ABSTRACT OF THESIS

DETERMINING AN EFFICIENT EXTENSION COURSE ON IGNITION, CARBURETION, AND SERVICE TESTING

Submitted by
Mannie Ray Wilson

In partial fulfillment of the requirements
for the Degree of Master of Science
Colorado State College
of
Agriculture and Mechanic Arts
Fort Collins, Colorado

August, 1941

Abstract of Thesis

DETERMINING EFFICIENT EXTENSION COURSES ON IGNITION, CARBURETION, AND SERVICE TESTING

by

Mannie Ray Wilson

The problem.--The problem of the present study has been to determine the course content for an evening school course in the Chanute Trade School, Chanute, Kansas, which is to be called "Ignition, Carburetion, and Service Testing".

Analysis of the problem.--The logical solution of the problem of this study involved the following points:

1. Determine if a new occupation does exist that may be called "Ignition, Carburetion, and Service Testing".

2. Determine which group of men could profit by this training.

3. Determine the attitude of the men in the field who could profit from this training.

4. Determine from men in the service field the material which could be used to formulate a course of study in this field for this particular area.

Reasons for selecting the problem.--Throughout many years of direct contact with the automotive service field in the capacity of automobile mechanic, as well as that of foreman of mechanics, and for several years as an instructor of motor-mechanics in a trade school, the writer has realized that ignition, carburetion, and service testing were the outstanding weak points of the average automobile mechanic.

In some communities, because of the weakness of mechanics in this field, the local electrician has stepped in and tried to take care of this service. The writer has heard many mechanics say that it is the electrician's job, but, in his opinion, the local electrician does not have the proper background in automobile repairing upon which to build for this work. This was a question to be settled by this survey.

More and more the modern, high speed, high compression motors used in today's automobiles demand a type of service for efficient performance that can not be given by mechanics unless they are especially trained for this work. Extension training for mechanics, who have had at least one year of practical experience as an automobile mechanic, is a possible solution to this problem.

Procedure and devices.--In order to carry out the objectives of this study it was first necessary to determine the sources of data.

In the search for published data connected with the field of "Ignition, Carburetion, and Service Testing", it was found that there is considerable data dealing with the general repair of the motor car.

This information is all good technical information related to general motor car repair, but the author has failed to find any published data that has been compiled in the field of "Ignition, Carburetion, and Service Testing" for the specific use of the selected group in extension training.

With this in mind it was decided to go to men directly connected with the automobile industry and who were making their living from automotive service, for the necessary data. These men were automobile mechanics, foremen of mechanics, garage owners, manufacturers of automotive service testing equipment, and auto-mechanic instructors.

Questionnaires incorporating questions, and questions on job units, necessary to supply data for this study were submitted, by personal visitation and letter, to members of the first four groups of the preceding paragraph.

It was necessary to set up some criteria or measure by which the data from the questionnaires could be evaluated in order to satisfy the objectives of the study.

The data were evaluated by submitting questionnaires to similar groups in a town of approximately the same size. Also corresponding data from the manufacturers were used to check data received from the groups in the two towns.

The job units of the questionnaires were the starting foundation upon which the course was to be built.

The results obtained from the questionnaires in regard to the job units are given in the following summary table.

Summary Table on Extension Course Content for "Ignition, Carburetion, and Service Testing", as Indicated by All Groups Interviewed.

Legend:

X. Manufacturers of service testing equipment.
C. Garage owners, foremen of mechanics, and mechanics of Chanute, Kansas.
M. Garage owners, foremen of mechanics, and Mechanics of Manhattan, Kansas.

Job Unit Code		X	C	M	Total
Should this course include:					
A. The fundamentals of electricity.	(Yes	7	18	12	37
	(No	1	3	2	6
B. How to trace electrical circuits and locate trouble.	(Yes	8	20	14	42
	(No	0	1	0	1
C. An understanding of storage batteries.	(Yes	8	19	13	40
	(No	0	2	1	3
D. How to rewire cars.	(Yes	7	16	12	35
	(No	1	5	2	8
E. Ignition timing.	(Yes	8	21	14	43
	(No	0	0	0	0
F. The use of motor gauges and synchronizing tools.	(Yes	8	21	14	43
	(No	0	0	0	0
G. The causes of ignition trouble.	(Yes	8	21	14	43
	(No	0	0	0	0
H. An efficient method of trouble shooting.	(Yes	7	21	13	41
	(No	1	0	1	2
I. The fundamentals of coils, condensers, cutouts, and distributors.	(Yes	8	19	11	38
	(No	0	2	3	5
J. Generating circuits.	(Yes	8	18	11	37
	(No	0	3	3	6

Summary Table on Extension Course Content for "Ignition, Carburetion, and Service Testing" as Indicated by All Groups Interviewed. (Concluded)

Job Unit Code		X	C	M	Total
Should this course include:					
K. Starting Motor circuits.	(Yes	8	19	13	40
	(No	0	2	1	3
L. Testing generators.	(Yes	8	18	14	40
	(No	0	3	0	3
M. Testing starting motors.	(Yes	8	18	14	40
	(No	0	3	0	3
N. How fuel pumps and fuel gauges function.	(Yes	8	20	14	42
	(No	0	1	0	1
O. How to repair fuel pumps and fuel gauges.	(Yes	8	21	14	43
	(No	0	0	0	0
P. An elementary knowledge of carburetion.	(Yes	8	20	14	42
	(No	0	1	0	1
Q. Characteristics of standard makes of carburetors.	(Yes	8	21	14	43
	(No	0	0	0	0
R. How to repair standard makes of carburetors.	(Yes	8	21	14	43
	(No	0	0	0	0
S. How to adjust carburetors.	(Yes	8	21	14	43
	(No	0	0	0	0
T. Principles of vacuum gauges as applied to carburetors.	(Yes	8	21	14	43
	(No	0	0	0	0

The job units of the summary table were next broken down into a series of job analysis items.

Seven of the auto-mechanics teachers of Kansas were used as a source of additional items.

Criteria were applied to these items and the items that had no bearing upon the extension course in the field of "Ignition, Carburetion, and Service Testing" were eliminated.

Competent judges were used to pass judgment upon the eliminated items of the job analysis.

From the remaining items of the job analysis the complete course in "Ignition, Carburetion, and Service Testing" was compiled.

The following abbreviated correlation table shows the relationship between the job units, the job analysis of these job units, and the course units:

(A detailed explanation of the table immediately follows its presentation.)

Table XIV. Correlation Between the Questionnaire Job Units, the Job Analysis, and the Course Units

Job Unit	Job Analysis	Job Analysis Additions	Job Analysis Eliminations	Course Units
D	D 1-2-3-4 5	D 6-7	D (2-e) (3-c) (4-e) (5-b)	VI D 1-6-7

(Job Unit "D" was used in this example because it is representative of all of the job units from "A" to "T" inclusive.)

Job Unit "D" in questionnaires "A", "B", "C", and "D" is as follows: "Should the course content include, how to rewire cars?"

Job analysis, D-1-2-3-4-5, is the original job analysis of Job Unit "D" and is as follows:

D. Job analysis.

1. Rewiring circuits.
2. Wire manufacture.
3. Switch design.
4. Switch manufacture.
5. Corona effect.

Job analysis additions, D-6-7, are the job analysis items that were added to Job Unit "D" by the auto-mechanic instructors and are as follows:

D. Job analysis additions.

6. Why renew wires.
7. Reading wiring diagrams.

Job analysis eliminations, D(2-e) (3-c) (4-e)

(5-b), are the job analysis items of Job Unit "D" that were eliminated when the criteria was applied. These items with the criteria are as follows:

D. Job analysis eliminations.

e. 2. Wire manufacture.
c. 3. Switch design.
e. 4. Switch manufacture.
b. 5. Corona effect.

Criteria:

b. This is in the field of engineering.
c. This is in the field of the designing engineer.
e. This is in the field of manufacturing.

Course Unit VI is the course unit in which the remaining job analysis items, D-1-6-7, of Job Unit "D" are incorporated. This course unit with the job analysis items is as follows:

Course Unit VI. Electrical Circuits and Trouble Shooting.

D. Job analysis items.

1. Rewiring circuits.
6. Why renew wires.
7. Reading wiring diagrams.

The final job analysis of all job units, after the criteria was applied, was checked by four authorities in the automotive service field. The changes they made were practically nil.

The job analysis, as completed, was used as a basis upon which to set up the course units for a night school course in "Ignition, Carburetion, and Service

Testing" for the specific use of the selected group previously mentioned.

Summary.--The writer feels the following statements to be justified by the findings of the present study:

1. A new field of endeavor does exist in the automotive service field that may be called "Ignition, Carburetion, and Service Testing".

2. Mechanics instead of electricians should be trained for this new field.

3. Mechanics as a class are willing to take advantage of additional extension training that will elevate their status and increase their earning capacity.

4. Foremen recognize the lack of technical knowledge and skill in this field on the part of mechanics.

5. Foremen favor additional training of this nature for mechanics.

6. Job units for the course content of extension training in this field, as determined by the results of this study, is indicated as being acceptable to those groups connected with the automotive service field.

7. The job analysis of the job units, as determined by the study, affords the basis for the job analysis items that were incorporated in an extension course of study in the field of "Ignition, Carburetion,

and Service Testing".

8. The course of study in the field of "Ignition, Carburetion, and Service Testing", as set up in the body of the thesis, is the answer to the major question of this study, which was to determine the course content for an evening school course in this field for the Chanute Trade School, Chanute, Kansas.

Recommendations.--The writer recommends the following:

1. That extension training in "Ignition, Carburetion, and Service Testing" be offered in night school work in the Chanute Trade School, Chanute, Kansas.

2. That the course content of this course be that which is set up in the body of the thesis, the units of which have been found acceptable to the different groups in the automotive service field that are directly connected with automotive service.

3. That only those mechanics who have had one year of practical experience working at the trade be admitted to the course.

T H E S I S

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COLORADO STATE COLLEGE

OF

AGRICULTURE AND MECHANIC ARTS

JULY 18 1941

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY MANNIE RAY WILSON

ENTITLED DETERMINING AN EFFICIENT EXTENSION COURSE ON IGNITION, CARBURETION, AND SERVICE TESTING

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

MAJORING IN TRADE AND INDUSTRIAL EDUCATION

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ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Professor Yingling, Professor Frasier, Doctor Betts, and Doctor Prosser, of Colorado State College, for their interest and guidance during the preparation of this thesis. The writer is greatly indebted to Wilfred M. Beach, of the Roy M. Heath Motor Car Company, Salina, Kansas, and Mr. Malcom D. Darrow, of the Chanute Trade School, Chanute, Kansas, for suggestions in preparing the questionnaires and aid in interpreting the data. The writer is also indebted to Doctor C.V. Williams, of the Department of Education, Kansas State College, Manhattan, Kansas, Professor Louis M. Jorgenson, of the Department of Electrical Engineering, Kansas State College, Manhattan, Kansas, and to Instructor Leo A. Moore, of the Shop Practice Department, Kansas State College, Manhattan, Kansas, for valuable assistance and suggestions in the compilation of the lesson units.

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DETERMINING AN EFFICIENT EXTENSION COURSE ON IGNITION, CARBURETION, AND SERVICE TESTING

Chapter I

INTRODUCTION

The problem.--The problem of the present study has been to determine the course content for an evening school course in the Chanute Trade School which is to be called, "Ignition, Carburetion, and Service Testing."

The need for and background of the study.--It has been recognized by some observers in the automotive field and others closely associated with it, that possibly a new field of endeavor has sprung up in the last few years that is closely related to that of an automobile mechanic. This new occupation, if there is such, probably will be followed by men closely identified with the automotive field and grounded in the fundamentals of motor mechanics.

Within the last five years the public has been demanding cars with quicker and better acceleration, more road speed, more power from smaller engines, and more gasoline economy. These demands have forced service men to give the public better service in motor testing, ignition, and carburetor work.

For the mechanic, it means that if he is to be able to give the service demanded to keep the modern high speed, high compression motors working at their highest efficiency, he must have additional schooling and training that will add to his present job intelligence, occupational intelligence, and social intelligence.

The field is new and the rewards will be given to the younger men. For this reason young men who have already entered the trade and have had at least one year of experience in the automotive field and have ambition to advance in their profession will be the logical persons to train for the more difficult field of "Ignition, Carburetion, and Service Testing."

The writer's background in motor mechanics.--Over a period of years from 1911 to 1917 and for one year after the war, the writer spent seven years in the actual servicing and repairing of motor cars, tractors, and trucks, A part of this time was spent as a motor mechanic and part as a foreman of motor mechanics. Small shops employing only three men were worked in during this period, as well as large service stations having as many as 35 employees. During this period of time many of the 500 or more different automobiles carrying names long since forgotten, passed through those shops--Dort, Rambler, Krit, Maxwell, Cameron, Jackson, Fuller, Gleason, Mason, Silent Northern, Great Smith, Carnation, Queen, Regal--to mention only a few.

During this time many changes have taken place in carburetors and ignition systems and these two pieces of automotive equipment gave mechanics a great deal of trouble. Carburetors and ignition systems were two phases of motor mechanics that were not very well understood, for mechanics had no fundamental background upon which to solve problems arising from carburetor and ignition trouble. It was no trouble to find men who understood the mechanics of bearing adjustment, valve grinding, etc., for every steam engineer and many blacksmiths had had some experience of this nature.

The first of these automobiles were equipped with jump spark ignition, and about the time the writer and his fellow workmen became familiar with the intricate details of this system, the low tension magneto was added. Then came the self starter to add to the woes of the mechanic. Following this came the high tension magneto and then the battery ignition system.

Through these years the writer realized his own, as well as other mechanic's, lack of knowledge in the fundamentals of electricity and gases, and decided to take a full four-year course in electrical engineering which was completed in 1924.

This was followed by nine years with the

Chanute Trade School, Chanute, Kansas, during which time the writer taught motor mechanics, on a vocational basis, to high school students.

In all of these years of contact with the service department of the motor car industry, it has been brought to the writer's attention almost daily that carburetion, ignition, and testing have been the fundamental weaknesses of a large percent of the mechanics working on motor cars.

Chapter II

REVIEW OF LITERATURE

In any new field of endeavor such as extension training in "Ignition, Carburetion, and Service Testing", some recognized method or methods must be used to gather the essential material pertaining to that work and to organizing this material into usable units for presentation to the students.

With the growth of vocational trade training in the United States a standardized method of determining the fundamental jobs one must be able to do and the information one must have in order to learn a trade, has been used quite successfully by educators in the field of vocational education.

Allen (1:42-45), one of the pioneers in the field of vocational education, may be given much credit for formulating this method, and makes the following recommendations:

That the investigator analyze the trade into all the jobs one must be able to do and all the information one must have to learn the trade. This must be done with the aid and assistance of men who are masters of that trade. The trade is then divided into units having a common set of learning difficulties. He determines the causes of learning difficulties which in turn affect the order of instruction. The learning difficulties may then be organized on successive levels. The objectives are stated for each unit and for each level of difficulty. He arranges the jobs in instructional order. He prepares instruction sheets for each job. The instruction sheet contains a statement of the objective, sketches of the work at various stages of progress, the order of operations, and questions requiring reasoning about the operations.

At a later date, Selvidge (13:24-36), working independently, developed a different technique. The outstanding characteristics of this technique and the recommendations are as follows:

That a trade should be analyzed into basic "Unit Operations", not jobs. An operation is a fundamental mechanical process of the trade and a list of these operations is the alphabet of the trade. For example, the trade of plumbing is divided into forty unit operations; bookkeeping into forty-six unit operations. Some unit operations in the plumbing trade are: (1) making a plan and layout sketch; (2) making a bill of material and tools needed for the job; (3) digging a trench; and (4) laying tile sewers; to list only a few of the elementary or beginning unit operations. Each unit operation is analyzed to indicate what the learner must do to acquire the necessary skill. For instructional purposes the directions are printed as operation sheets. For each trade, there are as many operation sheets as there are unit operations discovered in the analysis. Now when the student is confronted with a particular job in the plumbin g trade, he proceeds to select from the total operations those which are required in his particular, immediate job. Furthermore, he arranges these operations in their natural sequence. By consulting one operation sheet after the next and following the instructions, he completes the job. Thus, while the unit of analysis is the unit operation, the unit of instruction is the job. The learner works individually but the group may be called together for demonstrations.

Charters (5:38-39) states that there are at least four methods of making a job analysis and all should be taken into consideration in the pursuance of this task. The methods are as follows:

> 1. Introspection.--This is the method used by the person who is already familiar with the job whose duties are to be analyzed. The printer who purposes making an analysis of his occupation will naturally begin by listing all of the duties that have come within his experience.
>
> 2. Interviewing.--By this second method the interviewer asks the individual on the job to give a list of his duties; after the list has been jotted down by the interviewer and typewritten, it is returned to the worker for correction. Other workers on the same job are also interviewed and the lists compared. In every case a man in authority who knows the job is asked to check the list and add whatever items have been left out.

3. Working on the job.--The person making the analysis works on the job and carries through the operations himself.

4. Questionnaire.--The written questionnaire is sometimes used as a method of analysis, but it is not satisfactory in yielding more than a preliminary list. It is so inferior to the interview that its use is not recommended except in extreme cases.

Allen (1:66-67) gives another term closely related to "Unit Operations" used by Selvidge (13:24-36). This term is "Job Block" and is defined as follows:

A job block means a group of jobs which all offer to a learner the same kind of learning difficulties. Such a job block may, in itself, represent a complete course of training or it may be one of a number of blocks that are included in the required training course.

Upon close analysis there is found to be but little difference in the meaning of the two terms "Unit Operations" and "Job Blocks".

Common usage in the field of vocational education has evolved from these two terms the word "Job Unit", which also has the same meaning. This is significant on progress charts published by the American Technical Society. Still another name for the same representative grouping of skills or duties is used by Prosser (12:136); this name is "Instructional Block".

Although the present study was completed in 1938, Stead (15:96) in 1940 uses the work "Battery" in the same sense that the work "Job Unit" is used in this study.

The unit courses of this study are based upon the job units and the job analysis of the trade. Prosser (12:136) gives an indication of this correlation in the following words:

> In still other trades, this division into branches and corresponding instructional blocks might be made on the basis of the kind of material used. The plumbing trade, for example, deals with iron or brass pipe, vitrified pipe, and lead pipe. These differ so much in their working properties as to make different demands in skill and knowledge. From this viewpoint these materials might well be considered as branches of the trade and therefore as industrial blocks within each of which a special unit course or courses could be organized.

In the presentation of any instructional material there is always the question of evaluating this material in the order of learning difficulty and determining what course units should be given first. Charters (5:155) states that:

> Ease of learning affects the sequence of the material in the curriculum. Obviously, other things being equal, the easier items are taught first; and, other things not being equal (as for instance, when items of somewhat greater difficulty possess very much greater interest), interest rather than ease will be the deciding factor in placing the item.

Allen (1:92) places the responsibility of selecting the order of learning difficulty of instructional material with the instructor. This is indicated in the following quotation:

> The instructor in the illustration used in the last chapter has now got his checking level specifications and has the list of jobs he intends to teach in that job block. The next step is to determine in what order these jobs can be arranged to secure best practical instructional order.

Selvidge (13:27) has a different perspective of this problem which is given in the following paragraphs:

> The purpose in analyzing a trade is to discover and list the things to be taught, but neither relative difficulty nor teaching order need be considered in making the list. It is safe to say that in case of more than half the operations of a trade, it is impossible to determine which operation is the most difficult to perform. It is also true that an operation might be difficult for one person and easy for another. In practice the easy and difficult come together.
>
> The list of operations cannot be arranged in the order in which the operations are to be taught unless we wish to teach them entirely on the basis of a series of exercises. This is precisely what we should not wish to do. If the list were arranged to fit a series of exercises it would be found out of order for the first practical job.

Kimball (8) and other physicists give the units of elementary electricity as a basis for the work in electricity which is to follow in the text. This plan was used in placing the course units in "Ignition, Carburetion, and Service Testing", as the unit course in elementary electricity is basic for many of the unit courses which follow. The order of presentation of the rest of the unit courses could be made on the basis of interest.

Due to the limited number of effective questionnaires possible in a study of this kind, the author's choice of type was influenced by Charters (5:134-135) in the following statement:

> In all cases the oral questionnaire is preferable to the written form. This means

> that when the sender becomes an interviewer and asks the questions orally he will obtain more reliable answers. He can clear up misconceptions of his meaning, and can supplement his questions by others which will elicit more definite answers.

The authors of the foregoing excerpts, by suggesting ways of gathering and using occupational information for an extension course for adult workers in "Ignition, Carburetion, and Service Testing", have been of great value to the present writer.

Chapter III

MATERIALS AND METHODS

In the search for published data connected with the field of "Ignition, Carburetion, and Service Testing," it was found that there is considerable data dealing with the general repair of the motor car. And ignition, carburetion, and testing, as a part of motor car repair, is treated to a considerable extent. Packer (11), Kuns (10), Dyke (7, 8), motor car manufacturers (2, 6), and others have, in a general way, given information on work in the field of "Ignition, Carburetion, and Service Testing."

This information is all good technical information related to general motor car repair, but the author has failed to find any published data in the field of "Ignition, Carburetion, and Service Testing," for the specific use of the selected group previously mentioned.

With this in mind it was first necessary to set up some ground work or foundation upon which to build a course of study for this group.

The author's knowledge and experience gained in the field of general motor car repair, over a period of years, supplemented by published literature in the automotive field and conversations with two or three of the older men in the automotive repair field, were used to set up as a foundation a list of job units. A job unit is representative of a number of items of work or study (or both) into which any trade may be divided for various purposes. The large number of items into which the trade is divided is called a job analysis. A job unit may consist of only a few items or it may consist of a large number of items of the job analysis. Job units vary in the number of job analysis items because there is a difference in the number of component parts into which different job units may be broken down.

Questionnaire to garage owners.--The list of job units was used to set up a tentative interview questionnaire which would incorporate this list. This tentative questionnaire was corrected for content and structure, and became in its final form questionnaire "A" shown on an accompanying page.

Questionnaire "A" was used in personal visits to those men connected with the service departments of the automotive industry who could supply the necessary information for this study. Those most interested and the ones the author felt could furnish the most reliable data in the occupational field of "Ignition, Carburetion, and Service Testing," were automobile mechanics, foremen of mechanics, owners of garages, and manufacturers of automotive service testing equipment.

Questionnaire "A" was submitted to and approved by two professors 1/ of Colorado State College for general form. This questionnaire was next submitted to two competent automobile mechanics for possible points that had been omitted or that should be included, and suggested corrections were made. After trying this out on a few cases, question number two was changed to its present form, which is more direct than the original question.

1/ Dr. Charles R. Prosser and Prof. P.G. Frasier.

QUESTIONNAIRE "A"
(Garage Owner Questionnaire)

1. If your mechanics had a chance to improve their technical knowledge in a night school course should it include:

A. The fundamentals of electricity. Yes___ No___

B. How to trace electrical circuits and locate trouble. - - - - - - - Yes___ No___

C. An understanding of storage batteries. - - - - - - - - - - - Yes___ No___

D. How to rewire cars. - - - - - - - - Yes___ No___

E. Ignition timing. - - - - - - - - - Yes___ No___

F. The use of motor gauges and synchronizing tools. - - - - - - - - Yes___ No___

G. Causes of ignition trouble. - - - Yes___ No___

H. An efficient method of trouble shooting. - - - - - - - - - - - - - Yes___ No___

I. The fundamentals of coils, condensers, ammeters, cutouts, and distributors. - - - - - - - - - - Yes___ No___

J. Charging circuits. - - - - - - - - Yes___ No___

K. Starting motor circuits. - - - - Yes___ No___

L. Testing generators. - - - - - - - - Yes___ No___

M. Testing starting motors. - - - - Yes___ No___

N. How fuel gauges and fuel pumps function. - - - - - - - - - - - - Yes___ No___

O. How to repair fuel pumps and fuel gauges. - - - - - - - - - - - - - Yes___ No___

P. An elementary knowledge of carburetion. - - - - - - - - - - - - Yes___ No___

Q. Characteristics of standard makes of carburetors. - - - - - - - - - Yes___ No___

QUESTIONNAIRE "A" (concluded)

R. How to repair standard makes of carburetors. - - - - - - - - - - Yes___ No___

S. How to adjust carburetors. - - - Yes___ No___

T. Principles of vacuum gauges as applied to carburetors. - - - - Yes___ No___

2. Do you recognize that there is a new occupation in the automobile field that might be called "Ignition, Carburetion, and Testing?" - - - - Yes___ No___

3. Should mechanics or electricians be trained for this work? - - - - - - ________

The questionnaire was then used and filled out in personal interviews with six garage owners in Chanute, Kansas.

Questionnaire to shop foremen.--Questionnaire "B", which follows, was prepared for shop foremen. This questionnaire contains all of the job units of questionnaire "A" and, in addition, two questions which were added to determine the foreman's attitude in regard to the average mechanic's ability in ignition, carburetion, and testing, and also to determine if foremen thought it would relieve their load of responsibility to have better trained mechanics. If they did, it was felt that they would urge their mechanics to take advantage of any opportunity to improve their skill in this field.

This questionnaire was submitted to the same persons mentioned in a previous paragraph for checking, and the necessary corrections were made.

The questionnaire was used in connection with five personal interviews held with shop foremen of Chanute, Kansas.

QUESTIONNAIRE "B"
(Foreman Questionnaire)

1. Please rate the average mechanic on ignition, carburetion, and service testing. - - - - - - - - - - - - - - -Weak ___ Strong__

2. Would it relieve your load of responsibility if your mechanics were better posted on ignition, carburetion, and testing? - - - - - - - - - - - - Yes___ No___

3. If your mechanics had a chance to improve their technical knowledge in a night school course should it include:

   A. The fundamentals of electricity. Yes___ No___

   B. How to trace electrical circuits and locate trouble. - - - - - - - Yes___ No___

   C. An understanding of storage batteries. - - - - - - - - - - - - - - Yes___ No___

   D. How to rewire cars. - - - - - - - - Yes___ No___

   E. Ignition timing. - - - - - - - - - Yes___ No___

   F. Use of motor gauges and synchronizing tools. - - - - - - - - Yes___ No___

   G. Causes of ignition trouble. - - - Yes___ No___

   H. An efficient method of trouble shooting. - - - - - - - - - - - - - Yes___ No___

   I. The fundamentals of coils, condensers, ammeters, cutouts, and distributors. - - - - - - - - - - Yes___ No___

   J. Charging circuits. - - - - - - - - Yes___ No___

   K. Starting motor circuits. - - - - Yes___ No___

   L. Testing generators. - - - - - - - - Yes___ No___

   M. Testing starting motors. - - - - Yes___ No___

   N. How fuel gauges and fuel pumps function. - - - - - - - - - - - - - Yes___ No___

QUESTIONNAIRE "B" (concluded)

O. How to repair fuel pumps and fuel gauges. - - - - - - - - - - - - - - Yes___ No___

P. An elementary knowledge of carburetion. - - - - - - - - - - - - - Yes___ No___

Q. Characteristics of standard makes of carburetors. - - - - - - - - - Yes___ No___

R. How to repair standard makes of carburetors. - - - - - - - - - - Yes___ No___

S. How to adjust carburetors. - - - Yes___ No___

T. Principles of vacuum gauges as applied to carburetors. - - - - Yes___ No___

4. Do you recognize that there is a new occupation in the automobile field that might be called "Ignition, Carburetion, and Service Testing?" Yes___ No____

5. Should mechanics or electricians be trained for this work? - - - - - - - ____________

<u>Questionnaire</u> <u>to</u> <u>automobile</u> <u>mechanics</u>.--Questionnaire "C", which follows, was prepared for automobile mechanics and contains all of the job units as well as two of the questions of the previous questionnaire. Three different questions were included in regard to whether or not they liked to work on automobiles, if they would choose this vocation again as a trade, and if they would be interested in improving their technical knowledge in this field if they had a chance to do so. The first two questions were included, for it was felt by the author that if both of these questions were answered in the negative by all mechanics the data would be worthless for, as an instructor of auto mechanics, he has heard many times this expression from men working at

the trade: "Why train boys to be automobile mechanics, as it is the most disagreeable trade in existence?" The third question was added to determine the degree to which an extension course would be attended by men working at the trade.

This questionnaire was submitted to the same persons mentioned in a previous paragraph for checking and the necessary corrections made.

This questionnaire was used in connection with ten personal interviews held with automobile mechanics of Chanute, Kansas.

QUESTIONNAIRE "C"
(Auto Mechanic Questionnaire)

1. Do you like to work on automobiles? Yes___ No___

2. Would you choose this again as a trade? Yes___ No___

3. Would you improve your technical knowledge on carburetion, ignition, and testing, if you had a chance? - - - Yes___ No___

4. Should it include:

   A. The fundamentals of electricity. Yes___ No___

   B. How to trace electrical circuits and locate trouble. - - - - - - - - Yes___ No___

   C. An understanding of storage batteries. - - - - - - - - - - - Yes___ No___

   D. How to rewire cars. - - - - - - - - Yes___ No___

   E. Ignition timing. - - - - - - - - - Yes___ No___

   F. The use of motor gauges and synchronizing tools. - - - - - - - - Yes___ No___

   G. Causes of ignition trouble. - - - Yes___ No___

   H. An efficient method of trouble shooting. - - - - - - - - - - - - - Yes___ No___

   I. The fundamentals of coils, condensers, ammeters, cutouts, and distributors. - - - - - - - - - - Yes___ No___

   J. Charging circuits. - - - - - - - - Yes___ No___

   K. Starting motor circuits. - - - - Yes___ No___

   L. Testing generators. - - - - - - - - Yes___ No___

   M. Testing starting motors. - - - - Yes___ No___

   N. How fuel gauges and fuel pumps function. - - - - - - - - - - - - - Yes___ No___

   O. How to repair fuel pumps and fuel gauges. - - - - - - - - - - - - - - Yes___ No___

QUESTIONNAIRE "C" (concluded)

P. An elementary knowledge of carburetion. - - - - - - - - - - - - - - - - Yes___ No__

Q. Characteristics of standard makes of carburetors. - - - - - - - - - - - - - Yes___ No__

R. How to repair standard makes of carburetors. - - - - - - - - - - - - - - - Yes___ No__

S. How to adjust carburetors. - - - - - - Yes___ No__

T. Principles of vacuum gauges as applied to carburetors. - - - - - - - - - - - - Yes___ No__

5. Do you recognize that there is a new occupation in the automobile field that might be called "Ignition, Carburetion, and Service Testing?" - - Yes___ No__

6. Should mechanics or electricians be trained for this work? - - - - - - - - - Yes___ No__

Questionnaire to manufacturers.--It was suggested by Dr. C. A. Prosser, of Colorado State College, that manufacturers of automotive service testing equipment might be a reliable source of data, and that at least four letters including questionnaires should be sent to them to be filled out and returned.

Questionnaire "D", prepared for use with these manufacturers, and a copy of the letter are shown below.

In the judgment of several mechanics, the main points to be considered in the manufacturers' questionnaire were their views in regard to a new occupation in the automotive service field, if mechanics need additional training before using their equipment, and what should be the course content for extension training in this field. The job units included in Questionnaire "A" were also included in this questionnaire. The letter asked each manufacturer to include any additional comments or course content.

This questionnaire and the letter to the manufacturers of service testing equipment were checked by two competent mechanics and the necessary corrections made.

Eight of these letters and questionnaires were sent and eight were returned filled out. The letters received with the questionnaires indicate that these men are awake to the possibilities of extension training of this nature. No additional course content was suggested by any of these manufacturers.

QUESTIONNAIRE "D"
(Manufacturers' Questionnaire)

1. As a manufacturer of automotive service testing equipment, do you recognize that there is a field of endeavor or vocation where men make their living in what might be called "Ignition, Carburetion, and Service Testing?" - Yes___ No___

2. Are all men who term themselves mechanics in the automotive field qualified to take your equipment, without additional training, and set themselves up as experts in "Ignition, Carburetion, and Service Testing?" - - - - - - - - - - - - - - - Yes___ No___

3. Would you recommend that the majority of mechanics, including the beginners, have some additional training before they set themselves up as experts in this field? - - - - - - - - Yes___ No___

4. As a definite objective to encourage men to enter this field should the course content include:

   A. The fundamentals of electricity. Yes___ No___

   B. How to trace electrical circuits and locate trouble. - - - - - - Yes___ No___

   C. An understanding of storage batteries. - - - - - - - - - - - - Yes___ No___

   D. How to rewire cars. - - - - - - - Yes___ No___

   E. Ignition timing. - - - - - - - - - Yes___ No___

   F. The use of motor gauges and synchronizing tools. - - - - - - - Yes___ No___

   G. Causes of ignition trouble. - - Yes___ No___

   H. An efficient method of trouble shooting. - - - - - - - - - - - - Yes___ No___

   I. The fundamentals of coils, condensers, ammeters, cutouts, and distributors. - - - - - - - Yes___ No___

QUESTIONNAIRE "D" (concluded)
(Manufacturers' Questionnaire)

J. Charging circuits. - - - - - - - - - Yes___ No___

K. Starting motor circuits. - - - - Yes___ No___

L. Testing generators. - - - - - - - Yes___ No___

M. Testing starting motors. - - - - Yes___ No___

N. How fuel gauges and fuel pumps function. - - - - - - - - - - - - Yes___ No___

O. How to repair fuel pumps and fuel gauges. - - - - - - - - - - - Yes___ No___

P. An elementary knowledge of carburetion. - - - - - - - - - - - - Yes___ No___

Q. Characteristics of standard makes of carburetors. - - - - - - - - Yes___ No___

R. How to repair standard makes of carburetors. - - - - - - - - - - - Yes___ No___

S. How to adjust carburetors. - - - Yes___ No___

T. Principles of vacuum gauges as applied to carburetors. - - - Yes___ No___

The sample letter which was submitted to manufacturers of service testing equipment follows:

CHANUTE TRADE SCHOOL
Chanute, Kansas

July 15, 1937

The Blank Heat Control Company
9123 Inman Avenue
Cleveland, Ohio

Dear Sirs:

We are interested in the possibilities of a night school course for a town of ten to twelve thousand inhabitants. This course, which will be called "Ignition, Carburetion, and Service Testing," is to be given to those beginners in the automotive field who wish to advance in their profession.

Will you please answer the enclosed questionnaire and return it as soon as possible.

Any comments you wish to give, or additional course content you wish to send will be greatly appreciated.

I would like to receive some literature on your equipment.

Yours truly,

MRW/JA M. R. Wilson
Enc.

Questionnaires "A", "B", and "C" were next submitted, by personal interview, to five garage owners, three foremen, and six automobile mechanics, respectively, in Manhattan, Kansas, a town of about the same size as Chanute, Kansas. Five Questionnaires were received from garage owners, three from foremen, and six from mechanics. These were to be used in checking the results received from Chanute, Kansas, and to determine if the data could be used to advantage.

After collecting the data from the two towns it was recorded. The recorded data gave the specific job units that were to be used in the course of study.

It was then essential to set up a job analysis break down of each job unit that stood the test and to determine by some criteria what material of each job unit should go into the course of study and what should not.

Some criteria were necessary because any job unit that might be mentioned, for instance, the job unit on generators will call forth from any group dealing with generators a great many items that could be included as a job analysis of generators and a great many items that could not be included for they might be in the field of engineering or chemistry instead of the service field.

The author's experience and information derived from consultation with other men connected with the automotive service field, in the same manner as set forth at the beginning of this chapter, as well as information gained from available literature in the field dealing with ignition, carburetion, and service testing such as textbooks, service bulletins, and shop manuals in the field of engineering, physics, and automotive service repair were used to make a job analysis break down in the field of "Ignition, Carburetion, and Service Testing," under each job unit.

Every item that had a remote connection with this field was included in the list.

This list of items for a job analysis break down in the field of "Ignition, Carburetion, and Service Testing," was next submitted in turn to several of the outstanding teachers of motor mechanics in the state of Kansas. Each one was asked to add any items to the list that he deemed necessary for a job analysis break down in this field. The additional items submitted by each man were added to the list and the list submitted to the next man until in three cases no additional items were added to the list.

All of the items submitted, including the original list, were tabulated according to the job unit to which they were related.

Keeping in mind the fact that this course was to be prepared for men who are working as motor mechanics and not for engineers, chemists, manufacturers, or men in other service fields, the author eliminated from this list such items as he judged from past experience did not have a direct bearing on the extension training to be given to these mechanics.

These items and the reasons for their elimination are shown in the appendix.

The complete list, those items proposed for inclusion as well as those items proposed for elimination, together with the reasons for the elimination, was next submitted in separate conferences to Mr. Wilfred M. Beach who is an outstanding mechanic in Salina, Kansas, a town of 22,000 population, and to Mr. Malcom D. Darrow, the motor mechanic instructor in the Chanute Trade School. The complete list was also checked by Mr. L.A. Moore, a former Kansas motor mechanic instructor, but at the present time employed as a welding instructor in the Shop Practice Department of Kansas State College, Manhattan, Kansas; and by Mr. V.H. Stroud, the motor mechanic instructor in the Hutchinson, Kansas, High School.

Further additions or eliminations of items in the job analysis break down from these conferences were practically nil.

Furthermore, the questionnaire submitted to the eight manufacturers of automotive service testing equipment requested that they submit additional items if they saw a need for more. That they did not submit any additional items, is further evidence that no essential matter had been eliminated by the author or the judges mentioned.

The revised job analysis items under each job unit was used as a basis for setting up unit courses to be used in extension classes in the Chanute Trade School, Chanute, Kansas.

The author's experience in teaching a trade caused him to use a method outlined by Selvidge (13) in setting up the units of the course. This method lends itself very well to presenting technical information and skill to men taking extension training.

The course units parallel quite closely the job units with the exception that in a few cases a job unit may be so large that it will include several course units. And on the other hand several job units may be so small that they will all be included in one course unit.

A study of this nature cannot be perfect, for the towns upon which the study is based are limited in size. This in turn limits the number of reliable questionnaires that could be obtained. In an agricultural state, such as Kansas, the limit is soon reached in the number of auto mechanic teachers who could be used in checking and contributing to a job analysis outline. But for this particular area the results were quite applicable.

Chapter IV

PRESENTATION AND INTERPRETATION OF DATA

The two towns, Chanute, Kansas, and Manhattan, Kansas, from which the data were collected are about the same in size and lie in the midst of an agricultural section. Some industry is found in each town, but not enough to classify it as an industrial town.

On the following pages the data from questionnaires "A", "B", "C", and "D" are broken down into component parts and treated separately. In the collection of data, four main groups were dealt with, namely: manufacturers, garage owners, foremen of mechanics, and automobile mechanics. In each table will be found data pertaining to similar groups of men from Chanute, Kansas, and Manhattan, Kansas, and in some cases corresponding data pertaining to all groups.

A total of 43 questionnaires were received from which the data were tabulated.

Tables 1 to 3, inclusive, contain information obtained from mechanic's questionnaire "C".

Table 1.--MECHANIC'S ATTITUDE TOWARD AUTOMOBILE REPAIR WORK

(Question: Do you like to work on automobiles?)

Persons answering	Number answering	
	Yes	No
Mechanics of Chanute, Kansas - - - -	8	2
Mechanics of Manhattan, Kansas - - -	6	0
Total - - - - - - - - - - - - - -	14	2

Table 1 contains the answers to the first question submitted to automobile mechanics. This question was, "Do you like to work on automobiles?" Ten mechanics of Chanute, Kansas, were interviewed. Eight answered this question in the affirmative, and two answered this question in the negative. Six mechanics of Manhattan, Kansas, were interviewed on this same question, and six answered this question in the affirmative.

This question has a direct bearing on the results of all of the questions on the mechanic's questionnaire, in that it was felt that only those mechanics who liked to work on automobiles would give a truthful answer to the other questions on the questionnaire. The results, indicated by Table 1, signify that the majority of the mechanics interviewed were of this type.

Table 2.--MECHANIC'S ATTITUDE TOWARD AUTOMOBILE REPAIR WORK AS A VOCATION

"Question: Would you choose this work again as a trade?"

Persons answering	Number answering	
	Yes	No
Mechanics of Chanute, Kansas - - -	5	5
Mechanics of Manhattan, Kansas - -	4	2

Evidently, from the results tabulated in Table 2, mechanics do not have a high regard for their vocation.

Table 3.--MECHANIC'S ATTITUDE TOWARD ADDITIONAL TRAINING FOR THEMSELVES

"Question: Would you improve your technical knowledge on ignition, carburetion, and service testing, if you had a chance?"

Persons answering	Number answering	
	Yes	No
Mechanics of Chanute, Kansas - - - -	10	0
Mechanics of Manhattan, Kansas - - -	6	0

It is the concensus of these mechanics that they could profit by additional training in the field of ignition, carburetion, and service testing and would take advantage of such training, providing it was offered in a nearby school at such a time as they could avail themselves of it.

Tables 4 and 5 contain information that was obtained from the foreman questionnaire "B".

Table 4.--FOREMEN'S RATING OF MECHANICS IN THE FIELD OF IGNITION, CARBURETION, AND SERVICE TESTING

Persons answering	Number answering	
	Weak	Strong
Foremen's rating of mechanics in Chanute, Kansas - - - - - - - - - - -	5	0
Foremen's rating of mechanics in Manhattan, Kansas - - - - - - - - - -	3	0

Table 4 indicates that there was no disagreement among foremen as to the ability of mechanics in the more difficult phases of automotive repair work.

Table 5.--THE OPINION OF FOREMEN AS TO WHETHER MECHANICS, SERVICE TRAINED IN IGNITION, CARBURETION, AND SERVICE TESTING, WOULD LIGHTEN THE FOREMAN'S LOAD

Persons answering	Number answering	
	Yes	No
Foremen of Chanute, Kansas - - - - -	5	0
Foremen of Manhattan, Kansas - - - -	3	0

In all cases an affirmative answer to the above question, as shown in Table 5, from foremen of Chanute, Kansas, and from Manhattan, Kansas, would indicate that foremen would appreciate any method by which their men could be raised to a higher level of efficiency.

Tables 6 and 7 contain information that was obtained from questionnaire "D" submitted to manufacturers of automotive service testing equipment.

Table 6.--EVALUATION, BY MANUFACTURERS, OF THE TRAINING OF THE AVERAGE MECHANIC

Question answered	Number answering	
	Yes	No
2. Are all men who term themselves mechanics in the automotive service field qualified to take your equipment, without additional training, and set themselves up as experts in "Ignition, Carburetion, and Service Testing?" - -	0	8

Table 6 indicates that the title of "Automobile Mechanic" does not qualify a man to handle all of the tools connected with the different phases of automotive repair.

Table 7.--THE RECOMMENDATION OF MANUFACTURERS CONCERNING EXTENSION TRAINING FOR MECHANICS

Question answered	Number answering	
	Yes	No
3. Would you recommend that the majority of mechanics, including the beginners, have some additional training before they set themselves up as experts in this field? - - - - - - - - - - - - - -	8	0

Table 7 indicates that there is unity of agreement among manufacturers of automotive service testing equipment as to the need of additional training by mechanics before they would be qualified as experts in the field of "Ignition, Carburetion, and Service Testing."

Table 8 contains information that was obtained from the same question submitted to mechanics, foremen, and garage owners of Chanute, Kansas, and of Manhattan, Kansas, and from manufacturers of automotive service testing equipment.

Table 8.--RECOGNITION, BY THE DIFFERENT SERVICE GROUPS, OF A NEW OCCUPATION IN THE AUTOMOTIVE SERVICE FIELD

Question asked and persons answering	Number answering	
	Yes	No
Does a new occupation exist in the automotive service field that might be called "Ignition, Carburetion, and Service Testing?" a/		
Mechanics, foremen, and garage owners of Chanute, Kansas - - -	21	0
Mechanics, foremen, and garage owners of Manhattan, Kansas - -	14	0
Manufacturers of automotive service testing equipment - - - -	8	0

a/ Question numbers 2, 4, 5, and 1, in questionnaires "A", "B", "C", and "D" respectively.

The returns, as indicated by Table 8, leave no doubt as to the recognition by the automotive industry, as a whole, as to the existence of a new occupation in the automotive service field that may be called "Ignition, Carburetion, and Service Testing."

Table 9 contains information that was obtained from the same question which was submitted to mechanics, foremen, and garage owners of the two towns.

Table 9.--MEN THAT SHOULD BE TRAINED FOR THE NEW SERVICE OCCUPATION

In the opinion of mechanics, foremen, and garage owners

Location of respondents	Number replying	
	Mechanics	Electricians
Chanute, Kansas - - - - - - - - - -	21	0
Manhattan, Kansas - - - - - - - - -	14	0

The question was raised at the beginning of this study as who should be trained for this work in case it was definitely established that there was a new occupational field for which men should be trained. The results, as indicated by Table 9, show that the mechanic is the logical person to train for this field.

Table 10 is a compilation of information received from mechanics, foremen of mechanics, and garage owners of Chanute, Kansas, on questionnaires "A", "B", and "C" pertaining to the content of a night school course in "Ignition, Carburetion, and Service Testing."

Table 10.--THE COURSE CONTENT MATERIAL FOR AN EXTENSION COURSE EVALUATED BY CHANUTE, KANSAS, SERVICE MEN

Job unit	M a/		F b/		G c/		Total	
	Yes	No	Yes	No	Yes	No	Yes	No
Should this course include:								
A. The fundamentals of electricity? - - - - -	8	2	5	0	5	1	18	3
B. How to trace electrical circuits and locate trouble? - - - - - - - -	9	1	5	0	6	0	20	1
C. An understanding of storage batteries? - -	9	1	5	0	5	1	19	2
D. How to rewire cars? - -	8	2	3	2	5	1	16	5
E. Ignition timing? - - - -	10	0	5	0	6	0	21	0
F. The use of motor gauges and synchronizing tools? -- - - - - - - -	10	0	5	0	6	0	21	0
G. The causes of ignition trouble? - - - - - - - -	10	0	5	0	6	0	21	0
H. An efficient method of trouble shooting? - -	10	0	5	0	6	0	21	0
I. The fundamentals of coils, condensers, cutouts, and distributors? - - - - - -	9	1	5	0	5	1	19	2
J. Generating circuits? - -	9	1	4	1	5	1	18	3
K. Starting motor circuits?	9	1	4	1	6	0	19	2
L. Testing generators? - -	8	2	5	0	5	1	18	3
M. Testing starting motors?	7	3	5	0	6	0	18	3
N. How fuel pumps and fuel gauges function? - - -	10	0	5	0	5	1	20	1
O. How to repair fuel pumps and fuel gauges? - - -	10	0	5	0	6	0	21	0

Table 10.--THE COURSE CONTENT MATERIAL FOR AN EXTENSION COURSE EVALUATED BY CHANUTE, KANSAS, SERVICE MEN (continued)

Job unit	M a/		F b/		G c/		Total	
	Yes	No	Yes	No	Yes	No	Yes	No
P. An elementary knowledge of carburetion? - - -	10	0	5	0	5	1	20	1
Q. Characteristics of standard makes of carburetors? - - - - - - - - -	10	0	5	0	6	0	21	0
R. How to repair standard makes of carburetors?	10	0	5	0	6	0	21	0
S. How to adjust carburetors? - - - - - - - - -	10	0	5	0	6	0	21	0
T. Principles of vacuum gauges as applied to carburetors? - - - - -	10	0	5	0	6	0	21	0

a/ M. Mechanics of Chanute, Kansas
b/ F. Foremen of Chanute, Kansas
c/ G. Garage owners of Chanute, Kansas

Table 10, the job units of which were checked very carefully by the men in the field as to completeness of this phase of automotive service, shows a unity of agreement on what job units should be included in a night school course in this field. The greatest divergence of opinion was on job unit "D" in regard to rewiring cars. The answers in the negative came from mechanics who were working in service stations connected with the lower priced cars. On these cars the wiring is supplied in the form of looms or complete wiring units.

Table 11 is a compilation of information received from mechanics, foremen of mechanics, and garage owners of Manhattan, Kansas, on questionnaires "A", "B", and "C", pertaining to the content of a night school course in "Ignition, Carburetion, and Service Testing."

Table 11.--THE COURSE CONTENT MATERIAL FOR AN EXTENSION COURSE EVALUATED BY MANHATTAN, KANSAS, SERVICE MEN

Job unit	M a/		F b/		G c/		Total	
	Yes	No	Yes	No	Yes	No	Yes	No
Should this course include:								
A. The fundamentals of electricity? - - - - -	5	1	3	0	4	1	12	2
B. How to trace electrical circuits and locate trouble? - - - - - - -	6	0	3	0	5	0	14	0
C. An understanding of storage batteries? - -	5	1	3	0	5	0	13	1
D. How to rewire cars? - -	6	0	3	0	3	2	12	2
E. Ignition timing? - - - -	6	0	3	0	5	0	14	0
F. The use of motor gauges and synchronizing tools? - - - - - - - -	6	0	3	0	5	0	14	0
G. The causes of ignition trouble? - - - - - - -	6	0	3	0	5	0	14	0
H. An efficient method of trouble shooting? - -	6	0	3	0	4	1	13	1
I. The fundamentals of coils, condensers, cutouts, and distributors? - - - - - -	5	1	2	1	4	1	11	3
J. Generating circuits? - -	5	1	2	1	4	1	11	3
K. Starting motor circuits?	5	1	3	0	5	0	13	1
L. Testing generators? - -	6	0	3	0	5	0	14	0
M. Testing starting motors?	6	0	3	0	5	0	14	0
N. How fuel pumps and fuel gauges function? - - -	6	0	3	0	5	0	14	0

Table 11.--THE COURSE CONTENT MATERIAL FOR AN EXTENSION COURSE EVALUATED BY MANHATTAN, KANSAS, SERVICE MEN (continued)

Job unit	M a/		F b/		G c/		Total	
	Yes	No	Yes	No	Yes	No	Yes	No
O. How to repair fuel pumps and fuel gauges?	6	0	3	0	5	0	14	0
P. An elementary knowledge of carburetion? - - -	6	0	3	0	5	0	14	0
Q. Characteristics of standard makes of carburetors? - - - - -	6	0	3	0	5	0	14	0
R. How to repair standard makes of carburetors?	6	0	3	0	5	0	14	0
S. How to adjust carburetors? - - - - - - - - -	6	0	3	0	5	0	14	0
T. Principles of vacuum gauges as applied to carburetors? - - - - -	6	0	3	0	5	0	14	0

a/ M. Mechanics of Manhattan, Kansas
b/ F. Foremen of Manhattan, Kansas
c/ G. Garage owners of Manhattan, Kansas

Table 11 indicates that mechanics, foremen, and garage owners of Manhattan, Kansas, are in agreement on including all of the job units listed in a course in "Ignition, Carburetion, and Service Testing."

Table 12 contains information that was received from eight manufacturers of automotive service testing equipment, who are vitally interested in this phase of automotive service. These manufacturers were asked by letter to include any additional job units which they deemed desirable to include in this night school course. No additional job units were included.

Table 12.--THE COURSE CONTENT MATERIAL FOR AN EXTENSION COURSE EVALUATED BY MANUFACTURERS OF SERVICE TESTING EQUIPMENT

Job units	Number answering	
	Yes	No
Should this course include:		
A. The fundamentals of electricity?	7	1
B. How to trace electrical circuits and locate trouble? - - - - -	8	0
C. An understanding of storage batteries? - - - - - - - - - - -	8	0
D. How to rewire cars? - - - - - -	7	1
E. Ignition timing? - - - - - - - - -	8	0
F. The use of motor gauges and synchronizing tools? - - - - - -	8	0
G. Causes of ignition trouble? - -	8	0
H. An efficient method of trouble shooting? - - - - - - - - - -	7	1
I. The fundamentals of coils, condensers, cutouts, and distributors? - - - - - - - - - -	8	0
J. Generating circuits? - - - - - -	8	0
K. Starting motor circuits? - - - -	8	0
L. Testing generators? - - - - - -	8	0
M. Testing starting motors? - - - -	8	0
N. How fuel pumps and fuel gauges function? - - - - - - - - - -	8	0
O. How to repair fuel pumps and fuel gauges? - - - - - - - - -	8	0
P. An elementary knowledge of carburetion? - - - - - - - - - -	8	0

Table 12.--THE COURSE CONTENT MATERIAL FOR AN EXTENSION COURSE EVALUATED BY MANUFACTURERS OF SERVICE TESTING EQUIPMENT (continued)

Job units	Number answering	
	Yes	No
Q. Characteristics of standard makes of carburetors? - - - - - - - - -	8	0
R. How to repair standard makes of carburetors? - - - - - - - - - - -	8	0
S. How to adjust carburetors? - - - -	8	0
T. Principles of vacuum gauges as applied to carburetors? - - - - -	8	0

Table 12 indicates that the manufacturers of automotive service testing equipment are favorable to the job units that were listed on questionnaire "D". They listed no additional job units, and they were given the privilege of doing so. It also indicates that these job units would make a good course content for this night school subject.

Table 13 is a summation of information received from the mechanics, foremen of mechanics, and the garage owners of Chanute, Kansas; the mechanics, foremen of mechanics, and the garage owners of Manhattan, Kansas; and the manufacturers of service testing equipment pertaining to the course content of the extension course in "Ignition, Carburetion, and Service Testing."

Table 13.--A SUMMARY TABLE ON THE COURSE CONTENT MATERIAL FOR AN EXTENSION COURSE AS INDICATED BY ALL GROUPS OF SERVICE MEN

Job unit	X a/		C b/		M c/		Total	
	Yes	No	Yes	No	Yes	No	Yes	No
Should this course include:								
A. The fundamentals of electricity? - - - - -	7	1	18	3	12	2	37	6
B. How to trace electrical circuits and locate trouble? - - - - - - -	8	0	20	1	14	0	42	1
C. An understanding of storage batteries? - -	8	0	19	2	13	1	40	3
D. How to rewire cars? - -	7	1	16	5	12	2	35	8
E. Ignition timing? - - - -	8	0	21	0	14	0	43	0
F. The use of motor gauges and synchronizing tools?	8	0	21	0	14	0	43	0
G. The causes of ignition trouble? - - - - - - -	8	0	21	0	14	0	43	0
H. An efficient method of trouble shooting? - -	7	1	21	0	13	1	41	2
I. The fundamentals of coils, condensers, cutouts, and distributors? - -	8	0	19	2	11	3	38	5
J. Generating circuits? - -	8	0	18	3	11	3	37	6
K. Starting motor circuits?	8	0	19	2	13	1	40	3
L. Testing generators? - -	8	0	18	3	14	0	40	3
M. Testing starting motors?	8	0	18	3	14	0	40	3
N. How fuel pumps and fuel gauges function? - - -	8	0	20	1	14	0	42	1

Table 13.--A SUMMARY TABLE ON THE COURSE CONTENT MATERIAL FOR AN EXTENSION COURSE AS INDICATED BY ALL GROUPS OF SERVICE MEN (continued)

Job unit	X a/		C b/		M c/		Total	
	Yes	No	Yes	No	Yes	No	Yes	No
O. How to repair fuel pumps and fuel gauges?	8	0	21	0	14	0	43	0
P. An elementary knowledge of carburetion?	8	0	20	1	14	0	42	1
Q. Characteristics of standard makes of carburetors? - - - - - - - - -	8	0	21	0	14	0	43	0
R. How to repair standard makes of carburetors?	8	0	21	0	14	0	43	0
S. How to adjust carburetors? - - - - - - - - -	8	0	21	0	14	0	43	0
T. Principles of vacuum gauges as applied to carburetors? - - - - -	8	0	21	0	14	0	43	0

a/ X. Manufacturers of service testing equipment
b/ C. Service men of Chanute, Kansas
c/ M. Service men of Manhattan, Kansas

Table 13 shows a total tabulation of all of the groups of service men from which data was received. This table also gives a means of direct comparison of the data received from these groups, and indicates which job units were substantiated and to be used in gathering the next data which is a job analysis break down of each one of the job units, "A", "B", "C", etc., shown in this table.

Selecting job unit "A", which is the first one in Table 13, the following job analysis items were set up by the method outlined in Chapter III:

The gaps in the following list of job analysis items under job unit "A" were not predetermined but in order to maintain a logical sequence of items these gaps are the places where additional job analysis items will be placed which were received from seven auto mechanics teachers of Kansas by the method outlined in Chapter II.

Job Unit A. The fundamentals of electricity:

1. Electricity as a form of energy.
2. Static electricity.
3. Generated electricity.
4. Theory of electricity.
5. Conductors.
6. Non-conductors.
7. Insulation.
8.
9.
10. Material of wire.
11. Switch insulation.
12. Generator insulation.
13. Starting motor insulation.
14. Material of brushes.
15. Ohm's law.
16. Alternating currents.
17. Direct currents.
18. The generator and magnetism.
19. The generator, theory of operation.
20. The starting motor and magnetism.
21. The starting motor, theory of operation.
22. The horn motor, theory of operation.
23. The horn, its relation to magnetism.
24. The relay and magnetism.
25. The voltage regulator and magnetism.
26. The spark coil and magnetism.
27. The ammeter and magnetism.
28. The fuel gauge and magnetism.
29. The flux density of field and armature.

30. Eddy currents.
31.
32. The electron theory.

The following items were added to Job Unit "A" by auto mechanics teachers who were asked to check the job analysis:

8. Resistance of wires.
9. Resistance of circuits.
31. Hysteresis curves.

This made the complete list of job analysis items under Job Unit "A" as follows:

1. Electricity as a form of energy.
2. Static electricity.
3. Generated electricity.
4. Theory of electricity.
5. Conductors.
6. Non-conductors.
7. Insulation.
8. Resistance of wires.
9. Resistance of circuits.
10. Material of wires.
11. Switch insulation.
12. Generator insulation.
13. Starting motor insulation.
14. Material of brushes.
15. Ohm's law.
16. Alternating currents.
17. Direct currents.
18. The generator and magnetism.
19. The generator, theory of operation.
20. The starting motor and magnetism.
21. The starting motor, theory of operation.
22. The horn motor, theory of operation.
23. The horn, its relation to magnetism.
24. The relay and magnetism.
25. The voltage regulator and magnetism.
26. The spark coil and magnetism.
27. The ammeter and magnetism.
28. The fuel gauge and magnetism.
29. The flux density of field and armature.
30. Eddy currents.
31. Hysteresis curves.
32. The electron theory.

It is evident that any job analysis may include items that are not applicable to the particular study for which they were made. The course of study for the specific group previously mentioned should be limited to extension training in the field of "Ignition, Carburetion, and Service Testing." Any items not in this field but in the field of engineering, chemistry, or other fields of endeavor should be eliminated. Therefore the following criteria were set up and applied to each item in turn:

a. This is in the field of chemistry.

b. This is in the field of engineering.

c. This is in the field of the designing engineer.

d. This is in the field of battery rebuilding.

e. This is in the field of manufacturing.

f. This is in the field of electrical appliance rewinding.

g. As a mechanic he should already know this.

This complete list of job analysis items under Job Unit "A" was subjected to the criteria as set up in the preceding paragraph and the following items were eliminated for the reasons given:

b. 29. The flux density of field and armature.
c. 30. Eddy currents.
b. 31. Hysteresis curves.
b. 32. The electron theory.

Reason b. This is in the field of engineering.
Reason c. This is in the field of the designing engineer.

The remaining job analysis items of Job Unit "A" were used in the course units as indicated below:

Course Unit I. Elementary electricity.

A. Job Unit. The fundamentals of electricity.

A. Job Analysis.

1. Electricity as a form of energy.
2. Static electricity.
3. Generated electricity.
4. Theory of electricity.

Course Unit II. Volts, amperes, resistance, direct current, alternating current, conductors, and non-conductors.

A. Job Unit. The fundamentals of electricity.

A. Job Analysis.

5. Conductors.
6. Non-conductors.
7. Insulation.
8. Resistance of wires.
9. Resistance of circuits.
10. Material of wire.
11. Switch insulation.
12. Generator insulation.
13. Starting motor insulation.
14. Material of brushes.
15. Ohm's law.
16. Alternating currents.
17. Direct currents.

Course Unit III. Magnetism.

A. Job Unit. The fundamentals of electricity.

A. Job Analysis.

18. The generator and magnetism.
19. The generator, theory of operation.
20. The starting motor and magnetism.
21. The starting motor, theory of operation.
22. The horn motor, theory of operation.
23. The horn, its relation to magnetism.

24. The relay and magnetism.
25. The voltage regulator and magnetism.
26. The spark coil and magnetism.
27. The ammeter and magnetism.
28. The fuel gauge and magnetism.

This completes the development of Job Unit "A". The fundamentals of electricity, into its component parts by a job analysis. It also completes the listing of the job analysis items that were added, and by what means; the job analysis items that were eliminated, and by what criteria; and finally Job Unit "A" with the remaining job analysis items, and the course units in which they were used.

The remaining job units on the questionnaires, as determined by the results, were developed in the same manner.

A complete job analysis showing additions of items and eliminations of items will be found in the appendix. Additions will be indicated by a star and eliminations will be indicated by a letter representing the criteria which determined the elimination of the item.

Table 14 which follows shows the direct relationship that exists between the job units, the job analysis, and the course units.

Table 14.--CORRELATION BETWEEN THE QUESTIONNAIRE JOB UNITS, THE JOB ANALYSIS, AND THE COURSE UNITS

Job unit	Job analysis	Job analysis additions	Job analysis eliminations	Course units
A	A 1-2-3-4 5-6-7-10 11-12-13 14-15-16 17-18-19 20-21-22 23-24-25 26-27-28 29-30-32	A 8-9-31	A (29-b)(30-c)	I A 1-2-3-4 II A 5-6-7-8 9-10-11 12-13-14 15-16-17 III A 18-19-20 21-22-23 24-25-26 27-28
B	B 1-2-3-4			VI B 1-2-3-4
C	C 1-2-3-4 5-6-7-8 9-10-11 12-13-14 15-16-17 18-19-20 21-22-23		C (14-a)(15-e) (16-e)(17-d) (18-e)(19-b) (20-b)(21-d) (22-e)(23-b)	IV C 1-2-3-4 5-6-7-8 9-10-11 12-13
D	D 1-2-3-4 5	D 6-7	D (2-e)(3-c) (4-e)(5-b)	VI D 1-6-7
E	E 1-2	E 3		VII E 1-2-3

Table 14.--CORRELATION BETWEEN THE QUESTIONNAIRE JOB UNITS, THE JOB ANALYSIS, AND THE COURSE UNITS (continued)

Job unit	Job analysis	Job analysis additions	Job analysis eliminations	Course units
F	F 1-2-3			VII F 1-2-3
G	G 1-2-3-4 5-6			VI G 1-2-3-4 5-6
H	H 1-2-3			VI H 1-2-3
I	I 1-3-4-6 7-8-9-10 12-13-14 15-16-17 18-19-20 21-22-23 24-25-26 27-28-29 30-31-32	I 2-5-11	I (27-c)(28-c) (29-c)(30-e) (31-f)(32-f)	V I 1-2-3-4 5-6-7-8 9-10-11 12-13-14 15-16-17 18-19-20 21-22-23 24-25-26
J	J 1-2-3-4 5-6-7-8			IV J 1-2-3-4 5-6-7-8
K	K 1-2-3	K 4		IV K 1-2-3-4

Table 14.--CORRELATION BETWEEN THE QUESTIONNAIRE JOB UNITS, THE JOB ANALYSIS, AND THE COURSE UNITS (continued)

Job unit	Job analysis	Job analysis additions	Job analysis eliminations	Course units
L	L 1-2-3-4 5-7-8-9 10-11-12 13-14-15 16-17-18 19-20-21 22-23-24 25	L 6-26	L (9-b) (10-f) (11-f)(12-f) (13-c)(14-b) (15-c)(16-c) (17-e)(18-c) (19-b)(20-b) (21-b)(22-b) (24-g)(25-g) (26-c)	VI L 1-2-3-4 5-6-7-8 23
M	M 1-2-3-4 5-6-7-8 9-10-11 12-13-14 15-16-17 18-19		M (7-b)(8-f) (9-f)(10-c) (11-c)(12-c) (13-g)(14-b) (15-g)(16-e) (17-e)(18-c) (19-b)	VI M 1-2-3-4 5-6
N	N 1-2-3-4 5-6		N (5-e)(6-b)	X N 1-2-3-4
O	O 1-2-3-4 5-6			X O 1-2-3-4 5-6
P	P 1-2-3-4 5-6-8-9 10	P 7	P (9-a)(10-a)	VIII P 1-2-3-4 5-6-7-8
Q	Q 1-2-3-4 5-6-7		Q (5-e)(6-b) (7-c)	IX Q 1-2-3-4

Table 14.--CORRELATION BETWEEN THE QUESTIONNAIRE JOB UNITS, THE JOB ANALYSIS, AND THE COURSE UNITS (continued)

Job unit	Job analysis	Job analysis additions	Job analysis eliminations	Course units
R	R 1-2	R 3	R (3-e)	IX R 1-2
S	S 1-2-3			XI S 1-2-3
T	T 2-3	T 1		XI T 1-2-3

Legend: A to T inclusive in the left hand column refer to the job units of the questionnaire found in Tables 10, 11, and 12.

In the second column the different items of the job analysis breakdown under the various job units are referred to as A.1-2-3, etc. The content of each may be found in the appendix.

The third column gives the items of the job analysis that were added by the various motor mechanic instructors to the original list. The name of each may be found in the appendix.

The fourth column indicates the eliminations to the complete job analysis outline. A(29-b) for example, refers to job unit A and item number 29 in the job analysis of unit A which was eliminated by reason b as given in the job analysis outline found in the appendix.

Column five gives the course unit and the corresponding job analysis items that were incorporated into that particular unit. For example, under course unit I will be found A. 1-2-3-4. This indicates that job analysis items numbered 1, 2, 3, and 4 under job unit A are incorporated in course unit I.

Table 14 indicates quite clearly the breakdown of the job units into the job analysis and the use made of the various job analysis items in the units of the course in "Ignition, Carburetion, and Service Testing."

The course, which is the ultimate objective of this problem, is given in Chapter VII.

Chapter V

DISCUSSION

1. Of the ten questionnaires submitted to mechanics of Chanute, Kansas, eight were to men who, from choice, prefer to work on automobiles. All of the mechanics of Manhattan, Kansas, have a preference for automobile work. This indicates that the largest amount of the data comes from a reliable type of mechanic.

2. These men not only like their work but are almost evenly divided as to whether or not they would choose automobile repair work again as a trade. The results indicate that five men in Chanute, Kansas, would choose automobile repairing again as a trade and five would not, while in Manhattan, Kansas, four would choose this vocation again as a trade and two would not.

3. Table 3 speaks well for mechanics as a class in both towns, in that they are willing to improve their technical knowledge whenever they have an opportunity. This would indicate that a night school course in "Ignition, Carburetion, and Service Testing" would be well attended and would serve a useful purpose in Chanute, Kansas.

4. All foremen interviewed in both towns are of the opinion that mechanics are weak on ignition, carburetion, and service testing, and that their load of responsibility would be lightened if mechanics were better trained in this field. It would also indicate that foremen would encourage their men to go to night school if the proper type of work was offered.

5. Manufacturers of automotive service testing equipment are of the opinion that mechanics, as a whole, should have more training before using their equipment and before being classed as experts in the field of "Ignition, Carburetion, and Service Testing".

6. One of the purposes of this investigation was to establish the fact as to whether or not there is a new occupation in the automobile service field that might be called "Ignition, Carburetion, and Service Testing". Table 8 shows the results on this problem obtained from the questionnaires submitted to the men in Chanute, Kansas; in Manhattan, Kansas; and to the manufacturers of automotive service testing equipment. The results from all three sources are the same. All recognize that there is a new occupation in the automotive service field that could be called "Ignition, Carburetion, and Service Testing".

7. Eighteen out of twenty one of the men who answered questionnaires in Chanute, Kansas, and twelve of fourteen who answered questionnaires in Manhattan,

Kansas, indicated that mechanics, instead of electricians, should be trained for this new occupation.

8. Information obtained from mechanics, foremen, and garage owners connected with the automotive service industry in Chanute, Kansas, as to the job units on the questionnaire needed to determine the job analysis for the purpose of setting up the units of a night school course in "Ignition, Carburetion and Service Testing" indicates that they agree with similar groups in the same industry in Manhattan, Kansas. These groups in turn agree with the manufacturers of automotive service testing equipment as to the job units that should be included. There is some disagreement on this point, but no job unit listed on the questionnaires has less than 35 out of the 43 people who filled out the questionnaires, in favor of having this job unit retained. This is shown by tables 10, 11, 12, and 13.

9. The job analysis as originally set up under each job unit was added to, to some extent, by the auto-mechanic teachers of Kansas to whom it was submitted.

10. In many cases the items added to the job analysis by the teachers were already on the list but under a slightly different name.

11. The original job analysis, of the job units plus the items which were added and minus the items which were eliminated by the criteria set up,

was agreed to with but very little change by the four men in the automotive service field who judged the results of criteria that were applied to the job analysis of each job unit.

12. The major problem of this study has been to determine the course content for an extension course in the field of "Ignition, Carburetion, and Service Testing". The application of the data in the form of the job units as indicated by the results of the questionnaires and the resulting job analysis breakdown of these job units as shown in Chapter 4, gave the basis upon which to set up the necessary units for a course of study.

13. The course units as set up in Chapter 7 give a solution to the problem of this study as set forth in the previous paragraph and gives a practical application to the data received.

14. From the results of the study the writer recommends the following:

a. That extension training in "Ignition, Carburetion, and Service Testing" be offered in night school work in the Chanute Trade School, Chanute, Kansas.

4. That the course content of this course be that which is set up in the body of the thesis, the units of which have been found acceptable to the different groups in the automotive

service field that are directly connected with automotive service.

c. That only those mechanics who have had at least one year of practical experience working at the trade be admitted to the course.

15. It is impossible for a study of this nature to be perfect, for the towns upon which the study is based are limited in size. This in turn limits the number of reliable questionnaires that could be obtained. In an agricultural state, such as Kansas, the limit is soon reached in the number of auto mechanic teachers who could be used in checking and contributing to a job analysis outline. But for this particular area the results were quite applicable.

Chapter VI

SUMMARY

1. A new field of endeavor does exist in the automotive service field that may be called "Ignition, Carburetion, and Service Testing".

2. Mechanics instead of electricians should be trained for this new field.

3. Mechanics as a class are willing to take advantage of additional extension training that will elevate their status and increase their earning capacity.

4. Foremen recognize the lack of technical knowledge and skill in this field on the part of mechanics.

5. Foremen favor additional training of this nature for mechanics.

6. Job units for the course content of extension training in this field, as determined by the results of this study, are indicated as being acceptable to those groups connected with the automotive service field.

7. The job analysis of the job units, as determined by the study, affords the basis for the job analysis items to be incorporated in an extension course of study in the field of "Ignition, Carburetion, and

Service Testing".

8. The course of study in the field of "Ignition, Carburetion, and Service Testing", as set up in the next chapter, is the answer to the major question of this study, which was to determine the course content for an evening school course in this field for the Chanute Trade School, Chanute, Kansas.

Chapter VII

A SUGGESTED COURSE

IGNITION, CARBURETION, AND SERVICE TESTING

Guiding principles

1. Mechanics who have had at least a year of practical experience in actual automobile repair work are the persons with the proper background of experience to receive the most benefit from this course.

2. The course should include such material as will meet the mechanic's present needs and interests, and carry over into his future occupation.

3. Higher standards of workmanship among the mechanics taking this course should be developed.

4. Every mechanic should have an interest in, and an understanding of, this new occupational field.

Major objectives in terms of the mechanic

1. To improve his skill in the various phases of this new occupational field.

2. To improve his technical knowledge of the various elements involved in this new occupational field.

3. To improve his managerial ability in the handling of the various problems involved in this new occu-

pational field.

4. To promote a desire to be a better mechanic and a more skilled workman.

5. To promote a desire to improve his social status by entering this new occupational field either as an employee working at this occupation for an employer, or to set himself up in business in this new field.

UNITS OF THE COURSE

Unit I. Elementary electricity.

Unit II. Volts, amperes, resistance, direct current, alternating current, conductors, and non-conductors.

Unit III. Magnetism.

Unit IV. Storage batteries, generating circuits, and starting motor circuits.

Unit V. The ignition circuit and its major units.

Unit VI. Electrical circuits and trouble shooting.

Unit VII. Ignition timing and the use of motor gauges and synchronizing tools.

Unit VIII. Elementary carburetion.

Unit IX. Characteristics and the repair of standard makes of carburetors.

Unit X. Characteristics and the repair of fuel gauges and fuel pumps.

Unit XI. Carburetor adjustment and the use of the vacuum gauge in carburetor adjustment.

Unit I. Elementary Electricity

References

Kimball, Arthur L. A college text book of physics. New York, Henry Holt and company, 1917. Pages 320 to 541.

Dyke, Andrew L. Automobile encyclopedia. Chicago, The Goodheart-Wilcox company, 1930. Pages 175 to 188.

Information

In the field of ignition and carburetion, an elementary knowledge of the fundamentals involved is necessary. In this and subsequent lessons the learner will deal with some of the fundamentals but of course not to the extent that the designer or engineer would go into the same field. The list of references will be of aid to any mechanic who cares to go deeper into the fundamentals of electricity, fluids, and gases.

In this field the interest is primarily centered in three things: first, a hot spark that will bridge the points of the spark plug each time it is supposed to; second, the condition and quality of the fluid or fuel whether it be kerosene, as used in a tractor, or gasoline that is used in the automobile; third, the conditions existing for getting this fuel into the most desirable state for complete combustion.

There is one point that must be settled before proceding any further and that is the question as to the condition of the motor. Most mechanics have had experience enough to know that expert ignition and carburetor service cannot be conducted on a car or tractor that has leaky or burnt valves; weak valve springs; valves out of time; sticking valves; leaking cylinder head, gasket leaking, or cracked manifold; stuck governor; and many other things of a like nature. For the study in "Ignition, Carburetion, and Service Testing", therefore, it will be assumed that the motor is in fairly good shape as far as these outside factors are concerned.

One of the first questions asked by the beginner in this field is, "What is electricity?". To be perfectly honest, it must be stated that no one knows. Some of the things it will do are known. Some of the effects of electricity can be felt and seen. Certain people know how to control it to a certain extent and have it do work for them.

Electricity is a form of energy. Heat and light are also forms of energy but not the only ones. Now what is energy? Energy is the capacity to do work. Electricity, then, is a form of energy, that when properly controlled will do work. All of the electrical units on a motorcar, tractor, truck or other motorized vehicle or unit must be in the best possible condition so that they will work at the highest efficiency.

If you walk on a heavy thick rug for several feet without lifting your feet from the rug and then bring your finger close to a friend's nose or the lobe of his ear, a small spark will jump from your finger to him and it will feel to him like you have stuck him with a needle.

Stroke a cat's fur in the dark, or, comb your own hair with a rubber comb and very small sparks will be seen.

Electricity in the above form is usually spoken of as static electricity. Lightning is sometimes classified as static electricity.

That which you get from the generator of your motor car can be classified as generated electricity.

You may get electricity from another source and that is from the chemical reaction in the storage battery. This will be taken up again later.

As far as you are concerned in these lessons, you will not have much use for the static electricity as it is out of this field. It is, nevertheless, quite a factor in the field of radio and if time will permit it will add interest if the above experiments are carried out, and in addition, some experiments with a glass rod, silk cloth, and pith balls.

One thing you should keep in mind and that is the fact that whether you speak of static electricity or generated electricity they are not different kinds of electricity.

Summary exercises and questions for discussion

1. What methods are available for generating electricity?

2. What is a Leydon jar?

3. Could an automobile become charged with electricity?

4. A truck hauling gasoline is required by law to have a chain dragging on the ground. Why is this necessary?

5. Does the law require that a freight truck be equipped with this chain?

6. Serious accidents have been reported that involved the straining of gasoline through a chamois skin, or the washing of silk garments in gasoline. Explain why this is possible.

7. What is the electron theory of electricity?

8. Can you name any forms of electricity besides those mentioned?

9. What is an electric machine and how does it generate electricity?

10. Some of the late model cars have wheels that act as electric machines. What effect does this have on car radios? Can this trouble be eliminated? How?

Unit II. Volts, Amperes, Resistance, Direct Current, Alternating Current, Conductors, and Non-Conductors

References

Kimball, Arthur L. A college text book of physics. New York, Henry Holt and company, 1917. Pages 320 to 541.

Burns, E. E. Electricity, a study of first principles. New York, D. Van Nostrand company, Inc., 1929. Pages 63 to 82.

Information

In the automotive electrical field there are some electrical terms that you must know the meaning of before you can talk intelligently in that field.

You could memorize several Spanish words, and unless you knew their meaning, they could get you into trouble in any of our South American countries. So in this field you must know the meaning of some of the most important terms. The work in this chapter will be confined to those terms of which an understanding is necessary in the field of ignition, and service testing.

In the automotive field you are dealing exclusively with direct current, which means current that is flowing in one direction only. For instance, the current flowing from the generator on the car to the battery is direct current and is flowing continually in one direction. There is one exception to this on automobiles, generally speaking, and that is the case of the magneto on the Ford Model T motor which delivers an alternating current to the spark coils. As most mechanics remember, the field coil of this magneto has sixteen small coils of wire. Eight of these coils of wire are wound in one direction and eight are wound in the opposite direction. Alternating current electricity is generated by this unit which means that the electricity flows first in one direction and then in the opposite direction. This reversal takes place at the rate of sixteen times for each revolution of the fly wheel.

The question usually comes up at this point as to the kind of electricity flowing through the light bulbs in homes and business buildings. This in practically all cases, is alternating current, and it reverses its direction through each bulb at the rate of sixty times per second. This is designated as being sixty cycle current.

People must have a desire or ambition to get things done, otherwise there is no progress. There is the necessity for food and clothing, and the desire for automobiles, and homes that gives people the push to go forward. The same thing is true of electricity, and it remains stationary unless there is some push behind to force it to move along its path. This path may be any wire on the car or the wires in the various units such as the generator, starting motor, or spark coil.

This push, in the electrical field, is called voltage, electromotive force, or electrical pressure. The generator, when the motor is running, builds up a voltage or electrical pressure. The storage battery, when in good shape, has at all times en electrical pressure or voltage.

Now if you exert enough push in the right direction money will flow into your pocket. And the more push you exert the more money will flow. This money flowing into your pocket may be likened to the current flowing in the wires on the automobile. The same condition exists in the electrical field, for the more voltage you have the more current will flow, all other factors remaining the same.

The current flowing in the wires on the car is measured in units called amperes and it is the number of amperes flowing from the generator to the storage battery that are registered by the ammeter on the instrument board. You have noticed that as soon as the car speed falls to about seven miles per hour the ammeter hand comes back to zero, which indicates that the voltage of the generator depends upon the speed at which it is driven. In other words, there is not enough push at this speed to force any amperes along the wires of the charging circuit.

If there was no resistance to a flow of money into people's pockets they would soon be rich, for the more push they put forth the more money would flow into their pockets, but in actual life there is resistance to this push.

The same thing is true of electrical conductors. Electrical conductors on the automobile are the wires and also the frame which acts as one conductor for the charging and starting circuit. Resistance must be overcome in the conductors as it impedes the flow of electricity. Resistance is made use of in electrical cigar lighters and electrical soldering irons. Resistance causes heat if the resistance is such that a current will flow in the circuit.

Current flow or amperes, voltage, and resistance all have a direct relationship to each other as an increase of voltage or push increases the amperes flowing, while an increase in resistance decreases the amperes flowing. This relationship may be stated:

$$\text{Amperes} = \frac{\text{Voltage}}{\text{Resistance (designated as ohms)}}$$

which is usually expressed in the abbreviated forms:

$$I = \frac{E}{R} \quad \text{or} \quad R = \frac{E}{I} \quad \text{or} \quad E = \frac{I}{R}$$

This is called Ohm's law, so named in honor of G. S. Ohm, a German, who first discovered this relationship.

In the automotive electrical system will be found conductors and non-conductors.

All of the wires in the lighting circuit, the generating circuit, the starting circuit, and the ignition circuit act as conductors. The frame acts as a conductor in a part of the charging circuit and in a part of the starting circuit in practically all of our modern automobiles.

Non-conductors of electricity are used in those places where you do not want the current to flow. The rubber, and cotton, or silk on the wires, the mica between the commutator bars in the generator and in the starting motor, the wood fibre in the lighting switch, the wood or rubber separators in the battery, the varnish or shellac in the coil, the porcelain in the spark plugs are all examples of non-conductors.

<u>Summary exercises and questions for discussion</u>

1. Does the current flowing from the generator to the battery ever reverse its direction? Can it be reversed?

2. Alternating current generators in a powerplant must have the field energized from a source of direct current. Why is this not necessary on the Ford Model T magneto as it also generates alternating current?

3. What is the water analogy to volts, amperes, and resistance?

4. Do we have any way of measuring volts, amperes, and resistance?

5. What is a milli-ammeter?

6. What is meant by ampere shunts and voltmeter resistors?

7. How must an ammeter be connected?

8. How must a voltmeter be connected?

9. What precautions are necessary when connecting these two instruments?

10. With the proper resistors and shunts, what instrument can be used both as an ammeter and as a voltmeter?

11. What is a Wheatstone bridge and how does it work?

12. The gas analyzer for testing exhaust gas on motor cars makes use of the Wheatstone bridge. How is this accomplished?

13. What effect on car circuits has the practice of mounting motors on rubber had? Is any provision made to take care of this? Is rubber an insulator or a conductor?

14. Why is copper used in electrical wires?

15. What are watts, watt-hours, and ampere-hours?

16. What does the car generator have on it that causes it to deliver direct current?

17. Does a large wire or a small one have the greatest resistance?

18. Is the insulator of a spark plug a good conductor of electricity? Is soot and carbon? Is pure oil? Is dirty oil?

Unit III. Magnetism

References

Burns, E. E. Electricity, a study of first principles. New York, D. Van Norstrand company, Inc., 1929. Pages 21 to 35.

Packer, A. H. Electrical trouble shooting on the motor car. Chicago, The Goodheart-Wilcox company, 1932. Pages 73 to 84.

Information

All of the electrical units on the automobile are so dependent on magnetism for proper functioning, that it is essential that the student have a proper understanding of this phase of electricity before proceding further.

The earth is a magnet with a north magnetic pole and a south magnetic pole. Passing between these two poles of the earth are magnetic lines of force. It is these magnetic lines of force that cause the hand of a compass needle to take the position it does. In other words, the compass needle aligns itself parallel to these lines of magnetism passing between the poles of the earth. These magnetic lines of force have been very useful to man from ancient times, as they make the use of the compass possible to the mariner, the hunter, and even the auto-mechanic has some use for it. The compass is used to determine the polarity of permanent magnets, the residual magnetism of the automobile generator, and it was formerly used quite frequently to determine the proper setting of the magnets of the Model T Ford magneto or the Fordson tractor magneto, before charging them from an external source of direct current.

These magnetic lines of force passing between the poles of the earth will go through anything in their path; the human body, houses, machinery, masonry, etc. The only thing that will divert a magnetic field from its path is iron, or another magnetic field from some other direction. This gives rise to the belief on the part of many people that they can rest better at night if their head is to the North and their feet to the South.

Magnetic lines of force are passing between the poles of any permanent magnet. These can be bought, as a toy, at the ten cent store, but around any garage they can be obtained in the form of permanent magnets from Ford Model T magnetos or permanent magnets from any magneto on a gas engine, tractor, or automobile.

Procure one of these permanent magnets, small pieces of window glass, wood, cardboard, and some iron filings, Hold the magnet beneath the glass. Sprinkle some iron filings on top. Tap the glass gently. Notice how the iron filings arrange themselves. This represents what is called the magnetic field or the paths of the magnetism passing from one pole to the other.

Repeat this experiment using the wood and then the cardboard. As glass is considered to be one of the best insulators this will give you an idea of the penetrating ability of the magnetic lines of force or the magnetic field as it is commonly called.

About the only electrical units commonly found today using the permanent magnet as a source of supply of magnetism are the magnetos used on gas engines, tractors, and aeroplanes.

For the magnetic field on the electrical units found on automobiles some form of electro-magnet is used. An electro-magnet will produce the same kind of a magnetic field that the permanent magnet will produce, but much stronger. An electro-magnet consists of an iron core, usually made of a bundle of soft iron wire, around which a number of turns of insulated wire are wound.

Procure an old automobile ignition coil of any make--although an old Model T Ford coil is really the best for this experiment as the core extends beyond the winding. Carefully remove the wooden cover, the wax, and the tin-foil (which is a condenser). Also remove the secondary winding, which is the outside winding and consists of many turns of very fine wire. After the secondary winding is removed there remains a few turns of fairly heavy wire (primary winding) and the core. Procure a storage battery and connect it in series (one end of the coil to the positive post of the battery and the other end to the negative post) with the coil or primary winding. Repeat, with this electro-magnet, the same experiments that were performed with the permanent magnet. The results should be the same.

Attach a wire to a sensitive galvanometer, and pass it quickly through the magnetic field of the electro-magnet. Notice the hand of the galvanometer. Electricity has been generated. This is exactly the principle involved in the generator on the automobile. The field coil, in the generator, is an electromagnet and the wires on the armature, which are driven by the car engine, cut through the magnetic field set up by the field coil and voltage or electrical pressure is generated.

Disconnect the galvanometer and attach to the wire the two terminals of a dry cell. Make a loop of the wire and gently drop the loop into the field of the electro-magnet. It is thrust aside. This is the principle upon which the starting motor operates.

In addition to the starting motor, the generator, the cutout, the voltage regulator, the ignition coil, the electric gasoline gauge, and the ammeter all depend upon the magnetic field of some form of the electro-magnet for their proper functioning. The electro-magnet may be in bar form, as that in the ignition coil, or it may have the shape of a horseshoe, as that on the door bell electromagnet.

All magnets, whether they be electro-magnets or permanent magnets, have a north pole and a south pole. Take two permanent magnets and bring the poles together. Reverse one magnet and bring them together again. It is found that in one case they attract each other, and in the other case, they repel each other. It has been found by experiment that like poles repel each other and unlike poles attract each other. Please keep this in mind when replacing the permanent magnets on a magneto. Place like poles on the same side. In replacing new field windings in a generator or starting motor keep in mind that no two poles of like polarity shall be together, but that they alternate, first a north pole, then a south pole. In other words, the winding on one pole goes in one direction and on an adjacent pole it goes in the opposite direction. Remember also that a small amount of residual magnetism must be left in the pole pieces of a generator at all times. If this is lost it may be replaced by quickly closing and releasing the cutout points by hand. This permits battery current to flow through the field winding causing the pole pieces to become magnets. As the magnetism dies out of the pole pieces a small amount of magnetism will remain in the iron. This is called residual magnetism and is necessary before the generator will generate electricity.

Summary exercises and questions for discussion

1. Can you think of an experiment that would prove

to you that the earth is a magnet?

2. Are there any natural magnets?

3. Are some steels better for permanent magnets than others?

4. What is residual magnetism and where is it found?

5. Does a horseshoe magnet lose its magnetism? Can it be prevented?

6. Can a permanent magnet be recharged? If so, how?

7. Which can be made the stronger, a permanent magnet or an electro-magnet?

8. Why is the core of an electro-magnet not made of a solid piece of iron? Does your answer have any relation as to why the core of an armature on a generator is not a solid piece of iron?

9. Upon what does the strength of an electro-magnet depend?

10. What use is made of electro-magnets by large concerns handling carloads of scrap iron?

11. Will an electro-magnet operate on alternating current?

12. Why are vibrating points necessary on the Model T Ford spark coil and are not necessary on the Model A Ford spark coil?

13. Why is it necessary to have so many turns of fine wire on the secondary winding of the spark coil?

14. What is the principle of operation of late type horns?

Unit IV. Storage Batteries, Generating Circuits, and Starting Motor Circuits

References

Kuns, Ray F. Automotive trade training. New York, The Bruce publishing company, 1926. Pages 286 to 324.

Dyke, Andrew L. Automobile encyclopedia. Chicago, The Goodheart-Wilcox company, 1930. Pages 331 to 335.

Information

The storage battery has been improperly named as it does not store electricity. There is only one electrical device that can store electricity, and that is a condenser, and the condenser can store electricity for only short periods of time.

The storage battery would be more properly named if it were called a chemical device for the changing of chemical energy into electrical energy and in turn the changing of electrical energy into chemical energy.

When the generator is running and the ammeter on the instrument board gives a positive reading, electricity is flowing from the generator to the ammeter, then to the storage battery, and back to the generator through the frame of the car. In most of the later cars this path is reversed and the current is sent into the frame and then into the battery. This is true on those cars that have the positive terminal of the battery attached to some part of the motor or frame. One reason for this practice is that formerly car owners had considerable trouble with corrosion at the positive battery terminal. Another reason given was that on certain cars considerable trouble was experienced with corrosion at the horn terminals until the car manufacturers grounded the positive side of the battery.

The generator circuit, previously described, is complete in itself and must be closed before any current can flow. All connections in this circuit must be very closely examined at frequent intervals and kept in good condition, for a poor connection will develop high resistance. It is characteristic of generators, of the type found on automobiles, to build up voltage high enough to overcome this excessive resistance. An open circuit will cause the generator to do the same thing.

As the voltage becomes higher more current is sent through the field winding which in turn causes the voltage to become still higher. This condition leads to one of two things: either the lights are burned out, or the armature in the generator is destroyed.

For the good of all concerned it, therefore, is necessary for the service man to do a thorough job of checking the charging circuit.

As current from the generator passes through the charging circuit, it passes through the storage battery. This current causes a chemical reaction to take place in the battery and it is said that it becomes charged.

There is another circuit on the motor car into which the storage battery is connected at certain times. When the driver puts his foot on the starter button this circuit is closed, and the voltage or push of the battery immediately causes current to flow to the starting motor which in turn causes the crank shaft to revolve.

This current from the battery comes from the chemical energy of the battery being turned into electrical energy at the instant the driver puts his foot on the starting lever or button as the case may be.

One distinction should be clear with these two circuits, and that is that whereas the generating circuit carries current which in most cases is under 15 amperes, the starting motor circuit carries a current of 300 amperes, for a very short time, on some cold mornings. This is the reason the wires carrying the starting motor current must be so large. A small wire would have too much resistance to carry this current. Cheap, inferior wires are a poor investment, for the starting motor circuit.

To the service man the main points of interest, as far as the storage battery is concerned, are: the size of the plates, the number of plates, the material from which the plates are made, the capacity of the battery when new, and the condition of the battery at the present time.

The current flowing from the battery to the starting motor depends upon the chemical energy stored in the plates of the battery. The chemical energy stored depends upon the condition of the plates, their size, and the number of them.

Two batteries may look alike, but their ampere-hour rating may be much different. The normal ampere-hour capacity of a storage cell is equal to the quantity of electricity in ampere-hours that the cell will deliver when it is discharged at such a constant rate that the terminal voltage of the cell will fall to 1.7 volts in 8 hours. For example, a cell is said to have an ampere-hour capacity of 60 ampere-hours, which means that the cell will supply a current of 7.5 amperes continuously for 8 hours at 70 degrees Fahrenheit without the terminal voltage falling below 1.7 volts. Eight hours times 7.5 amperes equals 60 ampere-hours. Theoretically, the cell should deliver 60 amperes for one hour. The ampere-hour capacity of a battery formed by a number of cells connected in series, as they are in a car battery, will be the same as the ampere-hour capacity of a single cell, but the voltage will be equal to that of a single cell multiplied by the number of cells.

When battery trouble is encountered it is well to determine if the number of plates in the battery corresponds to the size of the motor it is to turn over. A 13-plate battery may do very well for a Model A Ford, but it takes a 17- or 21-plate battery to properly take care of motors that have the cubic inch displacement of a Buick or of a Chrysler.

One frequent cause of hard starting in the winter time is a battery of inadequate size to handle the load. As the starting circuit offers less resistance to the flow of current than the ignition circuit, the ignition circuit is robbed of its share of current from the battery and a very weak spark or no spark at all is delivered to the plugs. Connect an outside battery, temporarily, to the ignition circuit of a hard starting car, and you can tell at once if this is the cause of the trouble. Of course if it is, a larger battery with more capacity is the solution to the problem.

In the care of batteries only pure distilled water should be used for filling. Acid should be added to the battery if it has been upset, or in the case of a very old battery, a little additional acid will make up for that which is out of circulation in the sulphate at the bottom of the cells. The acid on the top of a battery and the corrosion at the battery posts may be neutralized with a weak solution of soda water. Corroded battery posts are points of high resistance and restrict the flow of current.

Batteries not in use should be charged once a month, as unused batteries discharge at the rate of 1 percent a day. A fully charged battery today would be practically discharged in 100 days.

A battery may be tested with a hydrometer which will give the specific gravity of the electrolyte. The best test of a battery is made by drawing a current from it which is equivalent to the current that the starting motor would draw, and while this current is flowing measure the voltage of each cell with a voltmeter. If the needle of the voltmeter kicks back against the stop pin when connected to any cell, it indicates that the cell is defective.

Summary exercises and questions for discussion

1. What electrical devices do scientists have that are similar in construction to a condenser and will hold a charge of electricity?

2. Why is a storage battery so heavy?

3. What is the chemical name for the corrosion that forms at the terminals of a storage battery?

4. What is fundamentally different between the circuits found on an automobile and the circuits found in the distributing system of electricity for the average city?

5. What gas is given off in the charging of a storage battery?

6. Why have such large wires in the starting circuit of automobiles and small ones in the charging circuit?

7. Why should the quality of the lead, the electro-

lyte, or the separators, make any difference in the efficiency or life of a storage battery?

8. Why does an 8 cylinder motor need a larger battery than a 6 cylinder motor of the same bore?

9. How full should a battery be filled?

10. If water is added to a battery in the winter time, what precaution should be taken?

11. What is the cadmium test for storage batteries? When and where is it used?

12. What materials are battery separators made of?

13. Why and where is sealing compound used in battery construction? How can it be removed?

14. Is there any difference between distilled water and rain water for filling batteries? Why not use well water?

15. What effect does freezing have on a storage battery?

16. Will a fully charged battery freeze in the state in which you live?

Unit V. The Ignition Circuit and Its Major Units

References

Kuns, Ray F. Automotive trade training. New York, The Bruce publishing company, 1926. Pages 325 to 428.

Packer, A. H. Electrical trouble shooting on the motor car. Chicago, The Goodheart-Wilcox company, 1932. Pages 84 to 215.

Information

The electrical transformer, which is usually found on tall poles in the alleys in many towns, is one of the main essentials of our modern electrical distribution system.

By means of the transformer, the electric power can be sent from the power house at a high voltage, usually 2300 volts in town, but much higher elsewhere, until it gets to the transformer in the alley where it is stepped down to 110 volts for light bulbs, electric irons and other electrical appliances. For the transmission of electricity over long distances a transformer is used to step the voltage up high in order to cut down on the losses. You can see from this that a transformer can be used to step a voltage up or to step it down. It always has two windings on it, a primary winding of a few turns and a secondary winding of many turns, all wound around an iron core.

The ignition coil on the automobile is only a miniature transformer. Without it modern high speed ignition systems would not be possible. Six or seven volts is all that is available from the storage battery. From 15,000 to 20,000 volts are necessary to force the current to jump the points of the spark plug. The higher the compression of the motor, the higher the voltage must be. An ignition system of fifteen years ago would not be very efficient on modern cars that have over one hundred pounds of compression per square inch. Formerly, sixty pounds of compression per square inch was considered rather high.

The six or seven volts available from the battery must be changed into several thousand volts, and the ignition coil does this for the ignition system in much the same way that the transformer does it for the distributing system of a utilities plant.

How does it do this? In the discussion on magnetism it was found that if a wire is thrust quickly through a magnetic field a voltage is built up in it, which in turn would send a current of electricity through the wire if the ends were connected together or to some other electrical unit.

It would not make any difference, as far as generating this voltage is concerned, if the wire was moved through the magnetic field or the magnetic field moved so that the lines of magnetism cut the wire. The latter method is used in both the transformer and the ignition coil.

In the case of the transformer, the magnetic field, set up by the current flowing in the primary winding, reaches a maximum intensity as well as a zero intensity each time the current reverses itself. As this magnetic field rises and falls it cuts across the wires of the secondary winding. This induces a voltage in the secondary winding which will cause a current to flow as soon as an electric appliance is connected into the circuit.

Direct current is used in the automobile ignition system and it must be treated in a different manner in order to get the magnetic lines of force to cut the wires of the secondary winding. The ignition system of the automobile contains a mechanical device called an interrupter, driven by the engine and at half engine speed, which causes the magnetic lines of force to cut the wires of the secondary winding. The interrupter has in it a pair of ignition points, one moveable and the other stationary. As the engine turns over, a cam on the distributor shaft causes these points to open and close at the proper instant. For good engine performance these points must be properly dressed and be the right distance apart when open.

When the ignition switch on the car is closed, current flows from the battery through the ignition points, through the primary winding and back to the battery. This causes the iron core of the coil to become an electro-magnet as was found in the lesson on magnetism. As the engine begins to turn over the ignition points are opened. When the points open the circuit is broken and the magnetic field collapses, cutting through the turns of wire on the secondary winding. This induces a high voltage in the secondary winding which causes a current to flow to the distributor and it in turn distributes this current to the proper spark plug at the right time.

Mechanics have some experience with condensers, and sometimes wonder what part is played by a condenser in the ignition system.

When the switch on the lathe, drill press, or other equipment driven by an electric motor is opened, a flash is noticed as the contacts break. This is because electricity in motion tends to continue in the same direction and does not want to stop at once. Any moving body has this characteristic and it is called inertia. In order to have a good hot spark induced in the secondary winding, the magnetism must die out quickly. But the arcing that takes place at the instant the contact points break causes the magnetism to die out slowly and gives a very weak spark at the spark plugs.

To overcome this trouble, a condenser is connected in parallel with the ignition points. The condenser acts as a shock absorber, in that it becomes charged with a part of the current that would otherwise arc at the points. This gives a sudden break to the current and accordingly generates a high voltage in the secondary winding. The initial charge that the condenser received is discharged in the opposite direction to the normal flow of current.

The sudden reversal, of the primary current, causes a quick drop in the magnetic field. This permits the magnetic lines to cut the wires of the secondary winding in the least possible time which induces a good hot spark at the points of the spark plug.

Summary exercises and questions for discussion

1. Carefully take apart the condenser which was found in the Ford spark coil. Repeat this on a discarded condenser from a battery ignition system. How are they made? Is there a metal connection from one side of the condenser to the other?

2. Is there any connection between badly pitted ignition points and a poor condenser? Explain your answer.

3. Remove and replace at least three condensers on distributors, so that you may develop manipulative skill in this operation.

4. Would it be a good plan for each repairman to carry, on service calls, a good condenser that could be connected to any car?

5. Prepare for yourself such a condenser and figure out how it may be attached to the ignition system of

various automobiles without being placed inside of the distributor case.

6. Figure out a method of attaching a storage battery to a car, that has had the ignition key lost, so that it can be started.

7. Dress and set two sets of ignition points.

8. Draw a diagram of a complete ignition system and trace the current in the different circuits.

9. Explain the effect on engine performance of ignition points being too close together, and the effect when they are set too far apart.

10. What size and approximately how much wire is used on the primary winding of a spark coil? The secondary winding?

11. Is it best to test a coil when it is hot or when it is cold? Under slow speed of the testing machine or under high speed?

12. Can condensers be tested? How?

13. What is the difference between a connection being mechanically tight and electrically tight?

14. Are rust, dirt, and corrosion good conductors of electricity?

15. What are the accepted methods of testing coils and condensers?

16. List ten causes for an inferior spark at the spark plug points.

17. How is the high tension spark induced in a

high tension magneto?

18. How can the armature of a high tension magneto be tested?

19. Can the magnets of a high tension magneto be recharged? Explain.

20. What units should a mechanic have in his tool kit for quick testing of the ignition system?

21. Do spark plugs wear out? Why?

22. What material is used for the ignition points of a battery ignition system? Of a high tension magneto?

23. Is there any reason for an ignition coil to cause a miss in the motor when the coil is hot but the motor will run without missing when the coil is cold?

24. What is the characteristic performance of a car with a bad condenser?

25. Is condenser failure a common occurrence on late model cars?

26. If you were caught many miles from a service station with condenser failure, and there was a complete Fort Model T ignition system at your disposal could you get to your destination? Explain.

27. What is the cam angle and what effect does it have on motor performance?

28. Why are different types of distributors used?

29. Why does each motor require a certain type of spark plug?

30. Explain how to repair a distributor.

Unit VI. Electrical Circuits and Trouble Shooting

References

Kuns, Ray F. Automotive trade training. New York, The Bruce publishing company, 1926. Pages 429 to 517.

Packer, A. H. Electrical trouble shooting on the motor car. Chicago, The Goodheart-Wilcox company, 1932. Pages 299 to 310.

Information

A direct current voltmeter with a range of 0-35 volts and a direct current ammeter, with shunts, having a range of 0-400 amperes are two instruments that every trouble shooter should have.

A milli-voltmeter, in one unit, with the necessary resistances and shunts can be purchased from several leading electrical concerns, and can be used as either an ammeter or as a voltmeter.

Every automobile has an ignition circuit, a generating circuit, a starting circuit, and a lighting circuit. Each one is a complete distributing system of electricity and must be treated as such.

A definite system must be used in hunting for trouble, and the process of elimination by the use of instruments is the most satisfactory method to use. In other words, guess work must be eliminated. Just because the self starting mechanism turned the motor over yesterday is no reason to censure the starting motor today and say that the battery is O.K. Because experience has shown that the battery is the offender many more times than the starting motor, the battery should be the starting point in the elimination of electrical trouble.

In one of the previous lessons, it was pointed out that a complete circuit is necessary before electricity will flow. In the starting motor circuit, the usual difficulty is that the starting motor refuses to turn, or does not have enough power to turn the engine over. Some mechanical trouble can enter here also, but first the starting motor's source of energy, which is the battery, should be considered.

The wise repairman first turns on the lights and then steps on the starter button. Just because the lights are good before you step on the starter button is no reason to assume that the battery is in good condition, for it takes a much greater amount of current to supply the starting motor than it does the lights.

With the lights on and by stepping on the starter button one of three things will be observed:

(a) If the lights go out, it indicates that a poor connection exists in the starting circuit, and it will usually be found at one of the battery posts, or at the ground connection. Electricity always takes the path of least resistance, and because of the low resistance of the starting motor circuit and comparatively high resistance of the lighting circuit, the lights are robbed of current.

(b) If the lights dim considerably it indicates a discharged battery, or mechanical trouble in the starting motor, or connecting linkage between it and the engine.

(c) If the lights stay the same brightness, it indicates that no current is flowing to the starting motor, and an open circuit will be found.

Each cell of the battery should be checked with the hydrometer, and also with the low reading scale of the voltmeter. The voltmeter readings should be taken when the current is flowing to the starting motor. No cell should be below 1.6 volts. A short circuited cell will give no reading.

With the starting pedal depressed, make a voltmeter test on every connection in the circuit. A horseshoe nail may be driven into the cable to make tests at the terminal joints. A reading at any joint indicates a bad connection. The connection may be mechanically tight but not electrically tight.

A quick test for a poor battery connection is to hold the hand on the connection while the current is flowing. A poor connection will feel warm because of the extra resistance.

Connect the ammeter with the shunt into the starting motor circuit. Most engines require a current of from 125 to 150 amperes. If 200 amperes or more are required, it indicates something is wrong in the starting motor, excessive drag in the engine, or trouble in the mechanism that connects the starting motor to the engine. Worn starting motor bearings cause an excessive drag of the armature against the pole pieces.

A ground in the starting motor will cause excessive current to show on the ammeter when testing for current consumption. This ground may be located by using 110 volt test points and testing between the starting motor terminal and the housing frame with the normal grounds disconnected. If the lamp lights, the starting motor is grounded.

If all tests indicate that everything is normal except the starting motor, it should be removed to the workbench, properly cleaned, and the following tests made in addition to the one above:

(a) Test the armature for short circuits, grounds, and open circuits. (A powerful growler and 110 volt test points are necessary for this test.)

(b) Test the bearings for wear.

(c) Test the brush holders for short circuits, and test the brushes for wear.

(d) Test the field winding for short circuits, grounds, and open circuits.

(e) The mechanism that connects the starting motor to the engine should be tested for wear and damaged parts. Also test the armature shaft for trueness.

(f) Examine the pole pieces and determine if they show any indication that the armature has been rubbing against them.

(g) Do not undercut the mica on a starting motor, but it should be undercut on a generator.

(h) Examine the brushes on the starting motor and determine if they are starting motor brushes.

(i) Never use anything but fine sandpaper for dressing brushes or commutators. Emery paper will ruin a commutator.

The generating circuit and the units of which it consists are to keep the battery properly charged, and to supply sufficient current to the battery to take care of a cigar lighter, a radio, a heater, and any other electrical unit that may be added.

The modern motor car places considerable strain on the generator, and for that reason air cooled generators of greater capacity and having a voltage regulator incorporated in the cutout are in use at the present time.

If the generator is not charging, as indicated by the ammeter, the voltmeter should be used to determine if the voltage of the generator is sufficient to bring the contact points of the cutout together.

The cutout has on it two windings. One is called the voltage winding, and the other is called the current winding. The cutout points are connected in series with the current winding. As the generator armature begins to turn over, a voltage is built up. The voltage winding of the cutout has one terminal connected to the generator terminal and the other terminal is grounded. Thus the core of the cutout is energized which pulls the points of the cutout together. As soon as the points are closed, the charging current flows through the current winding and this also energizes the core.

The purpose of the cutout is to act as an automatic switch connecting the generator to the battery at the proper time and disconnecting it when the speed of the car falls below a certain point.

If the voltage test shows a low voltage at the generator, it indicates that some corrections should be made.

The brushes and commutator of the generator can be sanded, but if this does not improve the output of the generator, it should be removed to the bench and put through the same tests that were previously listed for the starting motor.

If the voltmeter reads excessively high, that is, if it is very much above the voltage of the battery, it indicates a poor connection or an open circuit. If this is not readily found, the voltmeter may be connected at various places in the charging circuit, with the generator running, and the trouble is soon located.

The amount of current flowing to the battery may be regulated by shifting the third brush in the generator.

Shifting it with the direction of rotation of the armature increases the charging rate, and shifting the third brush against the direction of rotation of the armature decreases the charging rate.

With all of the late cars, the manufacturer's instructions should be followed in changing the charging rate, as the manufacturer has a definite procedure to follow before the third brush is shifted. (See the service manuals of car manufacturers or electrical equipment manufacturers.)

In testing the lighting circuit, the same method should be used as before and the voltmeter is essential. If you have seven volts at the battery you should have approximately this much voltage at the lamp bulbs. If you have not, there is a leak or a bad connection in the circuit.

The main requirement of the ignition circuit is that it supply a spark of such intensity that it will jump the electrodes of the spark plug under high compression. This means that it must jump at least one fourth of an inch in the open air and have sufficient body to ignite the gas. A thin stringy spark is inadequate.

Here again the source of current is the storage battery, and if the battery is not up to par, serious starting difficulties are encountered during cold weather.

As was stated before, electricity always takes the path of least resistance, and at the time of starting a car, two switches are closed, the ignition switch, which sends current to the spark coil for ignition purposes, and the starting switch, which sends current to the starting motor. The starting circuit has the least resistance, and in cold weather the battery is low in efficiency, consequently, in many cases, the starter turns the engine over but the spark is too weak at the plugs to fire the charge of gas.

In the case of a hard starting car, this condition may be checked by connecting another battery to the ignition system alone. If the car starts easily it proves that the ignition system is being robbed of current.

Another cause of hard starting that is overlooked many times is that in which the ignition points are too close together.

One of the first things to check in a complete failure of the ignition system is the amount of current at the ignition points. This current also registers on the ammeter on the instrument panel.

The process of testing by elimination is a good method to use in checking the ignition system.

On inspection, badly burned points in the ignition system, or points that do not last long, indicate one of two things--either the points were of inferior quality to begin with or the condenser is bad.

In turn the condenser, spark coil, plugs, wires, distributor cap, and ignition head should be tested with the proper equipment. If no testing equipment is available, units that are known to be good should be substituted, one at a time, for those on the car.

The electrical trouble shooter should be able to make all of the above tests, substitutions, and replacement of wires on any car that may be encountered.

By practice he should be able to check, by using a screw driver to short out the plugs, just which ones are firing and which ones are not. Some of the old time repairmen were so constituted that they could make this test with their bare hands, but this is not advised unless you like a good stiff charge of electricity.

Summary exercises and questions for discussion

1. What happens to an ammeter if it is connected in a circuit with the terminal wires reversed?

2. What is wrong if a battery apparently takes a good charge, but does not stay charged for any length of time?

3. Draw a diagram showing how two batteries may be used on an automobile, one for the starting circuit and one for the ignition circuit.

4. What trouble will a poor job of soldering on the terminals of a starting circuit cable cause?

5. Upon what principle does a growler work, and

how does it indicate armature trouble?

6. If a generator will run as a motor, does that indicate that it will generate electricity?

7. What is the difference between starting motor brushes and generator brushes?

8. Why will emery paper ruin a commutator?

9. What is the third brush on a generator for? How is it adjusted?

10. What effect does over oiling have on the generator or starting motor brushes?

11. Would it be possible to take current from a battery in one car to supply current for ignition so that a second car could be started? How could this be done? Show this by a diagram?

12. Some spark plug testers use a neon light. Is this type successful?

13. What type of testers are available for testing condensers?

14. Enumerate all of the instruments that could be used to advantage in carrying out all of the tests that come under the heading of Lesson VI.

Unit VII. Ignition Timing and the Use of Motor Gauges and Synchronizing Tools

References

Tenney, Frank E. Modern high speed ignition. Chicago, The Goodheart-Wilcox company, 1930. Chapters I, II, and III.

Kuns, Ray F. Automotive trade training. New York, The Bruce publishing company, 1926. Chapter V.

Information

There are certain factors pertaining to the timing of engines that the student must have clearly fixed in his mind.

All automobiles in use in the United States have engines that operate on the four cycle principle.

The four cycles of a four cylinder engine does not mean a cycle for each cylinder, as some students think, but each separate cylinder goes through each of the four cycles of intake, compression, power, and exhaust while it fires once. While one cylinder is going through one phase of a certain cycle, each of the other cylinders is going through a phase of a different cycle. No two cylinders are going through exactly the same phase of the same cycle at the same time. For example: When number one piston is at the top of the exhaust stroke, number one exhaust valve will have almost closed and number one intake valve will be starting to open. Piston number four will be at the top of the compression stroke, because when number one piston comes up on the exhaust stroke, number four piston (or number six piston in a six cylinder engine) comes up on the compression stroke. Just because two pistons of a four or six cylinder engine come to the top of the stroke at the same time is no reason to believe that they fire at the same time.

There is no object in putting six cylinders on a car, if two cylinders fire at once. A three cylinder engine, with each cylinder twice as large, would serve the purpose just as well. Some time during each revolution of the flywheel, half of the cylinders fire. All cylinders fire once during two revolutions of the fly wheel.

The spark occurs at the plug points at the instant the ignition points separate, not when they close. At the instant the points open the distributor arm must line up with a contact in the distributor cap.

The firing order of an engine is needed in order to replace the high tension wires in the right order. The direction of rotation of the distributor arm must be determined before the motor can be timed. The firing order of an engine is usually stamped upon the manifold or cylinder head. If it is not, the firing order may be obtained from an instruction book or by watching the opening, in turn, of each exhaust valve as the engine is turned over by using the hand crank.

The number one cylinder on an engine is the one next to the radiator. Number one cylinder on a V motor cycle engine is the rear cylinder. The number one cylinder on a V automobile engine is the one next to the radiator on the left hand side, as viewed from the front of the car.

The four cycles of a cylinder must be thoroughly understood, the valve that is open or closed on each cycle, the exact purpose of each stroke, and the point at which the spark should occur at the spark plug must be known before anyone is thoroughly capable of timing the ignition of an engine.

It is usually more convenient to work with the number one cylinder alone while timing a motor.

Consider number one cylinder alone, and as the piston in this cylinder goes down (starting with the intake stroke) the intake valve opens and a charge, composed of one part gasoline and approximately fifteen parts of air, by weight, is drawn into the cylinder. As the piston starts up, the intake valve is closed and as the exhaust valve is also closed the piston begins to compress the charge. This charge is fully compressed at the instant the piston reaches top dead center. The spark should occur at this point, or on most of the late model cars, a few degrees before this point. As soon as the firing takes place the piston is thrust downward with a terrific push. This stroke is called the power stroke. When the piston reaches the bottom of the power stroke, or in some motors a few degrees before this point, the exhaust valve opens and on the upward stroke, which is called the exhaust stroke, the burned gases are expelled from the engine. The next stroke, of course, is the beginning of a new intake stroke. The four strokes then are: intake, compression, power, and exhaust. It is well to remember that the firing point occurs between the end of the compression stroke and the beginning of the power stroke.

Before timing the ignition, the breaker points should be dressed and properly adjusted, as improper setting affects the timing.

Several years ago, manufacturers left the fly wheels of the engines in the open and gave the timing in so many degrees of the fly wheel. Today the fly wheels are enclosed and degrees on the fly wheel do not mean much to the mechanic as they can not be conveniently measured. Manufacturers now give the timing data in so many thousandths of an inch of piston travel. This development has been made possible by the advent of the "Motor Gauge", a device which accurately measures piston travel in terms of thousandths of an inch.

In one of the previous lessons the principle of the ignition coil was studied, and how a current of electricity flowing in the primary winding set up a field of magnetism, the collapse of which was necessary in order to get a voltage induced in the secondary winding, which then sent a current to the spark plugs.

Considering the lack of progress in automotive electricity, not much trouble was encountered with the ignition systems used with the old slow speed engines, but as manufacturers began to increase the speed of their engines it taxed the ignition system severely to keep pace.

Some manufacturers of six cylinder cars placed two sets of ignition points in the ignition head, three cylinders to each set, in order to give the primary winding a chance to build up the necessary magnetism. Other companies building six cylinder cars used two sets of points and a six lobe cam in the distributor. One set of points would break the circuit, and the other set was so arranged as to close the circuit shortly after the first set opened the circuit. This gave the primary circuit a longer period in which to build up a voltage. These cars run very well at moderate speeds with the second set of points removed.

In the first car mentioned, it was necessary that the two sets of cylinders of three each, have the spark occur at exactly the same instant of piston travel or the motor would be unbalanced. You can imagine the result of having three cylinders firing on top dead center and the other three firing ten degrees before top dead center. In other words the two sets of cylinders must be synchronized. This service should be rendered on these cars at periodic intervals. The Motor Gauge mentioned before or some other synchronizing tool is necessary for this purpose.

Straight eight motors must also be synchronized, as well as many of the V type multiple cylinder motors.

Summary exercises and questions for discussion

1. A motor boat engine was built some years ago that had thirty-two cylinders. How many fired at any one time? How many revolutions did the fly wheel make while they were all firing once?

2. Do the same timing rules apply to a radial aeroplane engine that apply to the automobile engine?

3. How is the timing changed on the Ford V-8?

4. What is the timing procedure on the Model A Ford?

5. It is recommended that the breaker point spring tension be checked on every motor tune up. What effect does a weak spring have on the ignition or motor performance?

6. What is the recommended opening for the ignition points on the late Ford, Dodge, Hudson, Chrysler, and Chevrolet?

7. What precaution should be taken when installing a new set of points to see that the fibre rubbing block on the movable point does not wear rapidly?

8. What trouble will this cause if it does wear?

9. Some of the late cars have the ignition head connected to the intake manifold. What purpose does this serve?

10. What effect does the governor have on the ignition setting?

11. Some late model cars have a device attached to the ignition head which takes care of different grades of fuel. Explain the operation of this device.

12. Some manufacturers recommend the use of a timing light on late model engines. How does it work and what provision has been made for its use?

Unit VIII. Elementary Carburetion

References

Dyke, Andrew L. Automobile encyclopedia. Chicago, The Goodheart-Wilcox company, 1930. Pages 670 to 840.

Kuns, Ray F. Automotive trade training. New York, The Bruce publishing company, 1926. Chapter IX.

Information

Experiments carried on by the Bureau of Standards, Washington, D. C., have shown that an internal combustion engine, commonly referred to as a gasoline engine, can be run on coal dust, elevator dust, and several other materials if mixed with the proper proportion of air.

Commercial gasolines supplied to the American market are usually a mixture of straight refinery gasoline, blended casing-head gasoline, and cracked and blended gasoline.

Some of these gasolines are too volatile to use separately and are blended to give a better fuel for certain seasons of the year.

Some companies selling gasoline have the United States divided into zones, as to climate, and render a very good service to their customers in supplying them with the right gasoline for each day of the year.

Gasoline, in order to burn properly, must be supplied with air in the ratio by weight of 15 to 1. In other words, 1 pound of gasoline, which is approximately one sixth of a gallon, requires 200 cubic feet of air at 62 degrees F.

Efforts are being made to find suitable substitutes for gasoline. Some of the important substitutes that have been tried with very good success are kerosene, alcohol, and benzol, which is a by-product of the distillation of soft coal.

Kerosene is used quite extensively in tractors. When it is used, more heat must be supplied to the manifold so that the fuel will vaporize properly.

Quite extensive experiments are being carried on in Kansas, at the present time, in the blending of ethyl alcohol and gasoline. This mixture is being offered for sale at some filling stations in the eastern half of the state.

Diesel engines, using cheap grades of fuel, may be a solution to the fuel problem in the future. At present, the poor acceleration and flexibility of the Diesel engine prevents a very wide acceptance of this type of motor in the automobile field. Car manufacturers are carrying on extensive experiments with this type of motor, and extensive developments are looked for in the near future.

While this type of motor offers great possibilities in cutting fuel costs, the fuel costs will rise sharply as soon as these motors are extensively used and the state and national fuel taxes are applied to Diesel fuel. Diesel motors also necessitate the use of sensitive vaporizing devices for this fuel. This complicates the servicing of Diesel engines.

In the first carburetors used on gasoline engines, the fuel was vaporized by passing the air over the surface of the liquid. This worked very well with a highly volatile fuel, but would not be very satisfactory with present day fuels.

All carburetor manufacturers strive to produce a carburetor that will thoroughly vaporize the fuel and mix it with the proper amount of air at all speeds. This would give the greatest mileage from a gallon of fuel. This goal has not yet been reached.

With late model cars, in order to increase the power and economy of the fuel consumption, the compression has been increased from year to year. It has not been many years ago since mechanics thought that fifty pounds of compression per square inch for a motor was quite high. Today motors are in use that have over one hundred pounds per square inch of compression.

This has led to other complications such as the use of tetra-ethyl lead in the gasoline, the recommendation of certain manufacturers that only gasoline of 70 octane rating or above be used in their cars, and devices placed on the ignition head for changing the timing for certain grades of fuel.

In all carburetors in use today the gasoline is vaporized by some form of jet. Some jets consist of a cone shaped stem placed directly over a small cup shaped depression, in the center of which is a small hole. By moving the cone shaped stem closer or farther away from the hole the amount of fuel that passes through may be regulated. Late model carburetors use this type of jet only for the low speed adjustment. The intermediate and high speed jets are small orifices, fixed in size, and can only be regulated by changing jets.

Procure an atomizer and press the bulb a few times. This produces a vaporization such as will give you an idea of what takes place at a jet in a carburetor as the suction of the motor is applied to the jet. At low speed the suction is low but at high speed it is very high. Yet it is inadequate to supply a full charge at high speed and a device known as a supercharger is being supplied on some motors to take care of this deficiency. The suction spoken of above is in reality the abhorrence that nature has for a vacuum. As the piston in a motor goes down a partial vacuum is created. Nature immediately tries to overcome the vacuum by supplying air to fill it. It is this rush of air through the carburetor that causes the spray of gasoline to come from the jet and the spray in turn is picked up by the rapidly moving air and carried to the cylinders as needed.

Summary exercises and
questions for discussion

1. What would happen if a car was placed in an air tight room and the engine started? How long would it run?

2. What gas comes from the exhaust of an engine?

3. Why does it kill so quickly?

4. Ether is sometimes used to start motors in extremely cold weather. Why is it more efficient than gasoline for this purpose?

5. Would it be possible to start engines with acetylene gas? Was it ever used?

6. Car engines formerly had priming cocks on the cylinder head. Why are they not used now?

7. Oil field workers sometimes use straight casinghead gasoline in their cars. Can you offer any reason why this practice would be injurious to the motor?

8. Do tractors start on kerosene?

9. What class of people will be helped if the blending of gasoline and alcohol proves satisfactory?

10. What is the approximate cost of Diesel fuel?

11. A notation in a Los Angeles paper stated that a truck owner in order to justify the installation of a Diesel motor in his truck, would have to drive it 35,000 additional miles each year. Why would this be so?

12. What is meant by the cracking process in the manufacture of gasoline?

13. What motors have a compression of one hundred pounds per square inch?

14. If a gasoline engine will produce more power by raising the compression, why not raise it to, say five hundred pounds per square inch?

15. Why not use some water in the gasoline as it can be vaporized?

16. Water is a product of combustion. What is the liquid that is seen dripping from the tail pipe of some automobiles? Why is this dripping liquid more noticeable on some cars than on others?

17. What is the white vapor coming from the tail pipe of cars on a cold day?

Unit IX. Characteristics and Repair of Standard Makes of Carburetors

References

Carter Carburetor Company. Shop manual, 1935. St. Louis, Mo., Carter carburetor company, 1935. 403 p. Pages 189 to 250.

Dyke, Andrew L. Carburetors. Chicago, The Goodheart-Wilcox company, 1935. Pages 1 to 75.

Information

The fuel level in any carburetor should always stand from 1/32" to 1/8" below the fuel nozzle. This level is regulated by the float which should be very carefully adjusted according to the manufacturer's specifications for that particular car.

It should be taken for granted, by any intelligent mechanic who wishes to improve his technical knowledge and skill on the electrical and fuel units of the automobile, that the manufacturer of that particular car is in a better position to carry on experimental work than the mechanic. For this reason information supplied by the manufacturer should be valued highly and his instructions carried out.

It is well at this point to obtain several makes of carburetors from late model cars, if possible, and increase your skill in their assembly and disassembly. Also note, if possible, how the fuel is carried to each jet. Also note how each manufacturer tries to get perfect carburization at all speeds from his carburetor.

All of the late model carburetors carry a fuel pump for the purpose of giving a richer mixture for rapid acceleration. Note the different mechanical structure of the fuel pumps.

Carburetor repair usually consists of the replacement of certain parts such as floats, jets, needle valves, and needle valve seats. These parts wear out the same as anything else. Care should be exercised to replace all gaskets with new ones. Some carburetor companies have an exchange plan which permits the car owner to turn in the old carburetor and obtain a new one for a stated sum of money.

Car owners frequently complain to service men about the excessive gasoline consumption of their automobiles. There are many causes for this trouble. A few are: the driver himself, the engine in poor shape mechanically, improper carburetor settings and adjustments, the wrong jet, worn needle valve and seat, which permits the pump to force an excessive amount of gasoline into the carburetor. This leaves the gasoline level too high in the carburetor bowl when the car is in motion.

Extreme care should be taken to see that all particles of sand, silt, and dirt are removed from the holes and passage-ways of any carburetor that is being repaired.

All manifold gaskets should be replaced at periodic intervals. Defective gaskets cause trouble that is sometimes blamed upon the carburetor. Faulty windshield wiper hose or faulty automatic clutch tubing also cause trouble of a similar nature.

Summary exercises and questions for discussion

1. What would cause the body of a carburetor to warp?

2. What effect on engine performance would a loose butter-fly valve shaft have?

3. What is vapor lock? Would a very thick asbestos gasket between the carburetor and the manifold have any effect on this trouble?

4. Is there ever any occasion to shield, from heat, the gasoline line or the fuel pump? Why?

5. Is a down draft carburetor more economical of fuel than the up draft type? Do all companies agree on this?

6. A partially clogged air cleaner would have what effect on a carburetor?

7. Do you think a carburetor that has several mechanical levers, pins, and cams exposed on the outside will have a long life? Can you name any carburetors of this type?

8. What carburetor has a series of jets that are opened as the speed of the motor increases?

9. What carburetor has a pair of reeds that open

and close the air passage with the speed of the motor?

10. What cars use carburetors with a double throat? Why is this type used?

Unit X. Characteristics and Repair of Fuel Gauges and Fuel Pumps

References

Buick Motor Division. Shop manual, 1934. Flint, Mich., Buick motor company, 1934. 207 p. Pages 41 and 155.

Chrysler Corporation. Master maintenance manual, 1935. Detroit, Mich., Chrysler corporation, 1935. Sixteen groups. Group nine, pages 1 to 3.

Information

Remarkable progress has been made in the last decade in the manufacture of fuel gauges and fuel pumps. Some text books that were published in 1926 carry no information on these devices. For many years automobile drivers were satisfied to carry a stick along for the purpose of measuring the amount of gasoline in the tank. Neglectful people often walked for miles in order to get to a filling station to procure some gasoline.

As manufacturers began to put the gasoline tank on to the rear of the car, they also put a dial indicator, actuated by a cork float, on the tank which would tell the driver approximately how much gasoline he had in the tank. This type is obsolete today for drivers do not like to walk to the rear of the car to note how much gasoline they have in the tank.

This was followed by the hydrostatic type in which the indicator was placed on the instrument panel. The hydrostatic principle means pressure according to depth. The air that is trapped in the air chamber in the gasoline tank will be under a pressure that is proportional to the depth of the gasoline in the tank. This chamber is connected by an air line to a U tube on the instrument panel containing a colored fluid. As gasoline is placed in the tank the pressure exerted will cause a difference in levels of the fluid in the U tube. These instruments can be calibrated quite accurately.

Most of the gasoline gauges found on late model cars operate on the same principle. The dash unit consists of two magnetically opposed coils. These are placed with the cores making a ninety degree angle, and in the apex of the V is mounted a small vane to which is connected the pointer. The two coils have an opposite direction of winding, but have the same current and magnetic characteristics. The same voltage is impressed upon both coils.

A resistance unit actuated by a cork float is in the tank. The operation of the gauge depends upon the relative magnetic strengths of the two coils caused by supplying more current to one coil than to the other. As the fuel level in the tank is raised or lowered, the resistance is changed thereby unbalancing the magnetic fields of the coils, which in turn causes the vane to register the amount of fuel in the tank.

Repair of the first type of fuel gauge consists essentially in removing air leaks and balancing the fluid in the U tube so that it gives the correct reading. It is important that the proper fluid be used when servicing this gauge. An eye dropper is a good tool to use for replacing the liquid. Defective tank units are very rare, so the trouble usually is in the gauge head, air line, or connections.

In servicing the electric type of gauge, alcohol only should be used when cleaning either the tank or the dash unit. Trouble with the electric type of gauge is simplified if an extra tank unit is available that can be connected to the dash unit. Do not forget to ground the tank unit to the chassis if this is done. The following should be checked in case of trouble: breaks in the line, poor connections, the tank unit burned out, wires on the dash unit reversed, the dash unit, or the gasoline tank not grounded.

As much improvement can be shown on automobiles in the method of getting fuel to the carburetor as in the method of registering the amount of fuel in the tank.

The first cars depended upon gravity for fuel flow to the carburetor, but this necessitated the placing of the fuel tank under the seat or under the dash. Some very disastrous fires resulted from this practice, and, besides, it was an inconvenient place to have the fuel tank.

When fuel tanks first began to appear on the rear of the chassis, air pressure was used to force the fuel to the carburetor. This was not satisfactory for air leaks developed and the pressure could not be maintained. The next big improvement was the advent of the vacuum tank, in which the suction of the motor created a vacuum, and the atmospheric pressure of the air on top of the fuel level in the gasoline tank forced the fuel to the carburetor.

The fuel pump, as we know it today, has proven to be so satisfactory and free from trouble that it has superseded all other methods of getting fuel to the carburetor.

This device consists of an intake valve, an exhaust valve, and a large diaphragm operated by means of a linkage and cam follower from the cam on the camshaft.

As the diaphragm moves downward a vacuum is created, as in the case of the vacuum tank, and atmospheric pressure forces the fuel to the pump and thence to the carburetor. When the carburetor is full the back pressure set up causes the pump to become inactive. The pump remains inactive until fuel is needed at the carburetor.

This makes the pump entirely automatic, and on late model cars a vacuum booster pump is incorporated with the fuel pump to supply a steady suction to the windshield wiper blades.

The manufacturer's instructions should be followed very closely in the installation of new parts in these pumps.

Some of the repairs that can be made without removing the pump from the engine are: tighten all of the pipe connections, tighten the glass bowl which is loose or leaking, remove the glass bowl and clean the screen, tighten the valve plugs, tighten the cover screws of the diaphragm flange alternately and securely, replace the valves and valve springs.

Extreme care should be exercised to replace the diaphragm in the proper position so that it will not be in a twist or strain when the pump is working. Valve seats should be carefully checked, and a drop of oil on the valves will cause the pump to start working without delay. The pump will be ruined and possibly the engine damaged, if the pump operating arm is not placed on the proper side of the cam shaft when the pump is bolted to the engine.

Never stretch any of the pump springs or replace the valves with anything else, such as steel balls or metal discs.

Whenever the pump is disassembled, it is the best policy to replace the diaphragm, valves, and valve springs with new ones. Also inspect the valve seats for pits and scratches.

If vacuum equipment is not available for testing the pump when reassembled, a satisfactory test may be made by connecting the suction side of the pump to a piece of copper pipe 30 inches long, and by working the pump arm the pump should raise gasoline from a container 30 inches below the pump in from twenty to forty strokes. It should be rechecked if it will not do this.

Summary exercises and questions for discussion

1. With the throttle approximately 1/4 to 1/3 open, how long will it take to feed a pint of kerosene through an engine, letting it take all it will without choking down completely? (This may be fed to the engine from an oil can to which a rubber tube is connected, taking it in through the windshield wiper connection on the manifold.)

2. Could excess gasoline be fed through the engine the same way?

3. What would be the effect, on the gasoline consumption of an engine, with a pump that is in good condition and a float needle valve that was slightly leaking?

4. How often should the glass sediment bowl be cleaned?

5. Why is it important that the sediment bowl gasket be tight?

6. How is gasoline fed to the carburetor on some racing cars?

7. What is the purpose of the fuelizer on the

Packard carburetor?

8. What kind of fluid is needed to service the fuel gauge on the Ford V-8?

9. What happens if the hole in the gas tank cap becomes stopped up?

10. Some manufacturers supplied a metal shield for their fuel pumps. What was its purpose?

11. Sometimes the fuel pump cover becomes distorted at the screw holes. What can be done about this condition?

12. A gas line or other metal tubing on the automobile frequently breaks. What can be done to cure this trouble?

13. Is there any fire hazard in the tank unit of an electric fuel gauge?

14. Of what material is the diaphragm and also the valves of a fuel pump made?

Unit XI. Carburetor Adjustment and the Use of the Vacuum Gauge in Carburetor Adjustment

References

Buick Motor Division. Shop manual, 1934. Flint, Mich., Buick motor company, 1934. 201 p. Page 48.

Carter Carburetor Company. Shop manual, 1935. St. Louis, Mo., Carter carburetor company, 1935. 403 p. Pages 60 to 187.

Information

Carburetors give such a small amount of trouble that all other sources of trouble should be checked and the motor tuned up before the carburetor is worked on. Any mechanic, who has had several years of experience, will tell you that he has many times refused a customer's request to adjust his carburetor, because he knows from experience that it is useless to try to adjust a carburetor when there is uneven compression on the cylinders or the ignition system is not functioning properly.

As was mentioned previously, the intermediate and high speed range on late model carburetors can only be changed by changing jets. The idling adjustment can be changed at will.

If a vacuum gauge is available it should be used before any changes are made in carburetor adjustment as it will indicate some of the things on the engine that need to be repaired before the carburetor adjustment is made. Engines are designed to draw from 16 to 18 inches of vacuum at the correct idling speed. With the vacuum gauge attached, the dropping back at regular intervals of the hand on the vacuum gauge indicates valve trouble. If the hand drops back at irregular intervals it indicates gummy valve stems, an improper mixture in the carburetor, or an occasional spark plug miss. A low vacuum indicates a leak someplace in the manifold system. A very heavy, irregular drop indicates a head gasket leak. If the hand flickers and the flicker becomes more pronounced with an increase of speed, it indicates weak valve springs. If the motor is in good condition, the vacuum gauge will tell you when the best idling adjustment is obtained. The hand should hold steady at from 16 to 18 inches of vacuum.

In the repair of carburetors, the jets should be replaced at periodic intervals, as the flow of fuel, which many times contains a fine silt, will eventually make the hole in the jet larger.

Many times a customer requests that a smaller jet be placed in the carburetor of his automobile for the purpose of decreasing the fuel consumption. Great care should be exercised in cutting down the size too much. The manufacturer carried on extensive experiments to determine the proper size jet for maximum performance of that engine. Too lean a mixture will cause excess heat which in turn will burn the valves.

A road test under varying conditions and speeds should always be made after carburetor adjustments have been changed.

A needle valve of any kind should never be screwed tightly against its seat. This practice will cut a groove in the needle and the valve seat will be distorted. Needle valves and needle valve seats should always be examined in cases where it is impossible to make a good idling adjustment.

As a final check on a carburetor, a gas analyzer should be used, where possible, to determine if all of the fuel is being utilized.

<u>Summary exercises and questions for discussion</u>

1. What is the principle behind the vacuum gauge that makes it valuable for an engine check up?

2. Can a vacuum gauge be used to check the condition of a fuel pump? Explain.

3. Will a manifold heat valve that is inoperative, have any effect on carburetor efficiency?

4. Sometimes the riser tube between the carburetor and the manifold has a small hole in the inner wall. What effect will this have on engine performance?

5. What is an easy method to use in checking for leaks in manifolds and manifold gaskets?

6. What should be the approximate air valve setting on a Marvel carburetor, as used on a Buick car?

7. If the dash pot controlling the metering pin on a Stewart carburetor becomes covered with fine silt and becomes inoperative, what will be the performance of the engine? Explain.

8. What three makes of carburetors are the most commonly found on late model cars?

9. Should any adjustment be made of the manifold heat control on certain cars?

10. Is the automatic choke universal on late model cars? Explain its use.

11. The late Stromberg carburetors have a thick insulating pad between the upper and lower body castings. What is the purpose of this?

12. How is carburetor size determined? Why not put a Dodge carburetor on a Ford or a Ford carburetor on a Plymouth?

13. Where is the manifold on the Ford V-8?

14. How many idling adjustments will be found on dual carburetors?

15. Where are dual carburetors used?

16. What is the best method to use when making idling adjustments on carburetors of this type?

17. What is the principle upon which a gas analyzer works? Explain.

APPENDIX

APPENDIX

JOB ANALYSIS WITH ADDITIONS AND ELIMINATIONS

Block A. The fundamentals of electricity.

Job analysis under A:

1. Electricity as a form of energy.
2. Static electricity.
3. Generated electricity.
4. Theory of electricity.
5. Conductors.
6. Non-conductors.
7. Insulation.

*8. Resistance of wires.
*9. Resistance of circuits.
10. Material of wire.
11. Switch insulation.
12. Generator insulation.
13. Starting motor insulation.
14. Material of brushes.
15. Ohm's Law.
16. Alternating current.
17. Direct current.
18. The generator and magnetism.
19. The generator, theory of operation.
20. The starting motor and magnetism.
21. The starting motor, theory of operation.
22. The horn motor, theory of operation.
23. The horn, its relation to magnetism.
24. The relay and magnetism.
25. The voltage regulator and magnetism.
26. The spark coil and magnetism.
27. The ammeter and magnetism.
28. The fuel gauge and magnetism.
b 29. Flux density of field and armature.
c 30. Eddy currents.
b *31. Hysteresis curves.
b 32. The electron theory.

Block B. How to trace electrical circuits and locate trouble.

Job analysis under B:

1. Tracing circuits by using the voltmeter.

Block B. How to trace electrical circuits and locate trouble.

Job analysis under B, continued:

2. Tracing circuits from charts.
3. Testing circuits with instruments.
4. The motor analyzer.

Block C. An understanding of storage batteries.

Job analysis under C:

1. Battery acid and water.
2. The battery, connection with different circuits.
3. Battery voltage.
4. Battery testing.
5. Battery care and storage.
6. Battery plate sulphation.
7. Battery terminal corrosion.
8. Battery rating.
9. Battery life.
10. Chemical and electrical energy of.
11. Battery size in relation to motor size.
12. Difference in batteries.
13. Quality of material used in batteries.

a 14. Chemistry of the battery.
e 15. Battery manufacture.
e 16. Battery separators.
d 17. Battery rebuilding.
e 18. Battery plates.
b 19. Local action in batteries.
b 20. Battery chargers.
d 21. Lead burning.
e 22. Battery hangers and boxes.
b 23. Battery efficiency.

Block D. How to rewire cars.

Job analysis under D:

1. Rewiring circuits.

e 2. Wire manufacture.
c 3. Switch design.
e 4. Switch manufacture.
b 5. Corona effect in wires.
*6. Why renew wires.
*7. Reading wiring diagrams.

Block E. Ignition timing.

Job analysis under E:

1. Timing the ignition.
2. Synchronization.
*3. The cam angle.

Block F. The use of motor gauges and synchronizing tools.

Job analysis under F:

1. Ignition timing with instruments.
2. Importance of instruments.
3. Eight cylinder motors and synchronizing tools.

Block G. The causes of ignition trouble.

Job analysis under G:

1. The use of instruments to locate trouble.
2. Switch testing.
3. The spark plug, ignition points, condenser, coil, distributor, wires and source of current.
4. Testing ignition units.
5. Servicing ignition units.
6. The adaptation of spark plugs to different motors.

Block H. An efficient method of trouble shooting.

Job analysis under H:

1. Method of substitution.
2. Method of elimination.
3. Testing with instruments.

Block I. The fundamentals of coils, condensers, voltage regulators, cutouts, and distributors.

Job analysis under I:

1. The ignition requirements of distributors.
*2. Elementary ignition principles.
3. Spark advance mechanism.
4. How to service distributors.
*5. The cam angle.
6. The distributor, principle of operation.
7. The distributor, how to connect into the circuit.

Block I. The fundamentals of coils, condensers, voltage regulators, cutouts, and distributors.

Job analysis under I, continued:

8. Ignition point adjustment.
9. Types of distributors and adjustment.
10. The spark coil, principle of operation.
*11. The spark coil, its relation to a transformer.
12. Speed of coil field build up and break down.
13. Spark coil testing.
14. Connecting a spark coil into the circuit.
15. Coil protection and insulation.
16. Condenser action on coil voltage.
17. The condenser, principle of operation.
18. Connecting a condenser into the circuit.
19. The relation of a condenser to a Leyden jar.
20. Condenser testing.
21. The effect of the condenser on the ignition points.
22. The relation of the condenser to the secondary voltage.
23. Condenser leakage.
24. Horn relays.
25. Purpose of voltage regulator.
26. Purpose of cutout.
c 27. Details of mounting coils, condensers, cutouts, voltage regulators, and distributors.
c 28. Theory of design of coils, condensers, cutouts, voltage regulators, and distributors.
c 29. Material of coils, condensers, voltage regulators, cutouts, and distributors.
e 30. Manufacture of coils, condensers, cutouts, voltage regulators, and distributors.
f 31. Rewinding of coils, voltage regulators, and cutouts.
f 32. Repair of coils, condensers, voltage regulators, and cutouts.

Block J. Generating circuits.

Job analysis under J:

1. Connecting a generator into the circuit.
2. Connecting an ammeter into the circuit.
3. Connecting a cutout or a voltage regulator into the circuit.
4. Testing for trouble.

Block J. Generating circuits.

Job analysis under J, continued:

5. Knowledge of the circuit.
6. Adjustment of the cutout.
7. Adjustment of the voltage regulator.
8. Testing the cutout.
9. Testing the voltage regulator.

Block K. Starting motor circuits.

Job analysis under K:

1. Connecting a starting motor into the circuit.
2. Testing for trouble.
3. Knowledge of the circuit.
*4. The starting switch.

Block L. Generators.

Job analysis under L:

1. Assembly and dis-assembly.
2. Generator performance.
3. Undercutting mica.
4. Dressing the commutator.
5. Generator testing assembled.
*6. Generator testing dis-assembled.
7. Mechanical defects of generators.
8. Repair of generators.
b 9. Theory of third brush control
f 10. Armature rewinding.
f 11. Field rewinding.
f 12. Rebuilding fields, armatures, and commutators.
c 13. Eddy currents.
b 14. Armature iron.
c 15. Armature laminations.
c 16. Materials of construction.
e 17. Generator manufacture.
c 18. Theory of design.
b 19. Types of generators.
b 20. Generating characteristics.
b 21. Efficiency of generators.
b 22. Theory of series, shunt, and compound generators.
23. Driving mechanism.
g 24. Mechanical construction.
g 25. Bearings.
c*26. Field distortion.

Block M. Starting motors.

Job analysis under M:

1. Starting motor testing assembled.
2. Starting motor testing dis-assembled.
3. Material of brushes.
4. Care of commutator.
5. Assembly and dis-assembly.
6. Mechanical defects.

b 7. Flux density of field and armature.
f 8. Armature and field rewinding.
f 9. Rebuilding of fields, armatures, and commutators.
c 10. Materials of construction.
c 11. Eddy currents.
c 12. Theory of design.
g 13. Mechanical construction.
b 14. Types of starting motors.
g 15. Starter drives.
e 16. Performance of.
e 17. Manufacture of.
c 18. Brush design.
b 19. Theory of series, shunt, and compound motors.

Block N. How fuel gauges and fuel pumps function.

Job analysis under N:

1. The fuel gauge, principle of operation.
2. The fuel pump, principle of operation.
3. Relation of the fuel pump to the carburetor.
4. Relation of the fuel pump to motor performance.

e 5. Fuel gauge and fuel pump manufacture.
b 6. Material of construction.

Block O. How to repair fuel gauges and fuel pumps.

Job analysis under O:

1. Repair of fuel gauges.
2. Testing fuel gauges.
3. Adjusting fuel gauges.
4. Repair of fuel pumps.
5. Testing fuel pumps.
6. Adjusting fuel pumps.

Block P. An elementary knowledge of carburetion.

Job analysis under P:

1. The carburetor, principle of operation.
2. Relation of fuel to air for combustion.
3. Vaporization.
4. Relation of compression to fuel economy.
5. Relation of compression to power.
6. Motor fuels.
*7. Relation of fuel to power at different speeds.
8. Relation of fuel consumption to speed.
a 9. Chemistry of fuels.
a 10. Chemistry of gases.

Block Q. Characteristics of standard makes of carburetors.

Job analysis under Q:

1. Types of carburetors.
2. Motor performance and the carburetor.
3. The relation of the carburetor to the fuel pump.
4. The accelerating pump.
e 5. Manufacture of.
b 6. Material of.
c 7. Theory of design.

Block R. How to repair standard makes of carburetors.

Job analysis under R.

1. The repair of carburetors.
2. Testing carburetors.
e *3. Rebuilding carburetors.

Block S. How to adjust carburetors.

Job analysis under S:

1. The principle of carburetor adjustment.
2. How to adjust different types of carburetors.
3. Lean and rich mixtures.

Block T. Principles of the vacuum gauge as applied to carburetors.

Job analysis under T.

*1. The vacuum of the manifold.
2. The vacuum gauge, principle of operation.
3. Checking motor performance with the vacuum gauge.

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