknown fuel was poured into the tank. Reference fuels of 55, 60, 65, 70, 75, 80, 85, 90, and 95 octane numbers were available for determining the octane number of the unknown fuel.

2. The water valve was opened to permit circulation for cooling.

3. The electrical switches were closed on the main switchboard.

4. The CFR engine was started and warmed up approximately thirty minutes to bring the engine to a steady operating condition.

5. The engine was operated at 900 ± 9 R.P.M. (This is regulated by the setup established for the CFR engine at the University of New Mexico Mechanical Engineering Laboratory.)

6. The temperature at the intake manifold was maintained by the operator, using a variable resistor behind the CFR engine control panel, at 300° F. ± 2°.

7. After the engine warm-up, the amplifier and the RCA voltmeter were connected to the 110V.-AC power line.

Observations were made regarding the readings obtained for the initial compression ratio setting of 7:1. If the reading of the unknown fuel was less than 7V on the upper RMS scale, the compression ratio was then raised until the reading was between 7V and 9V. Subsequently, reference fuels were run, starting with 90 and then 85, etc., until the readings of two reference fuels straddled the unknown fuel reading. As the reference fuels had been mixed in increments of 5 octane numbers, new batches of reference fuels were made within the 5 octane number straddle range, and the straddling continued until the unknown fuel octane number was determined. This procedure was followed many times on many unknown fuels with excellent repetitive results on

4. The [illegible] was [illegible] and [illegible] approxi-
mately [illegible] minutes to bring the engine to a steady operat-
ing condition.

5. The [illegible] was operated at [illegible] R.P.M. [illegible]
is regulated by the [illegible] established for the [illegible] engine at
the University of [illegible] [illegible]
Laboratory.)

6. The temperature [illegible] was main-
tained by the operator, using a [illegible] on the
CFR engine control panel, [illegible].

7. After the engine warm-up, the amplifier and the
RCA voltmeter were connected to the [illegible] pick-up unit.

Observations were made regarding the readings obtain-
ed for the initial compression [illegible]
reading of the [illegible] was [illegible]
RMS scale, the compression ratio was then raised until the
reading was between 28 and 30. [illegible], [illegible]
were run, starting [illegible] and [illegible], and [illegible] read-
ings of two reference fuels [illegible] the unknown fuel read-
ing. As the reference fuels had been blended in increments
of 5 octane numbers, new batches of reference fuels were
made within the 5 octane number [illegible] range, and the
straddling continued until the unknown fuel octane number
was determined. This procedure was followed many times on
many unknown fuels with excellent [illegible]

reruns. Mr. C. B. Gangwer[8] has developed a testing method whereby refinement of procedure and suitability of method has been made practical for use in the determination of knocking characteristics of commercial gasolines.

The pressure element and the amplifier were used also with the Dumont oscilloscope. The hookup was the same as for the RCA voltmeter, with the oscilloscope substituted for the voltmeter. Patterns were obtained that were distinctly different for various fuels and compression ratios. A study of Figures 13, 14, and 15 will serve to illustrate this condition. An index of octane rating values for unknown fuels would be difficult to obtain with the use of the oscilloscope; therefore, its use was abandoned in preference to the RCA voltmeter.

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[8] C. B. Gangwer, Development of a Test Method for Rapid Determination of Octane Ratings of Gasolines, (unpublished Master's thesis, University of New Mexico, 1952)

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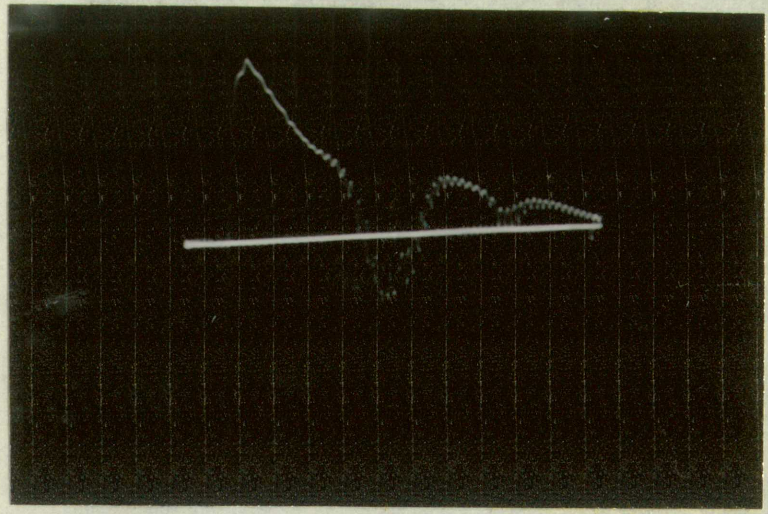
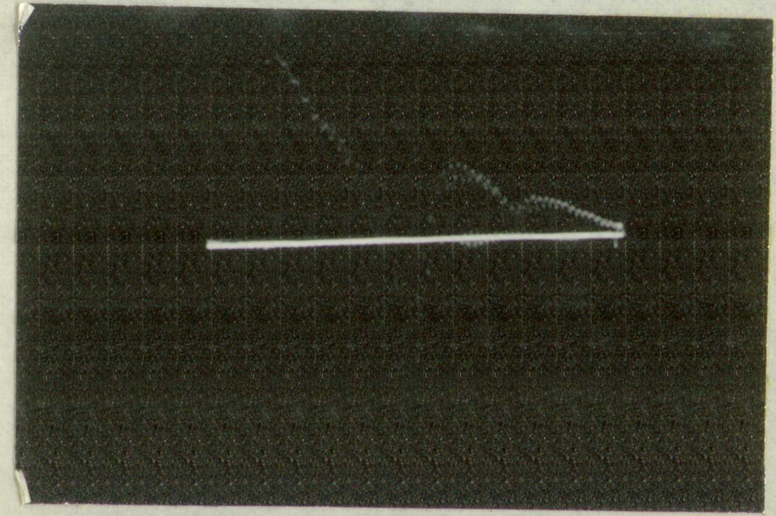
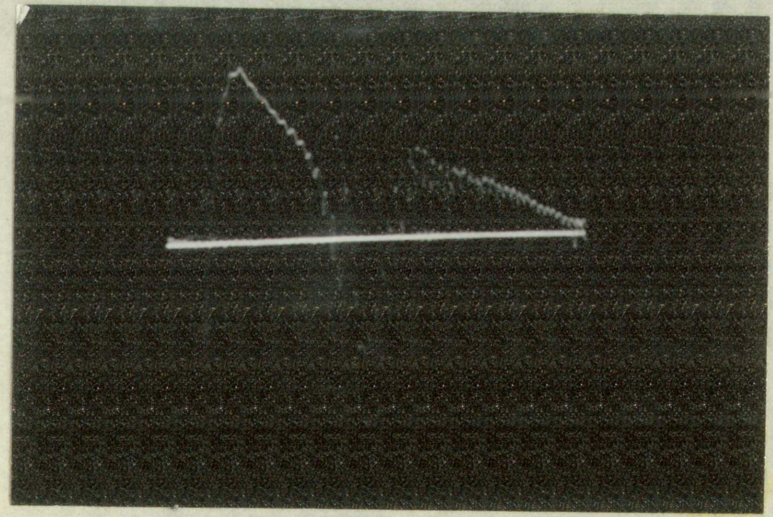
8 G. B. Langwey, Development of a Test Method for Rapid Determination of Octane Ratings of Gasolines, (unpublished Master's thesis, University of New Mexico, 1952)



7:1 COMPRESSION RATIO

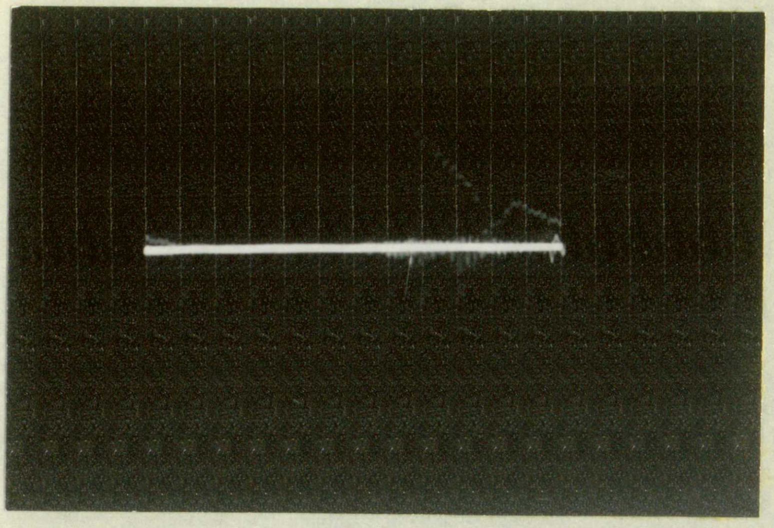


8:1 COMPRESSION RATIO

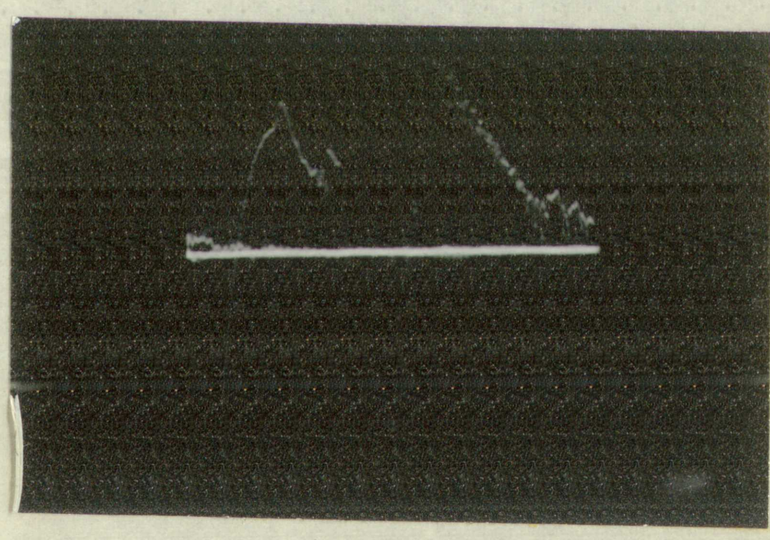


9:1 COMPRESSION RATIO

FIGURE 13: OSCILLOSCOPE PATTERNS OF 85 OCTANE GASOLINE

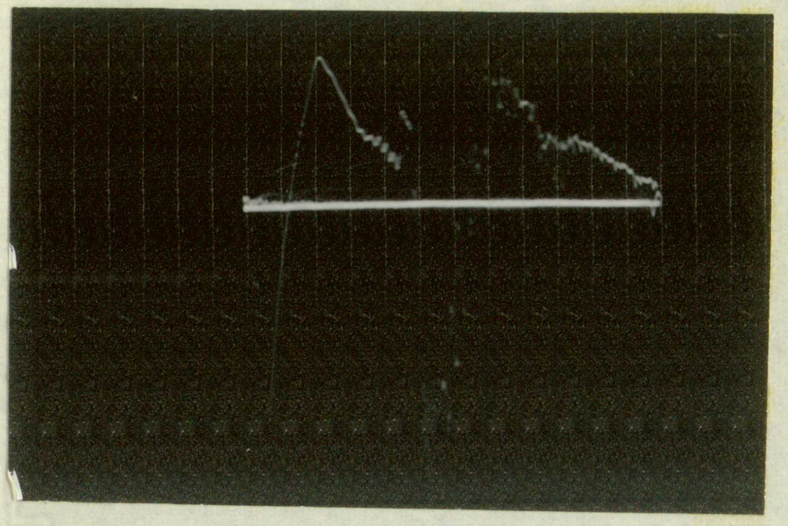


6:1 COMPRESSION RATIO

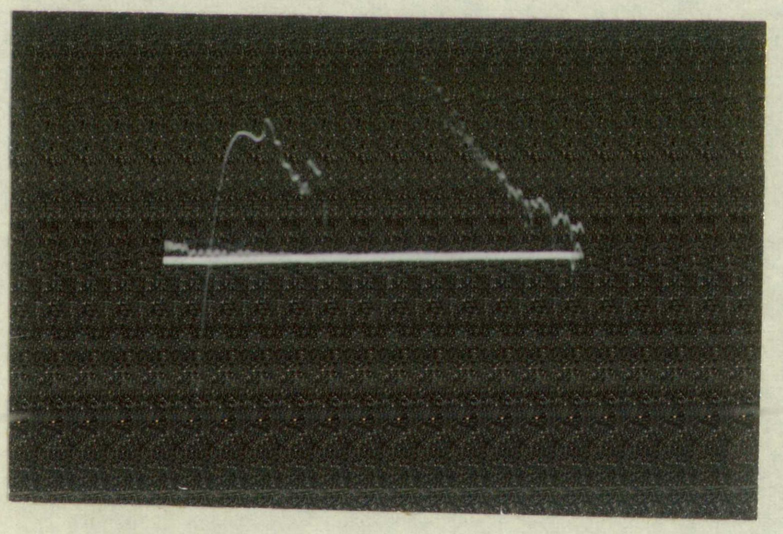


6.5:1 COMPRESSION RATIO

FIGURE 14: OSCILLOSCOPE PATTERNS OF 65 OCTANE GASOLINE



8:1 COMPRESSION RATIO



8.5:1 COMPRESSION RATIO

FIGURE 15: OSCILLOSCOPE PATTERNS OF COMMERCIAL GASOLINE "H"

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

It has been established that an electro-mechanical system, such as was developed during the two years of investigation, may be effectively used to determine octane ratings of gasolines.

A review of the test method, as developed by Mr. C. B. Gangwer[1] through the use of the equipment developed for this thesis, will substantiate the findings of this work in the contention that an effective determination of octane ratings of gasolines can be realized. Further, it has been demonstrated that good results may be obtained in a much shorter time than through the use of the standard ASTM - CFR Test Method.

The following recommendations are offered as possible channels of investigations to improve the equipment used in the proposed test method.[2]

1. The investigation of various commercial pressure elements, including the water-cooled type.

2. The investigation of various indicating elements used in vacuum tube voltmeters to discover one which will

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[1] Gangwer, op. cit.

[2] Gangwer, op. cit.

CHAPTER [illegible]

CONCLUSIONS AND RECOMMENDATIONS

It has been established that an electro-mechanical system, such as was developed during the early stages of investigation, may be effectively used to determine octane ratings of gasolines.

A review of the test method, as developed by Mr. G. D. Gangwer[1] through the use of the equipment developed for this thesis, will substantiate the findings of this work in the contention that an effective new method of octane ratings of gasolines can be realized. Further, it has been demonstrated that good results may be obtained in a much shorter time than through the use of the standard ASTM - CFR Test Method.

The following recommendations are offered as possible channels of investigations to improve the equipment used in the proposed test method.[2]

1. The investigation of various commercial pressure elements, including the water-cooled type.

2. The investigation of various dielectric elements used in vacuum tube systems and in different circuits with

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[1] Gangwer, op. cit.

[2] Gangwer, op. cit.

operate best with the existing equipment.

3. The design of fuel tanks to lead into a common orifice for flow into the intake manifold with the aim of obtaining identical fuel-air ratios for reference and unknown fuels being tested.

4. The investigation of oscilloscope patterns regarding the significance of the varying compositions of pattern lines for different fuels of equal octane numbers.

5. The correlation of the development of this thesis with the Road Test.

The aforementioned avenues of research, if followed, might develop a more refined process which could be adopted as the standard method, after adequate field testing, to measure knock characteristics and determine octane ratings of gasolines.

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