AN EXPERIMENTAL COMPARISON OF DIRECT-AND-DETAILED METHOD AND DIRECTED-DISCOVERY METHOD OF TEACHING SELECTED AUTOMOTIVE TOPICS TO SENIOR HIGH SCHOOL INDUSTRIAL ARTS STUDENTS

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CHAPTER I

INTRODUCTION

Orientation of the Problem

An important duty of the classroom teacher is to structure learning activities in such a way that students will initially learn, retain, and use the results of these activities in their daily living. The efficiency of various instructional methods has often been evaluated in terms of these criteria.

The methods employed in organizing and presenting the course content may determine to a large extent the degree to which students understand and are able to transfer the facts and principles which they learn in school. Logically, it seems that teaching methods should be based upon the principles of learning that have been established in the psychological laboratory and that have been experimentally tested in the classroom. Practically speaking, however, there seem to be too many controversial and confusing directions which face the discriminating teacher who wishes to offer the best teaching possible. For example, one may find support for a teaching method that involves highly direct and detailed instruction. Through this method, the subject material is presented to the student in great detail. The teacher poses problems and proceeds directly to the task of solving them in a step-by-step fashion. The students have little or no responsibility to discover methods of solutions or principles involved in the solution.

In arguing that the teacher should utilize a direct method of instruction and that errors in learning should be held to a minimum, Thorndike states:

> The attainment of active rather than passive learning at the cost of practice in error may often be a bad bargain. Refusal to supply information on the ground that the learner will be more profited by discovering facts by himself runs the risk not only of excessive time cost but also of strengthening of wrong habits. The learner's self-punishment when he makes a mistake may sometimes be no better than the punishment in our experiments. The almost universal tolerance of imperfect learning by gradual elimination of errors in later treatments, is probably unsound and certainly risky. What removes errors in later treatments is the rewarding of the right connections, and such rewarding might be better put to work earlier.[1]

Hilgard, et. al., concludes on the basis of an experimental study designed to evaluate a memorization method and an understanding method that whatever advantages of learning the understanding method may have, could be offset, because of the greater amount of time required in this way of teaching.[2]

Other educators believe in a directed-discovery method

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[1] E. L. Thorndike, The Psychology of Wants, Interests, Attitudes (New York, 1935), p. 147.

[2] E. R. Hilgard, R. P. Irvine, and J. E. Wipple, "Rote Memorization, Understanding and Transfer: An Extension of Katona's Card-Trick Experiments," J. Experimental Psychology, LIV, 1953, p. 288-292.

of instruction which places a greater responsibility upon the learner to participate actively in the learning situation. This method draws its support from cognitive theories of learning which are identified with gestalt psychology. Through this method, instruction consists primarily of posing leading questions, providing cue patterns, and providing suggestions so that the student is directed to the discovery of principles and relationships through the phenomenon of insight.

Research evidence on the direct-and-detailed method of instruction shows considerable variation. At one extreme the student, in Dewey's words, "becomes a spectator" as the teacher presents his rigid, highly organized course content.[3] The student listens, takes notes, and sometimes memorizes information in order to be able to give it back at test time. At the other end of the scale, the method is direct-and-detailed but emphasizes a logical organization of materials coupled with an attempt to provide an understanding of the principles being taught.

Research evidence on discovery methods of instruction also shows wide variation in meaning. Some researchers have used the term to mean pure and unassisted discovery; to others it means to employ varying degrees of direction; still others believe some help should be given in discovering the solution.

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[3] J. Dewey, Democracy and Education (New York, 1916), p. 146.

The present study is not concerned with evaluating the methods at either of the extremes. Instead, a method involving discovery with direction will be contrasted with a method that is admittedly direct-and-detailed, but which nonetheless emphasizes a logical organization of materials coupled with an attempt to provide an understanding of the principles under consideration.

Definition of Terms

Direct-and-Detailed Method of Instruction. This method of instruction presents the subject matter under consideration in detail. The instructor assumes the major responsibility for the continuity of development; reinforcement is generally overt. Closure is primarily extrinsic and problems are solved in a step-by-step procedure, providing little opportunity for the learner to discover methods of solution or to identify principles and make generalizations. The subject has less freedom for the establishment of broader meanings and understandings, due to the nature of this method. Teaching aids are mainly used to supplement verbal discourse and then only after explicit directions are provided in their interpretation and use. In this study, the direct-and-detailed method will be referred to as Treatment A.

Directed-Discovery Method of Instruction. This method of instruction provides greater opportunity for student participation in the learning process. Students share in the responsibility for the continuity of development and reinforcement is indirect. Closure is largely dependent upon the individual and problems are presented in such a way that there is opportunity for individual solution, and for identification of the principles and relationships. Extended time pauses as well as cues and questions encourage the student to think with greater independence and freedom. When teaching aids are provided as a supplement to the verbal presentation, discovery is a major consideration in their interpretation and use. In this study, the directed-discovery method will be referred to as Treatment B.

Initial Learning. In this project, initial learning refers to the character and extent to which the subjects are able to recall the principles, skills, and understanding which were presented in the lessons. A multiple-choice objective type test is used to determine the amount of initial learning as measured immediately after treatment. This test is identified as Test I.

Transfer. Transfer occurs when old learning and new problem situations are interrelated because of common principles, factors, stimuli, or applications. From the standpoint of education, transfer centers around the extent to which learning of one thing facilitates the learning of something else and to the extent to which learning in classroom situations carries over to live situations outside the classroom. In this study, transfer occurs when students are able to apply learned principles in the solution of new problems. The amount of transfer is measured by a multiple-choice objective type test, administered immediately after treatment which is designed to utilize problems that test for diversified applications of the principles taught in the lesson. This test is identified as Test II.

Ability Levels. Three ability levels are considered in this work--high, average, and low. The high ability group includes those subjects having an I. Q. score of one hundred and seven or above, the average ability group those subjects having an I. Q. score of ninety-five to one hundred and six, and the low ability group those subjects with I. Q. scores of ninety-four and below. The high, average, and low levels of intelligence will be referred to as X_1, X_2, X_3 respectively.

Statement of the Problem

While some studies in industrial education have found a directed-discovery method to be superior in retention and transfer of learning to the direct-and-detailed method of instruction, no conclusive and consistent evidence which supports this position has been found.

It is possible, however, that the effectiveness of the directed-discovery and the direct-and-detailed methods may vary with intelligence levels. For example, the directed-discovery method may be superior for students of high mental ability whereas the direct-and-detailed method may prove more effective with average and low ability groups. The design of this research study is such that the effectiveness of the methods under consideration may be evaluated in terms of high, average, and low ability groups. In addition to the fact that there has been no consistent evidence which supports the superiority of one method over the other, there have been no studies found in the search of literature which compare the two methods when a student is actually involved in a theory and laboratory type instructional unit. An additional feature is that this study utilizes only senior high school industrial arts students as subjects.

This study is designed to provide additional research evidence regarding the relative effectiveness between direct-and-detailed and directed-discovery methods of instruction by utilizing the instructional content found in a specific unit of automotive mechanics.

More specifically, an attempt will be made to answer the following questions in respect to the preceding statement.

1. What differences, if any, exist between the direct-and-detailed method and the directed-discovery method of teaching senior high school industrial arts students relative to initial learning on each of the three intelligence levels selected?
2. What differences, if any, exist between the direct-and-detailed method and the directed-discovery method of teaching senior high school industrial arts students relative to transfer of learning on

each of the three intelligence levels selected?

3. How do the senior high school industrial arts students compare on each of the three intelligence levels selected between initial learning and transfer of learning.

Statement of Hypotheses

1. There are no differences in initial learning, as measured by a criterion test given immediately following instruction, on any of the intelligence levels (X_1, X_2, or X_3) or between the treatment groups (A, B, or C) comprised of senior high school industrial arts students.
2. There are no differences in transfer of learning, as measured by a criterion test given immediately following instruction, on any of the intelligence levels (X_1, X_2, or X_3) or between the treatment groups (A, B, or C) comprised of senior high school industrial arts students.
3. There are no differences between initial learning and transfer of learning in the three treatment populations and the three intelligence levels as measured by criterion tests administered immediately following instruction.

In this chapter, the need for evaluating the efficiency of various instructional methods was introduced; the specialized terminologies related to the study were defined;

the problem was stated; and the hypotheses were constructed so that statistical inferences might be made after testing the experimental data. An overview of the development of the remainder of this study follows.

The review of literature pertaining to the study is presented in Chapter II. Since methods of teaching would appear to have their foundations based upon the principles of learning, the literature related to those principles was selected in respect to the two methods under investigation. The literature which was believed to be the most important in respect to the investigation of the two methods is presented under the following headings in Chapter II: structure in learning, reinforcement and guidance, and problem-solving.

Following the review of literature, the research experiment is developed and explained in Chapter III. In this chapter the design of the experiment, population and sampling, the learning task, the treatments, the instructional methods and materials, the objective tests, and the pilot study are developed and examined.

The first part of Chapter IV includes an explanation of how the research instrument in its entirety is validated. It consists of the following divisions: the statistical use of the control group, the test for homogeneity of variance, the test for disproportionality, and the mathematical means used to convert the individual test scores to standard scores. Since the individual scores between the initial learning and the transfer of learning tests were not equivalent, it was necessary to convert them to standard scores so that the mean differences of these scores could be statistically tested.

In the second part of Chapter IV, the results of the analysis of variance and individual t-tests are reported for each of the three hypotheses stated previously in this chapter.

Chapter V includes the summary and conclusions of the study. The first part of this chapter is comprised of a review of the entire study and it contains the following divisions: the purpose of the study, a statement of the hypotheses, the experimental design, the population and sampling, the treatments, the learning task, the objective tests, and the findings.

The second part of this chapter, which is concerned with conclusions, includes the following subheadings: limitations of the study, implications for further research, and educational implications.

CHAPTER II

REVIEW OF LITERATURE

Introduction to Learning

One major purpose of the review of the literature is to identify the principles of learning which are concerned with the two methods of teaching being investigated in this study. A second purpose is to assist in drawing out and interpreting the concepts or understandings which would give direction and aid in the development of this study. A third purpose for a review of the literature is to determine if there are any related studies conducted and if there are, to select findings from these studies which will aid and support or refute the findings of this experiment.

The literature concerned with the principles of learning indicates that the majority of writers and researchers in education agree that there is no simple solution to the complex problem of how man learns. The great void which separates education from an understanding of how learning is best accomplished appears to stem from the fact that the psychologists working at the frontiers of their science today have little interest in pedagogical problems.

Thorpe says:

> One of the more singular features of the American social scene is that the systematic foundations of educational procedures are so little understood that theory and educational practice commonly are regarded as having little or no relation to each other.[1]

Practices in education often have been launched without adequate direction from psychology. Theories of learning, when applied to education, have frequently been submerged into methods which merely appeared to the teacher to produce the best results.

Thorpe gives the following explanation for this apparent inadequacy in our educational system:

> Because traditionally they have been a nation of "doers," Americans have tended to look askance at theoretical considerations. Thus many teachers have been so imbued with the idea of "getting things done" that they have been impatient with theories of learning. Important implications of the problem of learning thus have been by-passed in favor of stereo-type methods of instruction. If the technique of instruction seemed effective, it was considered by the teacher as fulfilling its purpose.[2]

From the previous comments, it appears that neither teachers nor learners would be very satisfied with the results of their efforts.

Gage suggests that the teacher needs to understand the theories of learning to guide, predict, and control the learning process and in addition, the teacher needs to

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[1] Louis P. Thorpe and Allen M. Schmuller, <u>Contemporary Theories of Learning</u>, (New York, 1954), p. 3.

[2] Ibid., pp. 9-10.

understand and be able to apply the theories of teaching.[3] Gage makes a basic distinction between theories of learning and theories of teaching. He says: "While theories of learning deal with the ways in which an organism learns, theories of teaching deal with the ways in which a person influences an organism to learn."[4] Gage elaborates upon the previous statement by indicating that the theories of learning deal with what the learner does, but changes in education must depend in a large part upon what the teacher does. Changes in how learners go about their business of learning occur in response to the behavior of their teachers or others in the educational establishment.[5]

From the previous readings, it appears that much of our knowledge about learning can be put into practice only by teachers, that practical applications for teaching have not been gleaned from the theories of learning, and that once the implications of learning have been translated into implications for the behavior of teachers, the teachers will act upon these in such ways as to improve learning.

Structure in Learning

Granted that almost everyone admits the importance of

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[3]N. L. Gage, "Theories of Learning and Instruction," The Sixty-Third Yearbook of the National Society for the Study of Education, Part I, ed. by E. R. Hilgard (Chicago, 1964), p. 269.

[4]Ibid., p. 268.

[5]Ibid., p. 271.

making teaching more meaningful, the researcher still faces the task of finding out just how this can be done.

Bruner suggests that, "Grasping the structure of a subject is understanding it in a way that permits many other things to be related to it meaningfully. To learn structure, in short, is to learn how things are related."[6]

Bruner suggests that four claims can be made for teaching the fundamental structure of a subject. They include the following:

> The first is that understanding of fundamentals makes a subject more comprehensible. The second point relates to human memory. Perhaps the most basic thing that can be said about human memory after a century of intensive research, is that unless detail is placed into a structured pattern, it is rapidly forgotten. Detailed material is conserved in memory by the use of simplified ways of representing it. Third, an understanding of fundamental principles and ideas, as noted earlier, appears to be the main road to adequate "transfer of training." To understand something as a specific instance of a more general case--which is what understanding a more fundamental principle or structure means--is to have learned not only a specific thing but also a model for understanding other things like it, that one may encounter. The fourth claim for emphasis on structure and principles in teaching is that by constantly re-examining material taught in elementary and secondary schools for its fundamental character, one is able to narrow the gap between "advanced" knowledge and "elementary" knowledge.[7]

The importance of teaching fundamental structure in any meaningful learning situation appears to be unquestioned.

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[6] Jerome S. Bruner, The Process of Education (Cambridge, 1961), p. 7.

[7] Ibid., pp. 23-24.

There is some indecision, however, in respect to when the structure should be provided in the lesson.

In a recent experiment, Ausubel found that student performance is increased by providing structure before the learning begins.[8] He equated two groups of college seniors, majoring in education, on the basis of an examination over previous learning. One group was assigned to an "advance organizer" group and the other to an "historical introduction" group. Later both groups were to study an article dealing with metallurgical properties of carbon steel. Prior to studying this major article, however, the advanced organizer group spent two five-minute periods in reading a passage which set forth the main categories of the major paper. During the same two five-minute periods, the historical group read a selection on the historical evolution of methods of making iron and steel. After these different orientations, both groups spent thirty-five minutes in studying the basic paper on steel. Three days later, both groups were given a test on the basic paper. The advanced organizer group did significantly better on the test than did the historical introduction group.

In respect to the amount of structure needed, Stephens says: "Most of the time when we experience anything, we

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[8]David P. Ausubel, "The Use of Advance Organizers in the Learning and Retention of Meaningful Verbal Material," Journal of Educational Psychology, 1960, LI, pp. 267-272.

become aware of that thing as a part of a pattern or structure."[9] Stephens continues:

> The pattern may be simple and primitive, as when we see a splotch of mud on a white wall, or it may be extremely complicated, as we become aware of pattern imposed on pattern in a musical composition or other work of art. But, however, simple or complex, the pattern or structure is typically an important part of the experience.[10]

According to the adherents of gestalt psychology, or field psychology, such as Kohler, structure or pattern is the basic feature of all experience.[11] The structure is experienced first, and the details are filled in later.

Stephens says that although some pattern is bound to be noticed at the outset of any experience, the most obvious pattern is not bound to be the most interesting or useful one. He continues by suggesting that in the development of structure, sometimes the teacher can over-develop the structure. Sometimes new material presented so as to emphasize an elaborate and important structure proves no easier to learn than the same material presented in an arbitrary or rote fashion.[12]

Newman experimented with this theory. He had students

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[9]John M. Stephens, The Psychology of Classroom Learning, (New York, 1965), p. 146.

[10]Ibid., p. 146.

[11]W. Kohler, Gestalt Psychology, An Introduction to New Concepts in Modern Psychology (New York, 1947), pp. 15-30.

[12]Stephens, p. 147.

learn the meaning of the symbols used in electrical wiring. For some students, these symbols were grouped in a very logical pattern. Other students were given the same symbols grouped in a helter-skelter fashion. The experimenter compared the two methods at two different periods of time, eight and twelve minutes. For both time periods, the superiority of the free-style (unstructured group) was significant over the organized (structured) group.[13]

In this respect, Ausubel suggests a moderate position. He says, ". . . complete independent discovery, even if feasible, is seldom as effective as learning with reasonable amounts of help."[14] He continues with the following explanation of the importance of structure:

> Existing cognitive structure (an individual's organization, stability, and clarity of knowledge in a particular subject-field at any given time) is regarded as the major factor influencing the learning and retention of meaningful new material in this same field. The properties of cognitive structure determine both the clarity and validity of the meanings that emerge as new material enters the cognitive field, as well as the nature of the interactional process that takes place. If cognitive structure is stable, clear, and suitably organized, valid and unambiguous meanings emerge and tend to retain their individuality and dissociability.[15]

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[13] S. E. Newman, "Student Vs Instructor Design of Study Method," Journal of Educational Psychology, 1957, IIL, pp. 328-333.

[14] David P. Ausubel, The Psychology of Meaningful Verbal Learning (New York, 1963), p. 26.

[15] Ibid., pp. 26-27.

Although most writers and researchers consider structure as being an important ingredient in the learning process, they do not seem to be able to agree upon the amount of structure required for effective learning. Perhaps an answer to the conflicting amounts of structure necessary for effective learning may be found when the relationships are considered between structure and motivation. Bruner relates structure to motivation in the following way:

> Teaching specific topics or skills without making clear their context in the broader fundamental structure of a field of knowledge is uneconomical in several deep senses. In the first place, such teaching makes it exceedingly difficult for the student to generalize from what he has learned to what he will encounter later. In the second place, learning that has fallen short of a grasp of general principles has little reward in terms of intellectual excitement. The best way to create interest in a subject is to render it worth knowing, which means to make the knowledge gained usable in one's thinking beyond the situation in which the learning occurred.[16]

As Bruner sees it, student interest and initial motivation may be enhanced by proper structuring of the lesson.

Many theories concerned with motivation have been developed in recent years. The controversies regarding the precise nature of motivation stem from the change in the older theories of learning.

Sears and Hilgard suggest some reasons for the indefinite position, at the present time, regarding the precise nature or the status of motivation:

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[16] Bruner, p. 31.

> The once dominant need-drive-incentive theory, interpreting reinforcement as drive-reduction, has been undergoing searching re-examination. The drives usually studied (hunger, thirst, pain) were always treated as aversive drives, from which relief was sought; now the "neglected drives" of curiosity, manipulation, activity, and achievement, which emphasize the positive side of something sought rather than the negative of something to be escaped, have come to the fore.[17]

Although much of the motivation is done to get pupils into a situation in which learning can occur, it would appear that motivation can be a strong influence throughout the entire learning period. Providing knowledge of results is an excellent way of motivating students to apply themselves to the task at hand. In this way, a student's knowledge of previous performance would tend to make him compete against his own record.

Stephens says that when a student answers a question in class, the teacher's facial expression may clearly tell him whether his answer is right or wrong. If the student is right he probably feels good and is motivated to the next learning step. If he is wrong, the teacher encourages him and he continues.[18] These simple manipulative urges constitute almost the sole source of motivation used in teaching machines and introduce the concepts of reinforcement and guidance as these principles in learning relate to the two methods of teaching under investigation.

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[17] Sears and Hilgard, ed., E. R. Hilgard, p. 183.

[18] Stephens, p. 85.

Reinforcement and Guidance in Learning

The direct-and-detailed method of teaching as it is defined in Chapter I appears to have its basic foundations within the associationistic and behavioristic theories of learning. Hill indicates that most of the learning theories within academic psychology have a stimulus-response orientation, except those of a gestalist origin. He believes that there has been in recent years an acceptance of the behaviorists to the cognitive and purposive interpretations from the field theories of learning.[19]

In view of this, modifications in interpretations of drive and reinforcement appear to be significant because the behaviorists of early study have stressed that the stimulus-response formula must be limited to physical situations. The emphasis was on conditioning by contiguity; this was extrinsic in nature.

In contrast, the present-day behaviorists appear to be more interested in the intrinsic values. Skinner suggests some of the problems and the possible solutions in the following paragraphs:

> Whether by intention or necessity, teachers have been less given to teaching than to holding students responsible for learning. Methods are still aversive. The student looks, listens, and answers questions (and incidently, sometimes learns) as a gesture of avoidance or escape. The birch rod or cane are gone,

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[19] Hill, ed., E. R. Hilgard, pp. 27-28.

> but their place has been taken by equally effective punishments (criticism, possibly ridicule, failure) used in the same way; the student must learn or else.[20]

Skinner continues with the following discussion:

> Current efforts to use rewards in education show the same direction. Texts garnished with pictures in four colors, exciting episodes in a scientific film, interesting classroom activities--these will make a school interesting and even attractive, but to generate specific forms of behavior these things must be related to the students' behavior in special ways. Only then will they be truly rewarding or, technically speaking, "reinforcing." The marks, grades, and diplomas of education are conditioned reinforcers designed to bring ultimate consequences closer to the behavior reinforced. Like prizes and medals, they represent the approval of teachers, parents, and others, and they show competitive superiority, but they are mainly effective because they signalize progress through a system toward some ultimate advantage of, or at least freedom from, education. To this extent they bridge the gap between behavior and its remote consequences; but they are still not contingent on behavior in a very effective way.[21]

From the discussion so far, it seems that extrinsic motivation, whether it is in the form of avoidance of punishment or the provision of material wishes, will not develop within the student the intense desire for understanding. If the teacher's contact with the learner could be a continuous process throughout the learning period, there seems reason to believe that the inner desire to gain understanding could be enhanced for the student. When one relates this possibility to the two teaching methods under investigation, the pattern

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[20] Burrus F. Skinner, "Why we Need Teaching Machines," Harvard Educational Review, XXXI (1961), p. 378.

[21] Ibid., p. 379.

within the directed-discovery method appears to be the best suited of the two because in this method the student actively participates throughout the lesson by thought questions and cues.

Skinner says, ". . . perhaps the most serious criticism of the classroom is the relative infrequency of reinforcement."[22] He continues with this discussion in the following paragraph:

> Since the pupil is usually dependent upon the teacher for being right, and since many pupils are usually dependent upon the same teacher, the total number of contingencies which may be arranged during say, the first four years, is of the order of only a few thousand. But a very rough estimate suggests that efficient mathematical behavior at this level requires something of the order of 25,000 contingencies.[23]

In the following paragraph Skinner suggests that reinforcement need not be a complex condition:

> Fortunately, we can solve the problem of education without discovering or inventing additional reinforcers. We merely need to make better use of those we have. Human behavior is distinquished by the fact that it is affected by small consequences. Describing something with the right word is often reinforcing. So is the clarification of a temporary puzzlement, or the solution of a complex problem, or the opportunity to move forward after completing one stage of the activity.[24]

Skinner does not believe we need to stop to explain why

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[22]Ibid., p. 380.

[23]Burrus F. Skinner, "The Science of Learning and the Art of Teaching," Harvard Educational Review, XXIV (1954), p. 91.

[24]Ibid., p. 91.

these things are reinforcing. He indicates that it is enough that when properly contingent upon behavior they provide the control we need for successful educational design.

As Skinner sees it, the whole process of becoming competent in any field must be divided into a very large number of very small steps, and reinforcement must be contingent upon the accomplishment of each step. He does not agree with J. C. Pressey who designed one of the first units of programmed learning on the basis of using multiple-choice questions in which the student tested himself. Skinner gives the following reasons for this disagreement:

> In the first place the student should construct rather than select a response, since this is the behavior he will later find useful. Secondly, he should advance to the level of being able to emit a response rather than merely recognize a given response as correct. Thirdly, and more important, multiple-choice material violates a basic principle of good programming by inducing the student to engage in erroneous behavior.[25]

There appears to be a considerable amount of controversy about the effectiveness of auto-instruction. Adults using programmed instruction often equal or surpass those exposed to the traditional classroom situation. In a comparative study of programmed and conventional instruction in industry, Hughes and McNamara found a significant difference in favor of programmed learning. The mean scores from an examination given to the two groups who were taught a 16-hour

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[25] Skinner, p. 393.

course on servicing an IBM 7070 computer were 94.7 for the programmed instruction group and 86.9 for the conventional group.[26] From this study the dispersion of the scores were indicated to be much less for the programmed group. Two-thirds of the "programmed" scores were 95 or better and only 11 per cent fell below a grade of 90. The conventional group scores were spread over a much wider range. From this study, it would appear that all levels of students in technical subjects would learn more by the programmed method than by the conventional one.

Skinner--and others who advocate linear programming--tries to make sure that almost every response will be reinforced. He suggests the following manner in which the programmed material may be presented:

> Program material is stored on a fan-folded paper tapes. One frame of material, the size of which can be varied with the nature of the material, is exposed at a time. The student writes on a separate strip.
>
> The student sees printed material in the large window at the left. This may be a sentence to be completed, a question to be answered, or a problem to be solved. He writes his response in the uncovered portion of a paper strip at the right. He then moves a slider which covers the response he has written with a transparent mask and uncovers additional material in the larger opening. This may tell him the response is wrong without telling him which is right.--Cues may then be given.[27]

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[26] J. L. Hughes and W. J. McNamara, "A Comparative Study of Programmed and Conventional Instruction in Industry," Journal of Applied Psychology, VI (1961), pp. 225-231.

[27] Skinner, p. 385.

From the previous discussion of programmed learning and teaching machines, it would appear that there is a relationship between reinforcement and guidance in learning. Stephens suggests this relationship in the following paragraph:

> It is difficult to apply reinforcement without also providing some guidance. True enough, it can be done, but one must go to some trouble to arrange it. By the same token, it is difficult to provide guidance without at the same time providing reinforcement.[28]

Wohlwill and other psychologists do not agree that it is wise, or possible, to make sure that the student is guided into each response with no room for uncertainty or error. They believe that a period of uncertainty may be necessary for some kinds of learning.[29] This concept would be acceptable to the advocates of the directed-discovery or problem-solving method of teaching.

In an early study Craig investigated the relative effectiveness of different amounts of guidance in promoting transfer, in the transferability of such guided learning tasks with varying levels of difficulty, and in the changes in the dependence of transfer upon initial ability. Craig's study uses the word "guidance" to refer to clues or cues offered to the subject as an aid in solving the problem.

In this study two hundred college graduates were divided

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[28] Stephens, p. 125.

[29] J. F. Wohlwill, "The Teaching Machine: Psychology's New Hobbyhorse," Teachers College Record, LXIV (1962), pp. 139-150.

into four treatment groups. They were differentiated by receiving different amounts of guidance to aid in the discovery of the basis for the correct responses to a series of items. The relative effectiveness of the different amounts of guidance in promoting transfer was determined by a comparison of group post-training performances on a series of similar but non-identical items. Since the learning situations were organized according to meaningful principles, another indication of transfer effect was obtained by a comparison of the number of principles the several groups were able to identify in the post-training situation. The number of principles that a group can recognize and state may be interpreted as a relative indication of the understanding of relationships developed through the guidance provided. Craig concludes that transfer is facilitated not only by organization of the materials but also by increasing the number of clues provided to aid discovery. Findings also indicate that the more difficult the task, the greater the advantage of additional guidance.[30]

The evidence from Craig's experiment offers little support for the hypothesis that the ability to transfer is dependent to a greater extent upon initial ability than upon the degree of guidance in the learning process.

Although similar to ordinary learning in some ways,

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[30] R. C. Craig, The Transfer Value of Guided Learning (New York, 1953), pp. 1-6.

problem-solving presents more difficulties in the way of orientation, provides little reinforcement for early efforts, and requires the teacher to withhold guidance. With these features in mind, one might ask what the problem-solving method offers the teacher and the learner that other methods do not offer? Before this question can be answered, it is necessary to know how problem-solving is defined, what the extremes are, and how they relate to understanding.

Problem-Solving Method

Directed-discovery is a form of problem-solving defined in Chapter I as a method of instruction whereby the teacher allows the student to accept some of the responsibility of learning by encouraging him to use his basic knowledge to think through the solution to the problem.

There are some writers who claim that principles or rules have genuine meaning to the student only when they are independently discovered by that student.[31] This concept would appear questionable to many. To expect a student to comprehend important principles with no assistance by the teacher would seem to be a time-consuming and hopeless venture.

Brownell explains problem-solving as follows:

> One may define problem-solving so broadly as to make the term synonymous with learning. To do so, one needs to point out that all learning starts with

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[31] Brunner, pp. 58-59.

> some inadequacy of adjustment, some disturbance of equilibrium--and so, with a "problem" . . . and in the process of achieving adjustment and returning to a state of equilibrium one "solves" the problem.
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> According to this broad conception, the cat, when it learns to pull the cord or to depress the button and so to escape from the unfamiliar puzzle box; the student in the psychological laboratory, when he learns to run a finger maze while blindfolded or when he memorizes lists of nonsense syllables; the child in school when he grasps the meaning of a scientific principle and learns how to apply it . . . all of these engage in problem solving.[32]

Brownell recommends that, for clarity, problem-solving should be referred to in such a way that it becomes a process by which the subject extricates himself from the problem. He limits problem-solving to include only perceptual and conceptual tasks which the subject is capable of understanding but in which at the moment he has no direct means of satisfaction. He grants that the subject may experience perplexity in the problem situation; however, with the task within the capabilities of the student, it should not be an experience where utter confusion exists.[33]

After recommending that problem-solving be observed under the previously set limitations, Brownell continues to analyze this method of teaching and learning by making the following comments:

> Defined thus, problems may be thought of as occupying intermediate territory in a continuum

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[32] W. A. Brownell, "The Psychology of Learning," The Forty-First Yearbook of the National Society for the Study of Education, Part II, ed. N. B. Henry (Chicago, 1942), p. 415.

[33] Ibid., p. 417.

> which stretches from the "puzzle" at one extreme to a completely familiar and understandable situation at the other. In the case of puzzles, the nature of the task may vary from wholly novel (which the learner has no means of solving or escaping) to the slightly known (in which the learner may recognize vaguely where to work, though he does not know what to do). His present experience is one of bewilderment, and this is brought on by the strangeness of the situation and its lack of meaning to him. If he is successful in solving the puzzle, his success is the result of accident and the solution is not likely to be retained or to be transferable to other puzzle situations. In the case of completely familiar and understandable situations, no problem exists, as is true of puzzles, for the reason that the learner has available satisfactory responses which have been habituated, and there is no uncertainty as to procedure.[34]

Brownell says that the last fifteen years or so have witnessed promising changes in psychological research so far as problem-solving is concerned. One important change consists of an attempt to set problems which mean something to the subject, or at least which envisage the learning task as it most probably is seen by the subject. It is true that not all efforts to improve problem-solving ability have been successful. Brownell believes that the reason lies in the use of methods which are powerless to produce this end.[35]

Brownell thinks that some methods put too much trust in technique and disregard other essentials in effective problem-solving. He explains this by suggesting that in order to think clearly and well one must have something with which

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[34] Ibid., p. 417.

[35] Ibid., p. 418.

to think. This "something" refers to facts, to meanings, and understandings. Without these, a technique of problem-solving is considered useless. Brownell adds that it is precisely at this point that many modern instructional practices are deficient. He warns there is danger in the often repeated statement that "it is more important to teach how to think than what to think." The danger is that with neglect of understandings and meanings, the materials with which one thinks may well result in a complete stultification of thinking or, worse, in an over-confidence in the judgments and decisions reached in the absence of relevant data.[36]

As Brownell sees it, the problem-solving method of teaching requires that the student should gain understandings rather than merely learn a procedure. In addition, he believes that the student must enter the learning phase with some basic understandings.

There are some who believe that whereas the problem-solving method offers certain special benefits to the learner, this method should not be used in all types of learning situations. Stephens supports the preceding statement and offers suggestions as to those learning situations in which the problem-solving method might be considered superior:

> We often do find superior learning when there is emphasis on student activity and initiative, when

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[36] Ibid., p. 431.

> the search for a principle is clearly kept in mind, and when many examples are provided. This general approach, however, includes many features over and above sheer independent discovery on the part of the students. Any one of these features, moreover, may account for the frequent superiority of the general approach.[37]

In support of this and related to his study of the motivating effect of directed-discovery learning, Kersh concludes, "Among other things, the greater ego involvement may lead students to spend more time in practicing the tasks, or thinking about them outside the formal practice periods."[38]

Ausubel also indicates that an all-or-none position regarding use of the discovery method is warranted neither by logic nor evidence. The method itself is very useful for certain pedagogic purposes and in certain educational circumstances.[39] He suggests that the discovery method has obvious uses in evaluating learning outcomes in teaching problem-solving techniques and appreciation of the scientific method.

He believes that there is no better way of developing effective skills in hypothesis making and testing, in forming desirable attitudes toward learning and inquiry, and in gaining an ability to solve problems on one's own.[40]

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[37] Stephens, pp. 158-159.

[38] B. Y. Kersh, "The Motivating Effect of Learning by Directed-Discovery," Journal of Educational Psychology, 1962, LIII, pp. 65-71.

[39] Ausubel, pp. 142-143.

[40] Ibid., p. 143.

In addition Ausubel says, ". . . it seems plausible to suppose that the greater effort, motivation, and vividness associated with independent discovery lead to somewhat greater learning and retention."[41] He also indicates that with this method:

> One might expect the advantages conferred by discovery techniques to be even greater with respect to transferability, since the experience gained from formulating a generalization from diverse instances obviously facilitates the solution of problems involving this generalization.[42]

Over the past decade, there has been a continually increasing interest in research concerned with ways of improving industrial arts teaching. Searching inquiries are being directed especially toward teaching methods involving problem-solving.

Ray compared the direct-and-detailed and directed-discovery methods of teaching micrometer principles and skills. He was concerned with the relative effect of the method of presentation upon initial learning, retention and transfer. In addition, the experiment was so designed that it was possible to test for level times treatment, first order interaction, as well as for main effects. One hundred and seventeen ninth grade subjects were selected at random from three junior high schools. The task involved the use of a one-inch vernier micrometer caliper. The oral instruction was

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[41] Ibid., p. 144.

[42] Ibid., p. 144.

presented via the medium of a tape recorder and was supplemented by illustrations through the use of 35 mm. slides. An initial learning test was administered immediately following the instructional period and tests for retention and transfer were given at one and six week periods after treatment. All tests involved both performance and pencil and paper items.

Ray found no significant differences between the two experimental groups in terms of initial learning or retention at one week. However, there was a significant difference in retention as measured at six weeks, which favored the directed-discovery method. The directed-discovery group was found to be significantly superior in their ability to transfer principles and skills as measured at one and six weeks following instruction. There was no evidence of interaction between treatment and ability groups.[43]

As an extension of Ray's study, Rowlett compared direct-and-detailed and directed-discovery methods of teaching orthographic projection principles and skills. He was concerned with the relative effect of the two methods of instruction upon initial learning, retention and transfer, as well as testing for interaction. Three ability levels, similar to those used by Ray, were employed in this

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[43] W. E. Ray, "An Experimental Comparison of Direct and Detailed and Directed Discovery Methods of Teaching Micrometer Principles and Skills," (unpub. Ed.D. dissertation, University of Illinois, 1957), pp. 61-68.

experiment. Similar methods of stratifying the experimental population and selecting a stratified sample were used by both Rowlett and Ray. However, Rowlett also matched his groups on the basis of sex, since it was believed that these two groups of students would have dissimilar backgrounds of experience and familiarity with the task selected. Both Ray and Rowlett used standardized intelligence test scores as outside criterion for matching ability levels. In the experiment, 168 ninth-grade students from a single community high school served as subjects. Instruction was provided by a tape recorder and was supplemented by individual student work books and three dimensional models. An initial learning test was administered immediately following instruction, and retention and transfer tests were given to all subjects at twelve and forty-five days after treatment. Whereas Ray used an analysis of variance design for testing the null hypotheses, Rowlett employed t-tests in validating his hypotheses. Rowlett found no significant difference between the two experimental groups as measured by the initial learning test. This finding supports the comparative results of initial learning reported by Ray. However, Rowlett found that the directed-discovery group was significantly superior in both retention and transfer, when measured twelve days after instruction. Rowlett's findings relative to transfer at six weeks supports the results reported by Ray in that the directed-discovery group was superior to the direct-and-detailed group on this criterion measure. No interaction between teaching methods and intellectual levels was found.[44]

Moss investigated the relative effectiveness of two methods of verbal instruction, direct-and-detailed and directed-discovery, in which different amounts and types of teacher guidance were employed. The experimental population consisted of one hundred thirty-one male vocational-industrial high school students. Both methods were theoretically capable of providing meaningful learning experiences.

The criteria used to measure the outcomes of instruction, indicative of the relative effectiveness of these methods, were tests of initial learning, retention, and transfer.

The experimental design included a treatments by levels analysis of variance. The subjects were randomly assigned within a given I. Q. level to one of three treatment groups. The experimental population consisted of one hundred thirty-one male students in one high school.

The logical basis for testing the direct-and-detailed and directed-discovery methods of presentation rested upon the premise that at least one of these methods would result in greater learning than a no-teacher presentation. The control group was, therefore, included in the design to estimate the amount of learning attributable to the instruction

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[44] J. D. Rowlett, "An Experimental Comparison of Direct-Detailed and Directed-Discovery Methods of Teaching Orthographic Projection Principles and Skills" (unpub. Ed.D. dissertation, University of Illinois, 1960), pp. 93-101.

provided by the recorded lessons. The results of the criterion tests showed that the treatment groups receiving instruction performed consistently superior to the control group. The results of the criterion test also indicated that the subjects who were instructed by the direct-and-detailed method scored consistently better than the subjects who were instructed by the directed-discovery method. In the light of these results, and the generally inconsistent findings in this study with Ray's, Rowlett's, and Grote's studies, the writer was led to question the equivalence of the treatments, the learning tasks and the criterion tests.[45]

Grote, in a study similar to those already mentioned, compared the relative effectiveness of direct-and-detailed and directed-discovery methods of teaching selected principles of mechanics in the area of physics. The design permitted a test for differences between groups on the basis of an ordering of treatment sequences, as well as testing for differences between groups instructed at each learning session by the differential methods. In addition the experimental design provided tests for first and second order interactions involving sex, levels, and treatments.

The results indicated that the direct-and-detailed method was superior when compared on the basis of initial

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[45]J. Moss, "An Experimental Study of the Relative Effectiveness of the Direct-Detailed and the Directed Discovery Methods of Teaching Letterpress Imposition" (unpub. Ed.D. dissertation, Purdue University, 1960, pp. 1-12.

learning after the first instructional period. In the two lessons with the sequence in which the directed-discovery preceded the direct-and-detailed method, the transfer was superior.[46]

A study conducted by Sommers at the University of Minnesota involved an evaluation of selected teaching methods on the development of creative thinking. This study was based on the following assumptions:

> 1) that the abilities involved in being creative are universal, 2) that these abilities can be increased through training, 3) that one of the legitimate functions of the school is to provide such training, and 4) that it is desirable to develop creative abilities within the framework of existing school curricula.[47]

The following hypotheses were tested:

> 1) there is no difference, as measured by the subject matter test, in adjusted mean gain in subject matter understanding between the control group and the experimental group, and 2) there is no difference, as measured by the Test of Imagination (form DX), in adjusted mean gain in total creative thinking between the control group and the experimental group.[48]

Two groups of students were involved in two consecutive "runs" of the experiment. The control group received instruction involving the usual methods and course outline.

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[46] C. N. Grote, "A Comparison of the Relative Effectiveness of Direct-Detailed and Directed-Discovery Methods of Teaching Selected Principles of Mechanics in the Area of Physics" (unpub. Ed.D. dissertation, University of Illinois, 1960), pp. 126-133.

[47] W. S. Sommers, "The Influence of Selected Teaching Methods on the Development of Creative Thinking" (unpub. Ed.D. dissertation, University of Minnesota, 1961), p. 5.

[48] Ibid., p. 113.

The experimental group was taught by special methods which were developed by Sommers. The principle technique employed with the experimental group was called "sketchstorming."

The subjects were students at Stout State College who were enrolled in a course in freehand drawing.

The experiment was evaluated on the basis of scores yielded on tests given before and after the lessons were taught. A locally constructed test developed to evaluate the understanding of freehand drawing was administered to determine gains in subject matter. The Test of Imagination (Form DX) prepared by the Bureau of Educational Research at the University of Minnesota, was used to assess increases in creative thinking.

The two experimental hypotheses were rejected. The findings indicated that:

> 1) it is possible, by use of specific methods designed to increase creative thinking, to improve certain abilities associated with creative thinking in an industrial arts course, and 2) the use, in an industrial arts laboratory course, of special methods to improve creative thinking will not negatively affect subject matter learning. In fact, Sommers suggests that such methods may actually increase subject matter learning.[49]

With respect to further research, Sommers recommends that:

> 1) investigations should be conducted to determine the effectiveness of using special methods to increase creativity within industrial education laboratory courses other than just the drawing area, 2) investigations similar in design and purpose to this study, should be conducted to investigate the effectiveness

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[49]Ibid., p. 116.

> of other techniques for increasing creativity, 3) investigations, similar in design and purpose to this study, should be conducted to determine the feasibility of improving creative thinking within academic courses, and 4) an investigation should also be conducted to evaluate the persistence of effects of the inclusion of creative learning activities within subject matter courses.[50]

In a recently completed study at the University of Minnesota, Cornwell tested the value of instruction sheets in regard to the learning process in industrial education. Furthermore, he was concerned with the efficiency, in terms of alternative methods of organization, of the traditional pattern of instruction sheets.

Cornwell's study compared the achievement of college students in a classroom situation with one group of students using problem-centered instruction sheets and a control group using traditional instruction sheets. Cornwell's experiment was designed to provide answers to the following questions:

> 1) Will problem solving materials develop more knowledge of the subject matter than will more direct instruction? 2) Will problem solving materials develop more manipulative skills in the subject matter area than will more direct instruction? 3) Will students gaining knowledge by problem solving methods retain it better than students taught by more direct instruction? 4) Is it possible to prepare two similar sets of assignment sheets which will give significantly different results attributable to their organization? 5) Do students of various ability levels show different results when taught through the use of the two different types of instructional sheets? Is it possible that good students will learn more by solving problems, but that poor students will learn more by direct instruction? 6) Is there any relationship between student learning from these

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[50] Ibid., pp. 118-119.

two types of assignment sheets, and his previously stated preference for the type of instructional method? Is it possible to select a student who will learn more by problem solving, by determining his preferences for a type of instruction? and 7) Is it possible that one instructor will have better results with one set of instruction sheets, and another instructor have opposite results?[51]

Two instructors taught the four experimental classes in which the two types of instruction sheets were employed. Two classes met each quarter and the two instructors used opposing types of assignment sheets the first experimental quarter and exchanged experimental methods the next quarter. Three criterion tests were employed:

> 1) a performance test administered one week prior to the end of the course, 2) a final examination administered at the end of the course, and 3) a retention test given eight weeks after the final examination.[52]

Cornwell reports the following findings:

> 1) the classes using problem assignments made performance test scores which were significantly higher, 2) there were significant differences on the performance test between students having different instructors, and indications of a method-by-instructor interaction, though the latter appeared not be significant when ability level interactions were removed. Although both instructors had the best performance results with the problem methods, instructor B found it only slightly better, while instructor A found it much better on this measure. Any method-by-instructor interaction in this study could possibly be caused by quarter difference since the instructors taught each method in different quarters. 3) on the final examination scores there were no significant differences between the teaching methods, 4) there

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[51] R. L. Cornwell, "Written Instructional Materials: "An Experimental Comparison of Problem-Centered and Traditional Assignment Sheets" (unpub. Ph.D. dissertation, University of Minnesota, 1961), pp. 7-8.

[52] Ibid., p. 209.

> was significant instructor-by-method interaction and indications of instructor differences on the final examination. Instructor A had the highest achievement using problem methods while instructor B had better results using direct methods. The latter instructor had the highest average achievement, 5) on the delayed test score levels there appeared to be method differences in favor of the problem assignments but these were not significant when tested. However when difference scores were analyzed there were significant method differences in favor of the problem groups.[53]

Sommer's and Cornwell's studies appear to offer some valuable additions to the research literature in industrial education related to problem-solving and certainly demonstrate the values inherent in longitudinal studies when conducted under normal teaching situations.

The study by Ferns offers excellent guidance for those who are interested in developing experimental studies of similar problem-solving situations.

Ferns' study is best classified as philosophical; however, it might also be identified as synthetic research since its purpose was to focus on the concepts and findings originating in a number of studies.

In regard to industrial arts, Ferns' aim was to develop principles for guiding teachers when designing and conducting learning experiences for improving student problem-solving abilities. The principles were developed as the result of careful examination of, 1) writings of selected authorities in education who have dealt with problem-solving as an

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[53] Ibid., pp. 211-213.

objective and method of education, 2) the writings of educational philosophers John Dewey and William Kilpatrick, and 3) experimental research studies in problem-solving.[54]

Ferns developed the following underlying principles for guiding industrial teachers in conducting and designing problem-solving type of learning through a rational and an authoriative means. They include the following principles:

1. The greatest gains in improving student problem solving abilities can be effected when the teacher consciously plans learning experiences with the goal of improving problem-solving ability in mind.

2. The improvement of student problem-solving abilities is best accomplished by the teacher's regulating indirectly the conditions which guide it.

3. The exposure of students to direct experience in attempting to solve real-life problems through the use of problem-solving method is the teacher's most appropriate way to achieve improvement in problem-solving abilities.

4. In designing and selecting problem situations suitable for improving student problem-solving abilities, it is important that the teacher make the distinction between genuine problems and those which are not. The following criteria should serve to define authentic problem situations: a) There should be an objective in view, b) There should be something blocking the objective, c) There should be an awareness or consciousness of the goal and blocking obstacle. There should be intellectual activity. d) There should be a high degree of subjective identification or motivation, and e) Problem situations at both ends of a problem difficulty continuum, which range from extremes of the completely familiar (rectifiable through unthinking, habitual response) to

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[54]G. W. Ferns, "Principles for Designing and Conducting Learning Experiences for Improving Problem-Solving Abilities as Applied to Industrial Arts Teaching" (unpub. Ph.D. dissertation, Michigan State University, 1962), pp. 1-6.

puzzles (solvable through accident, rational means being of little consequence), are less desirable problem situations than those in between and should be minimized.

5. It should be recognized that problem-solving is both a method and an objective in education. It is a means for achieving numerous educational objectives, including improvement of problem-solving abilities. It is also an end or an objective of education because of its significance as a method in living and learning.

6. Problem-solving method is practically synonymous with learning; and there are indications that problem-solving is generally equal or superior to other methods of learning.

7. Learning experiences, to be educative, should provide for further growth, for interaction between individual and environment and for intelligent managing of ends and means. They should be continuous with past and future experience, should have both active and passive elements, and should include reflective thinking.[55]

The preceding principles developed by Ferns have proved to be of considerable assistance to the researcher in developing the problem-solving lessons, in conducting the lessons, and in the developing the transfer of learning examinations.

In addition to the seven underlying principles stated previously, Ferns developed seventy additional principles of a more specific nature that relate to the phases of problem-solving. The specific principles which are especially related to this problem will be discussed in the following paragraphs:

Under source and nature of problems, Ferns suggests that

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[55]Ibid., pp. 233-235.

problems should include a balancing of old and new. Without the new or strange elements there would be no problem; without the old or familiar, inquiry might be useless. He concludes that school activities, especially industrial arts, can furnish a real potential for development of problem-solving because of the abundant opportunity for active use of materials and equipment.[56]

In a school situation, Ferns indicates that suggestions for solutions of problems seem to occur with the interaction of, 1) developing an acquaintanceship with existing conditions in a situation, and 2) past experience. He believes the teacher should direct his efforts toward providing experiences which help create a rich experimental background, and toward encouraging the problem-solver to saturate himself with information surrounding the problem situation. In addition, Ferns indicates that the student should be provided with time for incubation by including breaks or diversions from the concentrated attention on problems.[57]

In respect to the use of questioning as a valuable technique in stimulating thinking, Ferns suggests, 1) that questions should motivate the student to use material already learned in dealing with the problem, 2) that questions should direct the student to subject matter rather than to the teacher's aim, thus avoiding a "guessing bee" as to what the

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[56]Ibid., pp. 197-199.

[57]Ibid., pp. 205-209.

teacher is really after, 3) that questions should build for the student a large inclusive situation within which there can be movement from one point to another, and within which meaningful relationships cannot be seen, and 4) that questions should periodically require a survey and review of subject matter that has been covered to extract new meanings and to gather together and hold what is significant.[58]

From the review of the fundamentals concerned with learning, it appears that, in most cases, without structure there will be no understanding or meaningful learning. A meaningful set or approach to learning only eventuates in a meaningful learning process and outcome provided that the learning material itself is potentially meaningful to the learner. If the learner's intention is to memorize, both the learning process and the learner's outcome must necessarily be rote and meaningless.

To this end, the teacher must develop and present the material in such a way that it is relatable to the particular cognitive structure of the learner.

It would seem that the concepts reviewed in relation to motivation would also find their place in the course development and methodology when selected by the type of teacher who elects to teach with meaning and understanding.

After providing the adequate structure in the learning situation, the next important consideration which faces the

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[58]Ibid., p. 206.

discriminating teacher is to maintain a schedule of success throughout the lesson. Reinforcement involves arranging the learning situation so that when conditions are appropriate, the learner will experience a series of motivating pleasant feelings as he progresses through the learning unit. In this process, it would be helpful if the student had more successes than failures.

From the suggestions and guidance offered in the review of literature concerned with problem-solving, it seems that one should approach the task of developing a lesson involving the problem-solving method with an awareness that the use of this method depends, 1) upon the individual's capacity--the more mature the individual, the more readily insight or understanding is achieved, 2) upon previous experience--although not guaranteed by such experience, since insight or understanding is not possible without it, and 3) upon the experimental design--unless a situation is so arranged that it can be structured by the individual, insight cannot be gained.

CHAPTER III

THE RESEARCH EXPERIMENT

Introduction

Although the review of literature reveals that learning is accepted as being important, there are many variations in methodology as to how it might be accomplished most efficiently. Many believe that the methods employed in organizing and presenting the course content will determine, to a great extent, the degree of student understanding and ability to transfer the facts and principles he learns in school to activities in his daily living. All educational programs presumably rest upon some sort of psychological theory, but in the case of recent educational practices, the theory appears to be implied more often than stated. This allows for many controversial and confusing directions which face the discriminating teacher who is committed to offer the best teaching possible.

Further investigation of the literature indicates that some educators support a direct-and-detailed method. Through this method, the subject material is presented to the student in great detail. The instructor assumes the major responsibility for the continuity of development, and reinforcement is generally overt. Other educators believe in a directed-discovery method of instruction which places a greater responsibility upon the learner to participate actively in the learning situation.

Additional investigation of the literature concerned with methods of teaching reveals that over the past decade there has been a continually increasing interest in research concerned with ways of improving teaching. While some of these related studies have found a directed-discovery method to be superior in retention and transfer of learning, no conclusive and consistent evidence has been found.

In view of the literature summarized in Chapter II, the design for an appropriate study should be concerned with contrasting a method of teaching, involving discovery with some assistance, with a method of teaching that is admittedly direct-and-detailed but that none-the-less emphasizes teacher assistance in understanding the principles under consideration. In contrast with other related studies, this work will employ only senior high school industrial arts students as subjects. The instructional content will be taken from a specific unit usually found in a course in auto mechanics. In addition, the instruction will involve the subjects in theory as well as in laboratory work. In this chapter, the research experiment is organized and developed so that the hypotheses stated in Chapter I can be statistically analyzed. The following organization will include an explanation of the design of the experiment, the population sampling, the learning task, the treatments, the instructional methods, the objective tests, and the pilot study.

Experimental Design

Three treatment groups, namely, the direct-and-detailed, the directed-discovery, and a control group, were established under the terms identified in Chapter I, Definition of Terms. The subjects were stratified on mental ability levels. This was accomplished by first stratifying the subjects into three ability level groups according to IQ scores. From each of the level groups, random assignments were made to the various treatment groups. Such a procedure was believed to insure that the final three groups were stratified relatively proportionate in regard to subjects with high, average, and low IQ scores.

As given under Definition of Terms in Chapter I, the high ability group included those subjects having an IQ score of 107 or above, the average ability group included those subjects having an IQ score of 95 to 106 inclusive, and the low ability group included those subjects with scores of 94 and below.

The design of this study lends itself to analysis of variance as a primary or "beginning" means of statistical analysis. The first and second questions under the Statement of the Problem in Chapter I are primary treatments which can be solved separately. In respect to these questions, the analysis of variance of initial learning scores and transfer of learning scores were developed as two separate 3 x 3 factorial design problems and both were analyzed for main effects and first order interactions.

Since an F-test is only an overall test of the entire group, it was necessary to test the null hypothesis applied to the mean difference by individual t-tests between treatments on each level for the initial learning and transfer of learning.

The third and final question in the statement of the problem requires a comparison of the same treatment on each of the three intelligence levels selected, between initial learning and transfer of learning. Since an analysis of variance had already been computed for both sets of scores, individual t-tests were computed for each intelligence level, between Treatment A for Test I and Test II and between Treatment B for Test I and Test II. The control group was not included in the final comparison.

The experimental variables in this study are: 1) instructional methods, and 2) ability levels. The criterion variables are: 1) initial learning, as measured by an objective test, administered following the instructional periods, and 2) a transfer of learning test, as measured following the initial learning test. The controlled variables include: 1) methods of presentation and content, 2) length of instruction time, 3) audio-visual aids, and 4) tests and testing conditions.

While the instructional methods were considered as an experimental variable, they were controlled to the degree that all instruction was tape recorded. This required that individual tape recordings be prepared for each of the two methods under consideration, including both the theory and laboratory parts. For this reason, the instructional methods were included in the experimental variables and also in the controlled variables.

Population and Sampling

The population used in this experiment were Iowa senior high school industrial arts students.

The subjects were selected at random from high schools which lie within a forty-five miles radius of Cedar Falls, Iowa. This sample includes the major cities and towns in twelve northeastern counties of the State.

The accuracy of the sample used in this experiment was expected to be improved by selecting at random, from the sample area, high schools from: 1) two cities which have populations of seventy-five hundred or more, and 2) two towns which have populations between two thousand and seventy-five hundred persons. A cut-off point was believed necessary in the selection of the small towns because of the lack of industrial arts departments in towns smaller than this in size.

The high schools in the major cities with populations of seventy-five hundred and over within the sample area included Cedar Falls, Charles City, Marshalltown, Oelwein, East Waterloo, and West Waterloo. Waterloo and Cedar Falls were the only two cities in the sample area having two public high schools. The experimenter decided that each of the high schools in these cities would be included individually in the experiment. The State College High School in Cedar Falls failed to qualify, however, because of the lack of senior high school industrial arts students.

The high schools in the towns with populations of between two thousand and seventy-five hundred which fell within the sample area included Grundy Center, LaPorte City, Independence, Iowa Falls, New Hampton, Waverly, and Vinton. Other towns within this population range which were in the sample area were not used in the experiment because of one or more of the following reasons: 1) too few industrial arts students at the high school level, 2) problems in scheduling the experiment, and 3) other administrative reasons. Those towns in the sample area which failed to qualify for selection were Eldora, Hampton, Sumner, and Toledo.

It was believed that a sample which might be more representative of the total population could be selected from this area because consolidation of schools, large area transportation of pupils, and the mass movement of population from rural to urban centers have already been contributing factors in increasing the uniformity of the schools throughout the State.

The size of the sample necessary to provide considerable dependability of the mean and standard deviation was determined and limited by the following criteria: 1) authoritative literature on the subject, 2) limitations of time and expense concerned with doing the experiment, and 3) the available numbers of senior high school industrial arts students in the towns and cities represented within the sample.

In respect to adequacy of the size of the sample, Garrett offers the following approximate standard deviation range covered by samples of different sizes when drawn from the normal population:

N = 10	Range ± 2.0 SD
N = 50	Range ± 2.5 SD
N = 200	Range ± 3.0 SD
N = 1000	Range ± 3.5 SD[1]

From the preceding information and that found in Table A, it is evident that an increase in numbers from two hundred to one thousand would raise the range only one standard deviation. This would increase the area under the normal curve less than one-quarter of one per cent.[2]

The second and third criteria related to the size of the sample were determined by the judgment and experience of the writer. The writer's position at the State College of Iowa requires numerous extension visits to various industrial arts departments in schools throughout the State. These visitations allowed for the opportunity to find the

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[1]H. E. Garrett, Statistics in Psychology and Education (New York, 1958), p. 208.

[2]Ibid., p. 446.

approximate number of subjects there who would be available in the schools within the proposed sample area. A total of two hundred and fifteen subjects were found to be available for the experiment. It was decided that twenty-three subjects would be selected at random for each cell, representing the four schools selected in the sample area. Since there are nine cells, representing three methods times three treatments, a total of two hundred and seven subjects were selected from those available. The initial distribution of subjects assigned to each cell is indicated in Table I.

Prior to carrying out the experiment, a personal data sheet was completed by all potential subjects within the sample area to assist in the organization and development of the study. Further explanation of the personal data sheet will be found later in this chapter.

In the attempt to arrive at a percentage of students who would be lost to the experiment through tardiness, absence from school, lack of complete records, and other unforeseen reasons, the writer checked previous attendance and tardiness records in each of the four schools involved in the experiment. A fifteen per cent loss or twenty-seven subjects from the total sample of two hundred and seven was believed to be adequate. This allowed the final sample size to be at least one hundred and eighty subjects. It was decided that the additional subjects who had completed the experiment beyond the one hundred and eighty required would be used in the statistical results. Indicated in Table II

TABLE I

INITIAL ASSIGNMENT OF SUBJECTS TO TREATMENTS AND LEVELS

Intelligence Level	Number of Subjects			
	Treatment A	Treatment B	Treatment C	Total
High 107 IQ and above	23	23	23	69
Average 95 to 106 IQ	23	23	23	69
Low 94 IQ and below	23	23	23	69
Total n	69	69	69	207

are the available numbers of subjects assigned to each of the three levels in respect to each of the two cities and the two towns which were selected in the same area.

The experimenter was concerned with using the maximum number of subjects and since there appeared to be no accurate way to predict which of the cells (the treatment groups or the ability level groups) would sustain the greater loss, no individual adjustments were made. The final distribution of subjects assigned to each cell is indicated in Table III.

Since homogeneity of the random sampling appears to be a concern of many statisticians, the experimenter decided to use a method of "counting off" the sample at random. Lindquist explains the difference between a random sampling of the total population and dividing a sample by random methods in the following paragraphs:

> It is very seldom that an experimenter can draw his subjects strictly at random from the real population in which he is basically interested. Usually he must be content to work with those numbers of that population who are readily accessible to him, even though the accessible members of the population may differ systematically from those who are not accessible. A research worker in psychology, for example, might wish to work with random samples from a population consisting of "all adult males," but may have to be content with a sample consisting of male students in a sophomore course in general psychology in a particular college or university. . . .
>
> Very frequently, however, the experimenter can draw his experimental subjects strictly at random from those subjects that are accessible to him. If not, he can nearly always at least randomize his experimental subjects with reference to the treatments.
>
> That is, by use of a table of random numbers he can leave it strictly to chance which subjects are to constitute each treatment group. Having done this, he may then fairly contend that his experimental

TABLE II

AVAILABLE SUBJECTS BY INTELLIGENCE LEVEL IN EACH SCHOOL

Intelligence Level	Number of Subjects				
	Cedar Falls	Waterloo	Waverly	LaPorte	Total
High 107 IQ and above	11	11	15	29	66
Average 95 to 106 IQ	15	8	14	23	60
Low 94 IQ and below	21	14	9	12	56
Total n	47	33	38	64	182

TABLE III

ASSIGNMENT OF SUBJECTS TO TREATMENTS AND LEVELS

Intelligence Level	Number of Subjects Treatment A	Treatment B	Treatment C	Total
High 107 IQ and above	21	23	22	66
Average 95 to 106 IQ	18	21	21	60
Low 94 IQ and below	19	16	21	56
Total n	58	60	64	182

groups are all random samples from the same hypothetical parent population--a population which may be roughly defined as consisting of all individuals "like those involved in the experiment."[3]

In the following paragraph Lindquist relates how the "counting off" method is accomplished:

> <u>The "counting off" method</u>: A more common situation is that subjects from some real population are available for experimental purposes, but it is not known that the available subjects are a strictly random sample from that population. In this situation also, the distribution of the control variable for the population may be unknown. In this case, we can regard the available subjects as a representative sample from a <u>hypothetical</u> population--one defined to fit the sample. The available subjects are first arranged in order of the control variable (arranging in random order all individuals having the same value of the control variable). The levels are then constituted by counting off <u>na</u> subjects at a time from the top of the distribution. . . .[4]

After the subjects were randomly assigned to one of the three treatments as to their intelligence level, a comparison of the means and standard deviations of the intelligence scores were computed. The results of this comparison on Table IV indicate that the treatments are relatively uniform on each individual ability level.

As a final check, a test for initial homogeneity of variance for the subgroups was computed. An inspection of the standard deviations of each of the cells in Table IV indicated that the highest variance was Treatment C high

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[3]E. F. Lindquist, <u>Design and Analysis of Experiments in Psychology and Education</u> (New York, 1953), pp. 73-74.

[4]Ibid., pp. 129-130.

TABLE IV

MEANS, STANDARD DEVIATIONS OF INTELLIGENCE * SCORES
AND NUMBER OF SUBJECTS BY CELL,
TREATMENT AND LEVEL

Level	Treatment A	Treatment B	Treatment C	Total
High	112.10	110.00	115.30	112.50
107 IQ	5.83	6.80	7.70	6.78
and above	21.00	23.00	23.00	22.00
Average	102.00	99.10	99.70	100.30
95 to	7.50	6.85	6.72	7.02
106 IQ	18.00	21.00	22.00	20.00
Low	87.80	90.80	90.00	89.53
94 IQ	5.92	6.00	5.36	5.76
and below	19.00	16.00	21.00	19.00

*Otis Gamma

level and the lowest variance was Treatment C low level. When the two variances were tested by dividing the smaller variance into the larger, the F-value of 2.06 was found not to be significant on the .05 level from the F-ratio table.

Previous to carrying out the actual experiment, the subjects were asked to complete a personal data sheet. Several items of information were requested of the prospective subject, including his full name, age, and grade in school. This information was used in organizing the recording sheet upon which the data from the objective tests were distributed and summarized. The mean, the standard deviation of ages and number of subjects by cell, and the treatment and level may be found in Table V in this chapter.

A test for initial homogeneity of variance for the subgroups in Table V indicated that the variances did not differ significantly from one another. An inspection of the standard deviations of each of the cells in Table V revealed that the highest variance was Treatment B average level and the lowest variance was Treatment C average level. When the two variances were tested by dividing the smaller variance into the larger, the F-value of 2.15 was found not be significant at the .05 level from the F-ratio table.

Other information requested on the personal data sheet were questions to determine whether the subject had any previous power mechanics or automotive instruction or any work experience in the automotive field. This information was used as a means of comparison with test results to ascertain

TABLE V

MEANS, STANDARD DEVIATIONS OF AGES AND NUMBERS OF SUBJECTS BY CELL, TREATMENT AND LEVEL

Level	Treatment A	Treatment B	Treatment C	Total
High 107 IQ and above	X=16.81 s=1.03 n=21	X=17.00 s= .86 n=23	X=16.86 s= .86 n=22	66
Average 95 to 106 IQ	X=16.67 s=1.04 n=18	X=16.76 s=1.93 n=21	X=16.76 s= .70 n=21	60
Low 94 IQ and below	X=16.67 s= .99 n=19	X=16.62 s= .71 n=16	X=16.77 s=1.03 n=21	56
Total	58	60	64	182

any unreasonable variations in test grades which might evolve from the experiment. The results of this information as compiled from the tally sheet is indicated in Figure 1. From Figure 1, the previous automotive training or work experience does not appear to affect test grades.

Another function of the personal data sheet was to collect certain information which might be used to verify the accuracy of the random assignment taken in this study with an actual statistic obtained from the real population. In Table VI the occupations of fathers of the subjects are compared with occupations of fathers of the Iowa labor force. From the table, the frequency of the sample expressed in per cent as compared with the frequency of the Iowa male labor force indicates a remarkably close relationship between the two populations. The greatest variations appear to be in the classifications of farmers and service workers.

The Learning Task

The learning task included two, fifty-minute periods for each of the two methods of instruction. The first period of instruction for both of the methods was entirely theoretical. The second period of instruction for both methods included both theoretical and applied sections in the lessons but was oriented toward the manipulative or laboratory type of instruction. The lessons for the first period of instruction for both methods were taped and keyed to a thirty-five millimeter colored filmstrip.

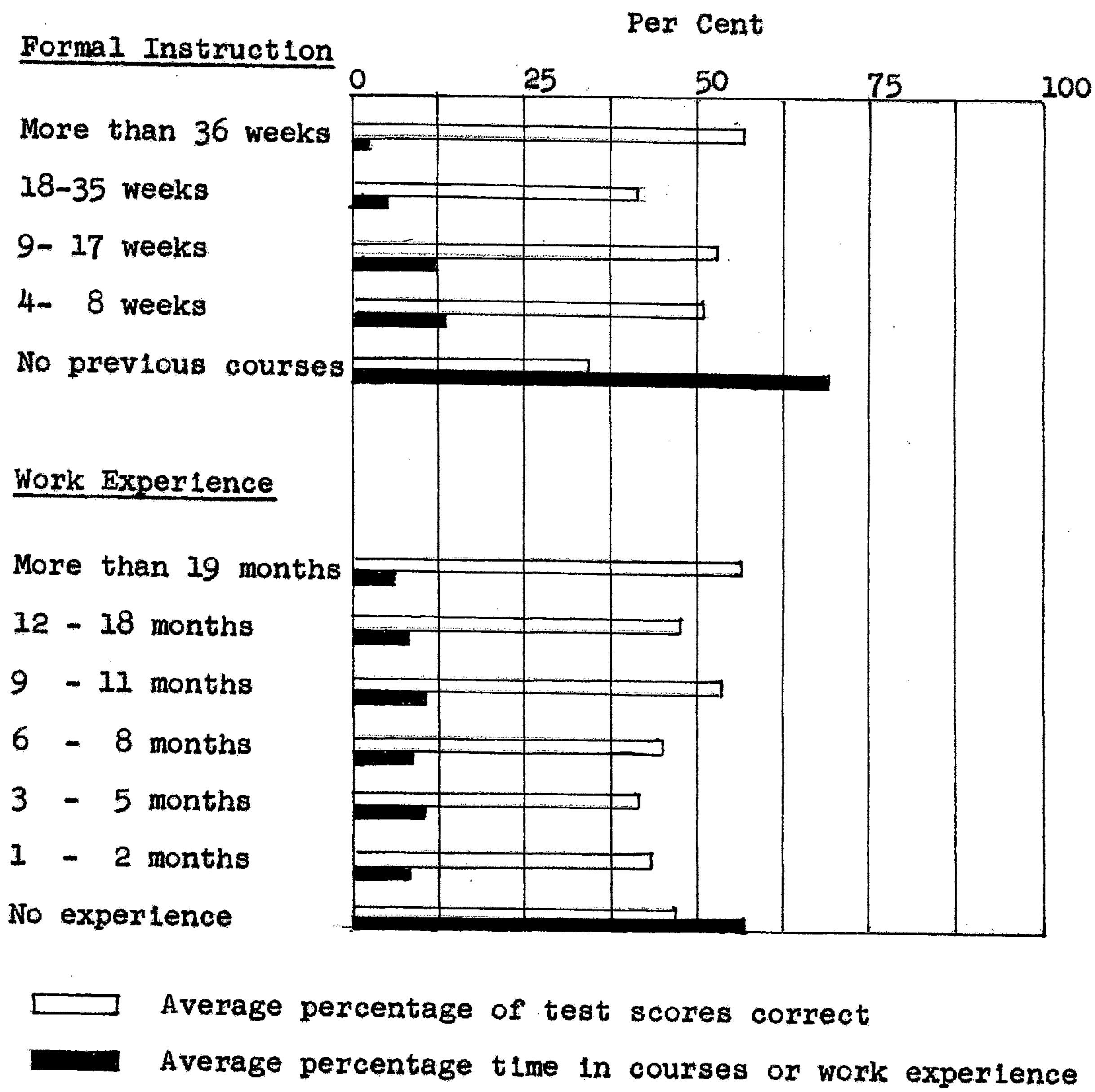

Fig. 1 - Average Scores on Initial Learning Tests as Compared with Subjects Average Previous Automotive Training and Work Experience

TABLE VI

ANALYSIS AND COMPARISON OF OCCUPATIONS OF FATHERS OF SUBJECTS WITH OCCUPATIONS OF MALE LABOR FORCE[5]

Classification	Frequency in Sample Total	Frequency in Sample Per cent	Frequency Male Population Total	Frequency Male Population Per cent
Professional, technical and kindred	16	8.69	48,471	8.41
Farmers and farm managers	26	14.30	140,065	23.24
Managers, official and proprietors	22	12.08	65,776	10.91
Clerical and kindred	10	5.38	34,313	5.82
Sales	9	4.84	38,091	6.32
Craftsmen, foremen and kindred	30	16.25	99,229	16.31
Operators and kindred	28	15.20	98,065	16.31
Private household	5	2.65	1,665	.02
Service workers except household	22	12.08	25,891	4.30
Farm laborers and foremen	0	0.00	10,929	1.82
Laborers except farm and mine	14	7.53	27,026	4.71
Occupations not reported	0	0.00	11,107	1.83
Total	182	100.00	601,046	100.00

[5]U.S. Bureau of the Census, Eighteenth Decennial Census of the United States: 1960. Population, Vol. I, Part 17, Iowa (Washington, 1961), p. 498.

The subjects were taught the following items: 1) the principles and relationships of carburetion in respect to basic engine operation, 2) the basic understandings of spark timing, the ignition system, valve timing, and other component parts or systems of the engine which affect carburetion, 3) the scientific or engineering principles related to the automotive type carburetors, and 4) the construction and function of the various parts and systems of a typical automotive type carburetors.

In the second hour lesson, the instruction in each method was taped but only the lesson taught by the direct-and-detailed method was correlated with the thirty-five millimeter filmstrip. In the directed-discovery part of the second lesson, the same filmstrips were used but the subject was not required in this case to direct his attention toward the screen at any particular time as was required in both lessons involving the direct-and-detailed method.

Both methods of instruction for the second hour included the following items: 1) the disassembly of the Rochester BC carburetor by each of the subjects, 2) the inspection and explanation of the function of the parts and systems, 3) the major adjustments on the carburetor, and 4) the reassembly of the carburetor.

One of the most difficult phases of the experiment was the selection of a learning task in the automotive field which could be successfully accomplished within the short time allotted.

The following criteria were developed to use as a guide in the selection and development of the learning task:

1) That the tasks be of such a nature that they can be effectively presented in two, fifty minute periods.
2) That the tasks be cognitive and manipulative in nature.
3) That the tasks contain meaningful scientific and technical material applicable to practical items and understanding.
4) That the instructional method be in the industrial education field, hence within the experimenter's major interest field.
5) That the tasks be within the ability levels of the subjects but still offer broadness of understandings from simple to complex.
6) That the tasks contain facts, principles, and generalizations adaptable to the two methods of presentation under consideration.
7) That the understandings and performance of the subjects be such that they admit to objective evaluation.

A number of the basic reference books in physics, engineering, and automotive as well as technical literature concerned with internal combustion engines and carburetion were surveyed for the purpose of selecting the science and engineering principles that would appear to be helpful in the development of the lessons. In addition, these same principles were used as an aid in the development of the transfer of learning objective-type test.

The following list of the science or engineering principles was used in the development of the direct-and-detailed lessons and the directed-discovery lessons: (These principles were also used in the development of a multiple choice type test which was intended to evaluate the subjects' ability to transfer these concepts to other applications.)

1. The bimetal thermostatic spring.
2. Centrifugal advance mechanisms.
3. Vacuum advance mechanisms.
4. Heat riser principles.
5. Burning time in constant pressure and constant volume engines.
6. Distribution of fuel in manifolding.
7. Fuel/air ratios and burning time.
8. Principles of engine pumping strokes (vacuum).
9. Combustion chamber shape and relation to burning time.
10. Restriction in gas or liquid flow (engine breathing).
11. Supercharging principles.
12. Vaporization of liquids.
13. Atmospheric pressure.
14. Economy and its relation to engine design and operation.
15. Principles of pumps.
16. Air flow characteristics in piping.
17. Metering liquids (fuel).

18. Venturi principles.
19. Atomization - methods of breaking up a liquid.
20. Boiling points of liquids and effects of pressure.
21. Filtering principles.
22. Differences in fuel molecules and relationships to vaporization.
23. Principles of air compression.
24. Expansion of air or fluids and relation to refrigeration.
25. Comparisons of high performance and low performance engines with various speeds and mixtures.
26. Force per unit area - P.S.I.
27. Pressure differential.
28. Altitude changes and relation to pressure change.
29. Barometers.
30. Manometers.
31. Specific gravity.
32. Pressure gauges.
33. Relationship between atmospheric pressure and vacuum.
34. Principles of aerodynamics.
35. Venting principles - internal, external, and combination.
36. Inertia.
37. Leverage principles - mechanical advantage, classes of levers.
38. Bouyancy - Archimedes' principles.
39. Instrumentation - actuated by pressure differential.

40. Controls - actuated by pressure differential.

41. Flowmeters.

42. Principles of cams.

43. Relative radial movement between two curved surfaces in relation to (two) flat surfaces.

44. Fastening, holding and locking devices.

45. Spring expansion, compression and tension.

46. Friction.

47. Pounds per square inch.

48. Orifice - control and measurement.

49. Linkage length changes - used for adjustment.

50. Temperature relationships to volume and pressure.

A separate bibliography located in Appendix D, contains the list of the previously mentioned reference books which were used in the development of the foregoing principles.

Teaching Methods

The two primary comparisons under consideration in this experimental study are the direct-and-detailed and directed-discovery methods of teaching. Although these two methods have been defined in Chapter I, a more detailed analysis of each, relative to its design, appears to be necessary. Since researchers and writers indicate wide variations in each of the two methods, it was believed necessary by the writer to formulate some method of determining where each method in question is located on a scale between the two extremes.

The experimenter attempted to identify criteria which could be employed by persons acquainted with the two experimental lessons as a basis for comparing the two methods. The first criterion is concerned with identification of the basic source and the amount of responsibility of the continuity of development in the learning process. In the direct-and-detailed method of instruction, the responsibility for adding new and meaningful material to the existing cognitive structure and/or developing relationships and generalizing was primarily the responsibility of the teacher. However, in the directed-discovery method of instruction, a greater responsibility for continuity of development resided with the subjects through use of thought questions, cues, and pauses during the presentation.

A second criterion used as a measure of method is the nature of the reinforcement when adding new meaningful material. In the direct-and-detailed method, the teacher assumed the major responsibility for reinforcement by means of detailed repetition and direct re-application. In contrast, the directed-discovery method was developed to place more responsibility upon the individual for reinforcement in the learning process through independent recall. This was stimulated by cues, guided questions, and individual applications.

A third basis of comparison was concerned with the nature of closure or the conclusion of the individual parts of the lessons. In the direct-and-detailed method of presentation, the actual principles were stated and the issues presented and resolved in detail. The major responsibility for closure was included in the design of the presentation. In the contrasted method, the nature of closure is closely related to the phenomenon of insight. Therefore, principles are approached but seldom stated in detail, issues are raised but not resolved, and summary statements are substituted with thought-type questions.

A final criterion applied as a measure of the nature and difference between the methods under consideration is concerned with the physical structure of the two lessons. Short periods of time must be allowed for the subject to think as various problems are presented throughout the lesson.

In the direct-and-detailed method no time is allowed. The subject must continually give his full attention to what is being said or he will miss that section.

The contrasted method allows time after each question or cues so that the subject will not be missing part of the instruction while he is thinking.

As a means of comparing the two lessons on the basis of the preceding criteria, certain graduate students from the State College of Iowa were asked to inspect the filmstrip and the two different presentations. Having acquired an understanding of the evaluative criteria previous to inspection of the lessons, these students were then asked to place the position of each of the criteria as accurately as possible on a specially prepared scale. A summary of the combined results of their ability to discriminate between the two methods presented is indicated graphically in Figure 2 on the following page.

In Figure 2, the two extremes of the directed-discovery method are (0) and (4) on the left side of the scale and the two extremes of the direct-and-detailed method are (0) and (4) on the right side of the scale. In this way the number (2) on both the left and the right sides of the scale is the average for each method.

Treatments

The subjects were assigned by intelligence levels to Treatment A, Treatment B, and Treatment C. Those subjects in Treatment C received no instruction but were tested with the same two tests along with the subjects in Treatments A and B. Since no pre-test was administered to any of the three groups used in this study, the main purpose of Treatment C (the control group) was to allow for a comparison through test scores between the direct-and-detailed method, the directed-discovery method, and the control group which had no instruction.

The subjects in Treatments A and B received approximately one hundred and ten minutes of instruction in each of the two different methods under investigation. This instruction was given in two fifty-five minute lessons. A general instruction period of ten minutes was held with both groups previous to individual group instruction. The instruction

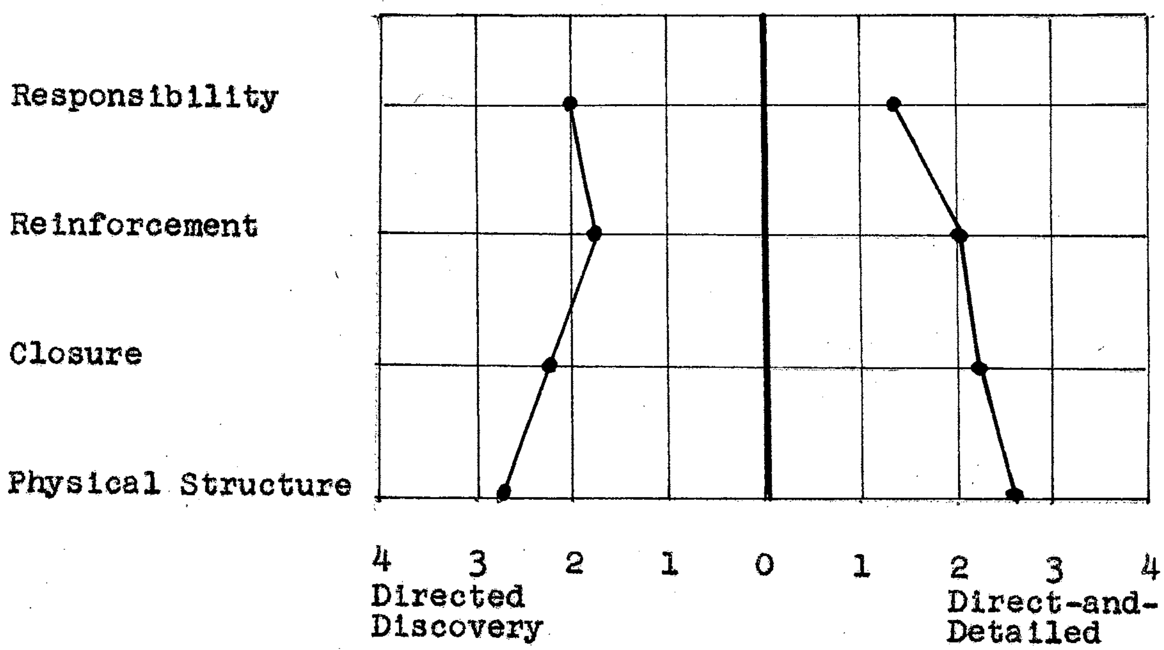

Fig. 2 - Relative Differences Between the Comparative Methods as Rated by the Validation Jury on Four Criteria

common to both groups included:

1) A brief statement of the importance of educational research.
2) A brief statement of the purpose of the study.
3) A statement explaining the use of the tape recorder and colored slides.
4) Statements to motivate students.
5) A statement indicating that they all would be tested. (Nothing was mentioned as to what subject material would be taught.)

A schedule of the experiment and the tests for each of the four schools in the sample cities and towns is indicated in Table VII.

Instructional Procedures and Materials

All instructional and testing sessions were conducted in well-lighted and adequately equipped classrooms that were adapted to the experimental situation. The laboratory work benches used for the disassembly and reassembly parts of the instruction were adequate for the minimum requirement of fifteen work stations. Each work station was equipped with one Rochester BC Carburetor, one parts pan, one shop cloth, two screwdrivers, and a float level gauge. One vacuum gauge, one U-tube manometer, and some cutaway vacuum and pressure gauges were available for all subjects to examine.

All oral instruction was provided through the medium of tape recordings. This allowed for a means of controlling

TABLE VII

SCHEDULE OF THE EXPERIMENT FOR EACH OF THE SCHOOLS IN THE SAMPLE CITIES

Sequence Days	Time Allotted	Treatment	Subject
1	10 minutes	A,B and C	Orientation
2	55 minutes	A and B	Lesson I
3	55 minutes	A and B	Lesson II
4	55 minutes	A,B and C	Test I
5	55 minutes	A,B and C	Test II

the presentations given to the various experimental groups.

During the first hour of instruction both A and B Treatment groups looked at colored filmstrips. The filmstrips were identical for both treatments, although the recordings to which they were keyed differed relative to the nature of the methods of presentation under comparison. The subjects in each treatment were exposed to equal amounts of time to each illustration.

Only in the Treatment B (directed-discovery method) were time pauses allowed where no sound was heard. The time pauses ranged in length from three seconds to ten seconds dependent upon the difficulty of the question or cue. Several trial runs in addition to the pilot study allowed the researcher to apportion the time pauses.

Objective Tests

A test intended to measure initial learning was administered to all treatment groups following the final instructional period. The following day a test designed to measure transfer of learning was administered to all treatment groups. Both tests consisted of multiple choice questions. An attempt was made in the design of both tests to induce considerable discrimination into the various choices for each question.

The initial learning test had fifty items, whereas the transfer of learning test had only forty-four items because the latter was expected to be the more difficult of the two.

There was no time limit set on either of the tests and after repeated trial runs, fifty minutes for each test proved that adequate time was allowed for all subjects.

Since there was ample opportunity to determine the reliability of the tests on trial runs, a high coefficient of reliability was expected when the questions were examined following the final study. A comparison between the coefficient of reliability for both tests on the pilot study and for the final study may be found in Table VIII in this chapter.

Examples of all the test questions in both the initial learning and transfer of learning tests may be found in Appendix C.

The Pilot Study

A pilot study was conducted at the Cedar Falls High School during the 1964 spring semester. The main purpose of the pilot study was to determine the appropriateness of the lessons and test to be used in the experiment for senior high school industrial arts students. All of the senior high students in two industrial arts classes participated in the experiment. The subjects in these two classes were assumed to be similar in intelligence, interests, and attitudes to the proposed sample of the population for the research study.

For the purposes of the pilot study, each class was considered as an experimental group. Both classes were equated

TABLE VIII

RELIABILITY COEFFICIENTS * OF CRITERION TESTS
OF THE FINAL STUDY AND THE PILOT STUDY

Test	Final Study	Pilot Study
Initial Learning	.96	.97
Transfer of Learning[1]	.95	.84

*(Split-halves reliability coefficient)

[1]The transfer of learning test was slightly revised between the pilot and the final study.

as to level of intelligence and from each of the levels of each class two subjects were selected randomly to serve as the control group. During the first experimental session, the two groups received a tape recorded lesson which was keyed to a thirty-five millimeter filmstrip. This lesson was concerned with basic scientific principles and the construction and functions of a typical automotive-type carburetor. Each of the two groups was taught by one of the two methods of instruction under investigation. In the second experimental session which was given the following day, the two groups received a tape recorded lesson concerned with disassembly, tracing circuits, and adjustment of the Rochester BC carburetor. Each group was taught by the same method of instruction administered on the previous day. The control group was not present during instruction of the experimental groups and did not receive any instruction.

Following instruction, all groups including the control group were administered, first, an objective test designed to evaluate wide applications of initial learning or transfer of learning.

The pilot study proved to be most valuable to the experimenter in that it provided an opportunity for the experimenter to: 1) try out the recorded lessons with senior high school industrial arts students, 2) determine the amount of time required for presentation of the illustrations and to determine the length of the pauses provided on the recording, 3) evaluate the appropriateness of the test items and determine the length of time necessary to administer the testing session, 4) determine the time necessary for disassembly and reassembly procedures and, 5) evaluate the general level of vocabulary and technical terms that were being used in the experiment.

CHAPTER IV

VALIDATION OF INSTRUMENT AND RESULTS

Validation of Instrument

Control group. The control group was included in the research design of this experimental study for two distinct purposes. First, it seemed pertinent to obtain objective measures of the extent to which the subjects included in this investigation had prior knowledge of the learning task. The performance of the control group subjects in respect to both the initial learning and transfer of learning tests indicated that they possessed some knowledge of the learning task. This was further supported by information obtained from the personal data sheets. From a total of sixty-four boys in the control group, twenty-six per cent indicated that they had some instruction related to the learning task. The control group, then, may not be regarded as a totally uninstructed group. In addition, since the subjects in Treatments A, B, and C were randomly assigned, it may be assumed that the subjects in Treatments A and B possessed a similar level of prior knowledge of the learning task.

Statistics indicate that the subjects taught by Treatments A and B proved superior to those in Treatment C in both initial learning and transfer of learning tests. Since these groups did differ significantly, it may be assumed that the test results of the subjects in Treatment groups A and B resulted in part from the differential treatments.

A second purpose for which the control group was used in this experimental study was to employ the test scores of this group as a means to determine the correlation between the initial learning and the transfer of learning tests.

In Chapter I, initial learning was defined as that learning which refers to the character and extent to which the subjects are able to recall the principles, skills, and understandings which were presented in the lessons. Transfer of learning, on the other hand, was said to occur when old learning and new problem situations are interrelated because of common principles, factors, stimuli, or applications. In this study, transfer of learning occurs when students are able to apply learned principles in the solution of new problems. Since this study was not concerned with contrasting the two methods at their extreme positions, it appears reasonable to assume that neither should the tests be constructed to evaluate these methods at their extreme positions. The correlation of initial learning with transfer of learning test scores by treatments and by levels is indicated in Table IX. For a number of reasons the correlations found in this table do not indicate that the methods are being measured at their extreme positions. The subjects in Treatment A who were taught by the direct-and-detailed method have the highest correlation individually as to levels

TABLE IX

CORRELATION OF INITIAL LEARNING WITH TRANSFER OF LEARNING TEST SCORES BY TREATMENTS AND LEVELS

Intelligence Level	Coefficient of Correlation (r) Treatment A	Treatment B	Treatment C	Total within Level
High 107 IQ and above	.935	.605	.353	.758
Average 95 to 106 IQ	.806	.449	.439	.617
Low 94 IQ and below	.788	.450	-.171	.035
Total within Treatments	.914	.609	.289	A+B+C .730

and also total within treatments. Those subjects in Treatment B who were taught by the directed-discovery method were found to show less correlation than was found in Treatment A between the initial learning and the transfer of learning tests. The control group who had no instruction indicated the least amount of correlation between the two tests in respect to total within treatments. The low IQ level of Treatment C (control group) indicated a negative or inverse relationship between the two tests. Although this statistic must be considered to have only illustrative value, it does suggest that in respect to the control group, the two tests are measuring two different things in some degree as indicated by Garrett.[1]

In an attempt to interpret the significance or meaning of a relationship expressed by a certain correlation coefficient, Garrett suggests a general guide upon which they may be judged. This includes: 1) the nature of variables with which we are dealing, 2) the significance of the coefficient, 3) the variability of the group, 4) the reliability coefficients of the tests used, and 5) the purpose for which the correlation was computed.[2]

To consider, first, the nature of the variables being correlated, Garrett suggests that measures between achievements considered high should usually have a correlation of

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[1]Garrett, p. 123.

[2]Ibid., p. 176.

from .40 to .60.[3] From this statement by Garrett, a correlation of .730 for the total within treatments (A+B+C) in Table IX would appear to denote a high relationship between the two tests.

In this study, the subjects were selected at random from industrial arts classes in high schools which were also selected at random from within a sample area. Since the IQ scores as to each treatment did not appear to differ significantly, the variability of the group would seem to be homogeneous. The fourth general guide relating to reliability of the two tests would appear to fulfill Garrett's requirements with correlations of .96 and .95 respectively as shown in Table VIII in Chapter III.

The correlation was computed in this study to determine whether there was a difference between the two tests in respect to what they measured. Since the correlation was high, the two tests were probably measuring somewhat the same things; however, the researcher decided to use the data from both tests in making the statistical analysis because there was no reason to believe the data would detract from the study and there was every possibility that it would give additional direction and clarity.

Homogeneity of subgroups. A need to test for the homogeneity of variance for the subgroups was indicated in Chapter III under Population and Sampling. Garrett suggests

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[3]Ibid., p. 176.

that a simple check on the equality of sample variances can be made by calculating the sum of squares for each group separately, by dividing by the appropriate degrees of freedom, and by then testing the largest variance against the smallest variance for significance by the F-test.[4]

An inspection of the standard deviations of each of the cells from Tables X and XI indicate that the highest variance under Test I was Treatment A, average level and the lowest variance was Treatment C, low level. When the two variances were tested by dividing the smaller variance into the larger, the F value of 2.24 was found not to be significant at the .10 level from the F-ratio table.

According to Garrett, the two-tailed test is used when the researcher is attempting to discover whether two groups have conceivably been drawn from the same population.[5] If the F-ratio table is used to test the significance of the preceding value of "F," the points of significance must be changed to levels of significance. This is accomplished by multiplying the point of significance by two.

Under Test II an inspection of the standard deviations of the cells indicate Treatment B, average level to be the highest variance and Treatment C, low level to be the lowest variance. When the two variances were tested under the same conditions as they were for Test I, the F-value of 3.004 was

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[4]Ibid., p. 286.

[5]Ibid., p. 217.

TABLE X

MEANS, STANDARD DEVIATIONS, AND NUMBERS OF SUBJECTS FOR INITIAL LEARNING TEST SCORES BY ALL TREATMENTS AND LEVELS

Level	Treatment A	Treatment B	Treatment C	Total
High 107 IQ and above	X=26.619 s= 6.777 n=21	X=27.087 s= 6.150 n=23	X=20.409 s= 5.985 n=22	66
Average 95 to 106 IQ	X=25.005 s= 7.136 n=18	X=22.619 s= 6.722 n=21	X=15.952 s= 4.754 n=21	60
Low 94 IQ and below	X=17.263 s= 4.90 n=19	X=20.125 s= 5.397 n=16	X=13.767 s= 4.522 n=21	56
Total n	58	60	64	182

TABLE XI

MEANS, STANDARD DEVIATIONS, AND NUMBERS OF SUBJECTS FOR TRANSFER OF LEARNING TEST SCORES BY ALL TREATMENTS AND LEVELS

Level	Treatment A	Treatment B	Treatment C	Total
High 107 IQ and above	X=19.857 s= 5.727 n=21	X=23.087 s= 4.779 n=23	X=16.909 s= 4.545 n=22	66
Average 95 to 106 IQ	X=20.778 s= 6.225 n=18	X=20.476 s= 6.640 n=21	X=14.286 s= 4.142 n=21	60
Low 94 IQ and below	X=14.526 s= 4.967 n=19	X=15.550 s= 3.886 n=16	X=11.409 s= 3.798 n=21	56
Total n	58	60	64	182

found not to be significant at the .10 level.

The results of the previous checks for homogeneity of the subgroups for Test I and Test II are accepted as having equal variances, since the two variances tested in each case were the extremes out of nine cells.[6]

Disproportionality. Table X and XI present the means and standard deviations of the criterion test scores by treatment and level for the initial learning and transfer of learning tests. From the tables, it is evident that the numbers of subjects in each of the cells are not equal in this experiment. The writer recognized that disproportionality may exist and that ordinary methods of computing the sums of squares for the analysis of variance may yield biased results from all sources other than from the within groups. However, according to Wert, frequencies need not be equal in order to be proportional.[7] He suggests a method by which the border means of the double classifications are successively adjusted until they are equal or near equal to the general mean. The adjustment terms are then used to compute the adjusted sum of squares for one or for both main effects.[8]

In this study, the border means of the double

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[6]Ibid., p. 286.

[7]J. E. Wert and C. O Neidt, Statistical Methods in Educational and Psychological Research (New York, 1954), p. 211.

[8]Ibid., p. 216.

classification were successively adjusted until they were equal to the general means for the initial learning test (Test I) and for the transfer of learning (Test II). The adjusted sums of squares were calculated for each test. The results indicated that the new F-values did not differ significantly from the original F-values, in the opinion of the writer, to warrant using them. A summary of the preceding test for disproportionality may be found in Appendix E.

Standard scores. In order to statistically compare the mean differences of the scores between the initial learning and the transfer of learning tests in this study, the individual scores in both tests must be comparable and equivalent. There were fifty questions in the initial learning test, whereas the transfer of learning test had only forty-four questions.

Garrett suggests a method whereby the raw scores in two different tests may be converted to standard scores. These scores allow for direct meaningful comparisons. He suggests that the shift from raw to standard score requires linear transformation. This transmutation does not change the shape of the distribution in any way; if the original distribution is skewed (or normal), the standard score distribution will be skewed or normal in exactly the same fashion. The formula for conversion of raw to standard score is as follows:

Let X = a score in the original distribution

X' = a standard score in the new distribution

M and M' = means of the raw score and standard distributions

σ and σ' = SD's of raw and standard scores

Then $\frac{X' - M'}{\sigma'} = \frac{X - M}{\sigma}$

or $X' = \frac{\sigma'}{\sigma}(X - M) + M'$[9]

The raw scores from the initial learning test and the transfer of learning test were converted to a standard scores by using the preceding formula. The standard scores were then used in computing the t-tests in order to evaluate hypothesis III.

Results

Test of hypothesis I. There are no differences in initial learning, as measured by a criterion test given immediately following instruction, on any of the intelligence levels (X_1, X_2, or X_3) or between the Treatment groups (A, B, or C) comprised of senior high school industrial arts students.

A 3 x 3 analysis of variance was computed and the summary is reported in Table XII. The analysis resulted in a significant F-value for the main effects of treatments and levels. Since the variances of the subgroups do not differ significantly, it would appear that the significant value of (F) found for the effect of treatment is the result of a difference in the means in the three experimental groups.

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[9]Garrett, pp. 312-313.

TABLE XII

ANALYSIS OF VARIANCE OF INITIAL LEARNING TEST SCORES BY TREATMENTS AND LEVELS

Source of Variation	Sum of Squares	Degrees of Freedom	Variance	F
Between	3785	8	473.01	13.23*
Within	6181	173	35.73	
Total	9966	181		
Between (X) Levels	1911	2	955.50	26.90*
Between (A) Treatments	1821	2	910.50	25.70*
X x A	53	4	13.30	.37
Within	6181	173	35.50	
Total	9966	181		

*Significant at .05 level

In addition, it would appear that the significant F-value found for effect between levels is the result of a difference in the means in the three experimental groups. On the basis of these findings, the null hypothesis is untenable.

Since an F-test is only an overall test of the entire group, individual t-tests were computed between the three treatments on all levels to find the cause of the significant F-value. Tables XIII, XIV, and XV indicate the mean difference scores and obtained t-values on the initial learning test between Treatment A and Treatment B, between Treatment A and Treatment C, and between Treatment B and Treatment C on the three intelligence levels. Table XIII shows a difference (though not significant at the .05 level) between Treatments A and B on the high and low levels of intelligence. These differences point in favor of Treatment B, whereas, on the average level of intelligence, the difference points in favor of Treatment A. In Tables XIV and XV, Treatment C proved to indicate a significant difference between Treatments A and B on all three intelligence levels.

A more complete investigation of the results of analysis of variance and t-tests for Hypothesis I will be attempted in Chapter V of this study.

<u>Test of hypothesis II</u>. There are no differences in transfer of learning, as measured by a criterion test given immediately following instruction, on any of the intelligence levels (X_1, X_2, or X_3) or between Treatment groups (A, B, or

TABLE XIII

MEAN DIFFERENCE SCORES AND OBTAINED T-VALUES ON INITIAL LEARNING TEST BETWEEN TREATMENT A AND TREATMENT B ON THE THREE INTELLIGENCE LEVELS

Level	Treatment A	Treatment B	D=B-A	T-Value
High 107 IQ and above	26.619	27.087	.468	.239
Average 95 to 106 IQ	25.005	22.619	-2.386	1.095
Low 94 IQ and below	17.263	20.125	2.862	1.634

*Significant at .05 level

TABLE XIV

MEAN DIFFERENCE SCORES AND OBTAINED T-VALUES ON INITIAL LEARNING TEST BETWEEN TREATMENT A AND TREATMENT C ON THE THREE INTELLIGENCE LEVELS

Level	Treatment A	Treatment C	D=C-A	T-Value
High 107 IQ and above	26.619	20.409	-6.210	3.182*
Average 95 to 106 IQ	25.005	15.952	-9.053	4.220*
Low 94 IQ and below	17.263	13.767	-3.496	2.335*

*Significant at .05 level

TABLE XV

MEAN DIFFERENCE SCORES AND OBTAINED T-VALUES ON INITIAL LEARNING TEST BETWEEN TREATMENT B AND TREATMENT C ON THE THREE INTELLIGENCE LEVELS

Level	Treatment B	Treatment C	D=C-B	T-Value
High 107 IQ and above	27.087	20.409	-6.578	3.70*
Average 95 to 106 IQ	22.619	15.952	-6.667	3.71*
Low 94 IQ and below	20.125	13.767	-6.258	3.81*

*Significant at .05 level

C) comprised of senior high school industrial arts students.

A 3 x 3 analysis of variance was computed and the summary is reported in Table XVI. The analysis resulted in a significant F-value for the main effects of treatments and levels and for first order interactions. Since the variances of the subgroups do not differ significantly, it would appear that the significant value of (F) found for the effect of treatment is the result of a difference in the means in the three experimental groups. In addition, it would appear that the effect between levels is the result of a difference in the means in the experimental groups. On the basis of these findings, the null hypothesis is untenable.

In the case of testing hypothesis II, it was necessary to test the mean differences between the three treatment groups on each of the three levels by individual t-tests. Tables XVII, XVIII, and XIX indicate the mean difference scores and obtained T-values on the transfer of learning test between Treatment A and Treatment B, between Treatment A and Treatment C, and between Treatment B and Treatment C on the three intelligence levels. Table XVII shows a difference (though not significant on the .05 level) between Treatments A and B on the high and low levels of intelligence. These differences point in favor of Treatment B, whereas, on the average level of intelligence, the difference points in favor of Treatment A. In Tables XVIII and XIX, Treatment C proved to indicate a significant difference

TABLE XVI

ANALYSIS OF VARIANCE OF TRANSFER OF LEARNING TEST SCORES BY TREATMENTS AND LEVELS

Source of Variation	Sum of Squares	Degrees of Freedom	Variance	F
Between	2645	8	330.6	12.86*
Within	4448	173	25.71	
Total	7093	181		
Between (X) Levels	1360	2	680.	27.1*
Between (A) Treatments	994	2	497.	19.79*
X x A	291	4	72.75	2.89*
Within	4448	173	25.13	
Total	6305	181		

*Significant at the .05 level

TABLE XVII

MEAN DIFFERENCE SCORES AND OBTAINED T-VALUES ON TRANSFER OF LEARNING TEST BETWEEN TREATMENT A AND TREATMENT B ON THE THREE INTELLIGENCE LEVELS

Level	Treatment A	Treatment B	D=B-A	T-Value
High 107 IQ and above	19.857	23.087	3.230	2.023
Average 95 to 106 IQ	20.778	20.476	-.302	.151
Low 94 IQ and below	14.526	15.550	1.024	.685

*Significant at .05 level

TABLE XVIII

MEAN DIFFERENCE SCORES AND OBTAINED T-VALUES ON TRANSFER OF LEARNING TEST BETWEEN TREATMENT A AND TREATMENT C ON THE THREE INTELLIGENCE LEVELS

Level	Treatment A	Treatment C	D=C-A	T-Value
High 107 IQ and above	19.857	16.909	-2.948	1.855
Average 95 to 106 IQ	20.778	14.286	-6.492	3.182*
Low 94 IQ and below	14.526	11.409	-3.117	2.25*

*Significant at .05 level

TABLE XIX

MEAN DIFFERENCE SCORES AND OBTAINED T-VALUES ON TRANSFER OF LEARNING TEST BETWEEN TREATMENT B AND TREATMENT C ON THE THREE INTELLIGENCE LEVELS

Level	Treatment B	Treatment C	D=C-B	T-Value
High 107 IQ and above	23.087	16.909	-6.178	4.54*
Average 95 to 106 IQ	20.476	14.286	-6.190	3.362*
Low 94 IQ and below	15.550	11.409	-4.141	2.23*

*Significant at .05 level

between Treatment A and Treatment B on all three intelligence levels.

A more complete investigation of the results of the analysis of variance and t-tests for hypothesis II will be attempted in Chapter V of this study.

Test of hypothesis III. There are no differences between initial learning and transfer of learning in the three treatment populations and the three intelligence levels as measured by criterion tests administered immediately following instruction.

Since an analysis of variance was computed for the initial learning test and the transfer of learning test in the computations concerned with testing hypothesis I and hypothesis II, it was only necessary to employ individual t-tests in the computation of the mean differences of the same treatment between the two tests.

Tables XX and XXI indicate the mean difference scores and obtained T-values between Treatment A on the initial learning test and the transfer of learning test and between Treatment B on these same two tests. Table XX shows that, although there is no significant difference between the two tests for Treatment A, the low and average levels of intelligence point in favor of the initial learning test whereas the high level of intelligence points in favor of the transfer of learning test. Table XXI also shows no significant difference between the two tests for Treatment B, but the low and average levels of intelligence point in favor of

TABLE XX

MEAN DIFFERENCE SCORES AND OBTAINED T-VALUES BETWEEN TREATMENT A ON INITIAL LEARNING TEST AND TRANSFER OF LEARNING TEST ON THE THREE INTELLIGENCE LEVELS

Level	Treatment A' (1)	Treatment A' (2)	D=A'-A'	T-Value
High 107 IQ and above	100.304	100.354	.050	.716
Average 95 to 106 IQ	100.701	100.090	-.611	.237
Low 94 IQ and below	99.970	99.720	-.250	.099

*Significant at .05 level
'Converted to standard scores
(1) Treatment A, the initial learning test
(2) Treatment A, the transfer of learning test

TABLE XXI

MEAN DIFFERENCE SCORES AND OBTAINED T-VALUES BETWEEN TREATMENT B ON INITIAL LEARNING TEST AND TRANSFER OF LEARNING TEST ON THE THREE INTELLIGENCE LEVELS

Level	Treatment B' (1)	Treatment B' (2)	D=B'-B'	T-Value
High 107 IQ and above	100.221	100.361	.140	1.335
Average 95 to 106 IQ	100.122	100.041	-.081	.039
Low 94 IQ and below	100.068	99.966	-.098	.061

*Significant at .05 level
'Converted to standard scores
(1) Treatment B, the initial learning test
(2) Treatment B, the transfer of learning test

the initial learning test, whereas the high level of intelligence points in favor of the transfer of learning test.

CHAPTER V

SUMMARY

Overview of the Study

Orientation to the study. This study is concerned with an attempt to compare the relative efficiencies of two methods of instruction.

One method, called directed-discovery, places considerable responsibility upon the learner to participate actively in the learning situation. Through this method, the teacher provides some structure for the student as the learning develops. This is followed by posing leading questions and suggesting clues so that the student is directed or guided to the discovery of some of the principles and understandings.

In the contrasted method, called direct-and-detailed, the teacher assumes that the major responsibility for the continuity of development and reinforcement is generally overt. The teacher presents the subject material in detail and answers the problems presented. Very little responsibility is placed upon the student.

The subjects involved in this experiment were equated on mental ability levels and assigned at random to one of three treatment groups.

An initial learning test and a transfer of learning test were developed to measure the relative effectiveness of the two methods in respect to the following questions:

1. What differences, if any, exist between the direct-and-detailed method and the directed-discovery method of teaching senior high school industrial arts students relative to initial learning on each of the three intelligence levels stated?
2. What differences, if any, exist between the direct-and-detailed method and the directed-discovery method of teaching senior high school industrial arts students relative to transfer of learning on each of the three intelligence levels selected?
3. How do the senior high school industrial arts students compare in each of the three intelligence levels selected between initial learning and transfer of learning?

Statement of hypotheses. The three preceding questions were then stated as null hypotheses so that they could be tested statistically. They are as follows:

1. There are no differences in initial learning as measured by a criterion test given immediately following instruction on any of the intelligence levels (X_1, X_2, or X_3) or between treatment groups (A, B, or C) comprised of senior high school industrial arts students.
2. There are no differences in transfer of learning as measured by a criterion test given immediately

following instruction on any of the intelligence levels (X_1, X_2, or X_3) or between the treatment groups (A, B, or C) comprised of senior high school industrial arts students.

3. There are no differences between initial learning and transfer of learning in the three treatment populations and the three intelligence levels as measured by criterion tests administered immediately following instruction.

Experimental design. The design of this study lends itself to analysis of variance as a primary means of statistical analysis. The first and second questions in the statement of the problem were solved separately as two 3 x 3 factorial design problems. Each was treated for main effects and first order interactions. Following this, individual t-tests were computed between treatments on each level for the initial learning test and the transfer of learning test. The third and final question in the statement of the problem required a comparison of the same treatment on each of the three intelligence levels selected between initial learning and transfer of learning. Individual t-tests were computed for each intelligence level between Treatment A for Test I and Test II, and between Treatment B for Test I and Test II.

Population and sampling. The population used in this experiment consisted of Iowa senior high school industrial arts students which were selected at random from high schools that lie within a forty-five mile radius of Cedar Falls, Iowa. The size of the sample was determined by the authoritative literature on the subject and by the limitations of time and financial outlay. A total of two hundred and fifteen subjects were found to be available for the experiment. Since there were nine cells, representing three methods times three treatments, it was decided that twenty-three subjects would be selected at random for each cell. From a total of two hundred and seven subjects in the experiment, a loss of twenty-seven subjects was expected. This allowed the final sample size to be at least one hundred and eighty subjects.

Treatments. The subjects were equated as to intelligence levels and randomly assigned to Treatment A, Treatment B, and Treatment C. Those subjects in Treatment C received no instruction but were tested with the same two tests along with the subjects in Treatments A and B. Since no pretest was administered to any of the three groups used in this study, one purpose for the control group was to provide the experimenter with some indication of the prior knowledge of the instruction presented. A second purpose of the control group (Treatment C) was to allow for a comparison of the test scores between the direct-and-detailed method and the directed-discovery method of instruction with the control group which had no instruction.

The subjects in Treatments A and B received approximately one hundred and ten minutes of instruction in each of the two different methods under investigation. In addition, a general instruction period of ten minutes was held with both groups previous to individual group instruction. The instruction common to both groups included statements which explained the importance of educational research, the purpose of the study, the use of the tape recorder and colored filmstrip, and the fact that they all would be tested.

The learning task. The learning task included two, fifty-five-minute periods for each of the two methods of instruction. The first period of instruction for both methods was entirely theoretical. Both methods of instruction for the second part included both theoretical and applied sections in the lessons but were oriented toward the manipulative or laboratory type of instruction. For the first period, both methods were taped and keyed to a thirty-five millimeter colored filmstrip.

The following items were taught: 1) the principles and relationships of basic carburetion in respect to engine operation, 2) the basic understandings of spark timing in regard to the ignition system, valve timing, and other component parts or systems of the engine which affect carburetion, 3) the scientific or engineering principles related to the automotive-type carburetor, and 4) the construction and function of the various parts and systems of an automotive-type carburetor.

The instruction in the second hour for each method was taped but only the lesson taught by the direct-and-detailed method was correlated with the filmstrip.

Both methods of instruction for the second hour included the following items: 1) the disassembly of the Rochester BC carburetor by each of the subjects, 2) the inspection and explanation of the function of the parts and systems, 3) the major adjustments on the carburetor, and 4) the reassembly of the carburetor.

Objective tests: A test designed to measure initial learning was administered to all treatment groups following the final instructional period. The following day, a test intended to measure transfer of learning was administered to all treatment groups. Both tests included multiple-choice questions.

The initial learning test had fifty items, whereas the transfer of learning test had only forty-four items because it was expected to be the more difficult of the two. There was no time limit set on either of the tests; however, fifty minutes proved to be adequate in both cases.

Findings. Appropriate statistical techniques were employed to analyze the data and test the null hypotheses. On the basis of the test results the researcher found:

1. In terms of initial learning, the analysis resulted in a significant F-value for the main effects of both treatments and levels. When individual t-tests were computed to determine what caused the significant F-value in respect to initial learning, the control group was found to be the cause for Treatment A and B on all three levels of intelligence.

There were no significant differences found between Treatment A and B on any of the three levels of intelligence for initial learning.

2. In terms of transfer of learning, the analysis resulted in a significant F-value for the main effects of treatments and levels and for first order interactions. When individual t-tests were computed to determine the cause of the significant F-value in respect to transfer of learning, the control group was found to be the cause for Treatment A and Treatment B on all three levels of intelligence with the exception of Treatment A for the high level. There were no significant differences found between Treatment A and B on any of the levels of intelligence for transfer of learning.
3. In terms of mean difference between initial learning and transfer of learning on all three intelligence levels, there was found to be no significant difference on any level as computed by t-tests.

Limitations and Implications

Limitations of the study. Any generalization which may result from the findings of this experimental investigation should be made only after consideration of the following limitations:

1. Although special attention was employed to attain a true sample of the population by selecting at

random two towns and two cities from within the sample area and assigning the subjects at random to one of the three treatments, the experimental population may not be a true sample.

2. Although it was necessary, as a control in the experiment, to present all verbal instruction through the use of tape recordings, it must be recognized that this technique imposed certain limitations on the learning situation. First, it placed all students on the same level and did not provide for individual differences. Second, it prohibited normal student-teacher interaction.
3. As to motivation, the students served voluntarily, and probably were not intrinsically interested in the experiment even though the selection of the learning area was considered for its motivating value. Also, the students were told at the beginning of the experiment that the test scores would not affect their grade; therefore, they had nothing to lose with minimum effort.
4. There were indications that the subjects in the control group were more highly motivated than those in the other two groups. This was evident in at least two ways. First, the control group members from all four schools were much more insistent and anxious to see the results of the tests. The second indication was reported by the industrial arts

teachers of all four schools. They found that the control group members appeared to be much more interested in the total experiment than the members of the other two groups were. With this amount of interest, communication between subjects during the course of the experiment probably occurred. The greater ego involvement of the control group may have led these subjects to ask questions of the members of the other two groups, to carry on some independent study, and thereby to gain a higher grade on the tests.

Implications for further research. The findings reported in this study and the common elements and discrepancies of the related studies which were reported in Chapter III may perhaps provide source material for continued research inquiries along the following suggested lines:

1. An attempt to identify and define the distinquishing elements or characteristics between the variations of the two instructional methods should precede a second study of this type. A study designed to compare the two methods in their extreme forms with a method of complete independent study should also be investigated. The subjects receiving the independent study could be provided with the identical instructional aids used by the other groups, but they would be expected to learn without oral instruction.

2. It seems that an important aspect of all research concerned with evaluation of learning activities is the retention characteristics. Although retention was investigated in a number of related studies, it appears that there would be merit in a longitudinal study, possibly extending over a period of a year, to determine long-term retention effects of the two methods. It must be recognized, however, that problems in the control of certain variables may be difficult with a long-term investigation of the two methods.
3. In related studies as well as in the present study, common instructional aids have been used for all experimental groups, whereas the oral instruction has been presented differentially in respect to the variation in method. It is possible that the characteristics of the illustrations or visual instructional aids used in this type of study may be important in the total effect of the method of presentation. A related study should be attempted in which the visual part as well as the oral part of the instruction is designed to represent varying degrees of each of the two methods.
4. An investigation similar to the present study might be conducted to compare the two methods under two levels of intelligence. The findings in this study suggest that the problem-solving method might be

superior to the direct-and-detailed method for those subjects of higher level of intelligence. By contrasting the two methods for very high and for very low intelligence subjects, more conclusive evidence of this possibility might be found.

5. As pointed out in the review of literature, there is an ever-increasing accumulation of knowledge in all fields of education, especially in the technological areas. A need for quality of instruction along with efficiency appears to be an absolute necessity. Possibly a form of the directed-discovery method may have considerable merit in obtaining efficiency of instruction in certain types of programs and at certain levels of intelligence. From the review of literature and the understandings gained from this study, it appears that the courses where benefits from this method might be derived would be found in the fields of mathematics, science, industrial arts, technology, and engineering.

6. A number of suggestions in the review of literature point toward the fact that the problem-solving method does offer benefits to the learner in certain learning conditions. These suggestions, however, are followed quite often with the comment that it takes longer to teach subject material by the problem-solving method, thereby discounting the

gains in this method over other methods. This writer believes that there may be too much emphasis placed upon the element of time in regard to certain types and levels of learning. Perhaps the loss in efficiency due to the additional time allotted for this method may be offset by the benefits gained in greater understanding of subject material and increased abilities in problem-solving methodology.

This writer recommends that an investigation similar to the present study be conducted to compare the two methods under conditions in which additional time be allowed for one method and then additional time be allowed for the opposite method.

7. The level of difficulty of the lessons in this study was one of the major concerns of the researcher in the preparation of this experiment. The use of the filmstrip correlated with verbal instruction was believed to aid greatly in the structure of the lesson. Just how much assistance a filmstrip gives the learner in the structure of the lessons would seem to be the basis for a significant research problem.

Educational implications. In view of the findings in this study, it is the investigator's opinion that the classroom teacher with students similar to the subjects used in this experiment could select either the direct-and-detailed method or the directed-discovery method to instruct students in theoretical and manipulative technical content. However, although it was reported that there were no significant differences between the direct-and-detailed method and the directed-discovery method, the computed results of this study definitely point in favor of the directed-discovery method. It is on this basis only that further implications will be set forth.

Before continuing, however, the writer wishes to make clear that any further educational inferences which may be made beyond the opening statement in this paragraph should be viewed with extreme care before putting them into practical use in a classroom.

The subject groups included in the higher level and the lower level of intelligence which were instructed by the directed-discovery method scored higher on both the initial learning and transfer of learning tests than did the direct-and-detailed group.

If the preceding inspection of the statistics in this study is accepted, it then seems that there are some reasons for this possible superiority of the directed-discovery method over the direct-and-detailed method. First, with the directed-discovery method, the lower intelligence level student may gain a more clear-cut understanding of what he is expected to learn and what the problems are. In addition, because of the time pauses, the lower level student will have more time to think than would be allowed with the conventional method.

In the case of the higher intelligence level student, the directed-discovery method appears to offer a challenge which would spur the individual on to higher levels of learning. This method may also reduce the monotony which may accompany the direct-and-detailed method. The time pauses allowed in the directed-discovery method would appear to benefit the higher level student, as well as the lower level, by allowing him time to reason.

There are two additional observations which seem to be important.

First, the directed-discovery method has often been criticized in educational literature for requiring more time than the direct-and-detailed method. However, the present study, as well as all of the studies summarized in Chapter II, used equal amounts of time for the presentation of both methods. Since all but one of the studies found in the review of literature reported the directed-discovery method to have the greater gains, the criticism of this method concerned with time seems to be questionable.

Second, the present study and most of the related studies reported in the review of literature used either a tape recording and a filmstrip or a tape recording and a workbook for the entire presentation of the lessons. Since all of the studies reported considerable gains in both of the methods over the accomplishments of the control groups that had no instruction, it is reasonable to assume that a student could learn and be able to transfer skills and understandings as a consequence of taped and visual instruction. This instruction is viewed by the writer as a supplement, not as a substitute for the teacher.

Although much has already been accomplished with taped instruction in the teaching of foreign languages, there are many subjects in which this means of presentation has not been developed. It seems possible that other types of instruction may be introduced through this medium. Certainly in remedial instruction and in independent study taped instruction correlated with visual presentations would hold genuine promise.

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APPENDIXES

Appendix A

Verbal part of the lessons

Treatment A and B

The first hour lesson using the direct-and-detailed method in teaching.

INTRODUCTION TO CARBURETION

Students, this lesson is concerned with the fundamentals of carburetion. Please listen carefully to what is being said while you are studying each slide.

Slide #

1 Engine performance is dependent upon how efficiently the air/fuel mixture can be moved into the cylinder compressed, burned, and the exhaust gases removed so that the cylinder is clear for the next charge. This is sometimes referred to as engine "breathing ability."

2 The internal combustion engine, in a sense, is nothing more than a vacuum pump. A piston traveling up and down in a cylinder is constantly increasing and decreasing the volume in the cylinder. It is this action that is the controlling force of engine operation. Most automotive engines are four cycle engines, meaning that it takes four strokes of the piston to complete a cycle. The strokes are intake, compression, power, and exhaust.

3 As the piston moves down on the intake stroke, it increases the volume in the cylinder and creates a pressure drop below atmospheric. Atmospheric pressure which surrounds the engine causes air to flow through the air cleaner, carburetor, intake manifold, and intake valve into the low pressure area in the cylinder. As the air flows through the carburetor, it mixes with fuel flowing out of the carburetor and becomes a combustible mixture.

4 When the intake stroke is completed, the piston moves up, squeezing the fresh charge upward into the combustion chamber where both valves are now closed.

5 As the piston ends the compression stroke, an electrical charge is released into the combustion chamber by the spark plug. This causes the air/fuel mixture to ignite and burn. Rapid generation of heat within the cylinder causes an expansion of gases which pushes or forces the piston down. This action is called the power stroke. Desired combustion is the complete burning of all gases

across the combustion chamber. The combustion should be carefully controlled; it should not be a sudden explosion.

6 After the power stroke, the piston pushes gases out through the open exhaust valve, exhaust manifold, muffler, and tailpipe. This completes the 4-cycle operation of an internal combustion engine.

7 It might seem logical that the 4 strokes would start and stop at the top and bottom dead center, but this is not generally true for the following reasons:

1. Engine performance is dependent upon breathing ability.

2. The vertical motion of the piston is very slight near top dead center and bottom dead center.

3. A mixture of fuel and air has to overcome the force of inertia to stop moving.

This diagram indicates the actual valve timing of a high performance engine.

<u>The intake stroke</u> identified in red opens at 29° before top dead center and closes at 74° after bottom dead center. This gives an intake stroke of 283° and allows time even at high R.P.M. to fill the cylinder.

<u>The compression stroke</u> starts when the intake valve closes and continues to top dead center. This allows 106° of crankshaft rotation for compression.

<u>The power stroke</u> starts at top dead center and ends when the exhaust valve opens. This means the power stroke is only 98°.

<u>The exhaust stroke</u> identified in yellow begins when the exhaust valve opens 82° before bottom dead center and closes at 31° after top dead center. This gives an exhaust stroke of 293°. Notice that the two longest strokes are the breathing strokes.

Observe that both valves are open for 60° near top dead center. This is called valve overlap and is conductive to good high speed breathing but is detrimental at idle speeds.

8 Intake manifolds must be a compromise between a large bore size necessary for high speed breathing and a small bore size necessary for low idling speed. The actual compromise on modern engines is a manifold bore size between these two extremes. In order to atomize or break up the liquid fuel into small particles, the air must move rapidly.

9 On an "in-line" engine the manifold is long and the distance the air fuel mixture must travel to reach each cylinder varies. Therefore, the mixture varies from cylinder to cylinder and good distribution is difficult.

10 On a V-8 engine, the manifold is designed to give the same distance to each cylinder thereby giving better distribution between cylinders. Most V-8 engines use two or four barrel carburetors, each bore feeding four cylinders. Notice the black arrows show that one carburetor bore connects to the two end cylinders on one side and two center cylinders on the opposite side. The white arrows indicate the opposite cylinders that the other carburetor bore will feed.

11 The purpose of the exhaust passage in the intake manifold is to heat the intake gases so that they vaporize when the engine is cold. To control this heat, a heat riser valve is used. The valve is controlled by a thermostatic spring. When the engine is cold the spring forces the valve closed causing the exhaust gas to cross over past the carburetor to the other exhaust pipe. As the engine and thermostatic spring warm up, the spring releases its tension on the valve, the valve opens, thereby reducing the heat in the manifold around the carburetor. Without this valve in operation, flat spots in acceleration will occur when the engine is cold. The tiny droplets of atomized fuel must be further broken up in the engine. This is called vaporization and requires heat and low pressure.

12 The exhaust system has the important job of carrying away the exhaust gases and promoting quiet operation while still allowing engine breathing capacity. Sometimes in high output engines it is necessary to use dual pipes to insure breathing and reduce back pressures.

13 Now let's see what ignition has to do with basic carburetion and the proper functioning of the engine.

14 For proper operation the air/fuel mixture in the cylinder should finish burning at approximately 10° to 20° after top dead center for <u>all</u> conditions of engine operation. The number of degrees the crankshaft will travel during the buring time of the mixture will vary with engine speed and engine load.

If the burning time of the gas mixture is approximately .003 of a second, an engine running at 1000 RPM (revolutions per minute) would travel through 18° of rotation during this time. The timing should be set at 8° before top dead center for the mixture to burn completely by 10° past top dead center.

Now at 2000 RPM this same engine would rotate through 36° in .003 of a second and would require a timing of 26° before top dead center to complete burning at 10° after top dead center.

15 Here is a typical centrifugal advance curve. Notice the tolerance. Notice from 500 RPM to 1500 the spark advances rapidly and from 1500 to 3500 more gradually.

16 To obtain this necessary timing advance as speed increases is a job for the ignition distributor. The distributor contains centrifugal weights which move out against spring tension as the speed increases. As the weights move out, they cause the breaker cam on the distributor to move with rotation. This causes the points to open faster.

17 The vacuum advance unit consists of a spring-loaded diaphram connected through a linkage to the distributor breaker plate. Manifold vacuum, when applied to the diaphram, overcomes the spring tension and causes the breaker plate to rotate opposite distributor rotation. A reduction in vacuum produces a retarded spark and an increased vacuum advances the spark. The lean mixture obtained through part-throttle operation at cruising speeds will burn slower; therefore, the spark is advanced to give more burning time.

18 The typical advance curve shows that under cruising conditions the manifold vacuum is high and under full power condition very low. This allows a vacuum advance unit to be used on the distributor to give additional advance for economy.

19 For maximum economy, under cruising conditions, the spark timing has to be advanced further than the

full power at the same speed. This is because the lean mixtures of cruising speeds burn slower than the richer mixtures of full throttle operation.

20 Initial timing is a basic spark timing position, usually a few degrees before top dead center. It varies with different engines but is always set at a specific RPM, at idle speed.

21 Total spark advance is the sum of initial, centrifugal, and vacuum advance and is derived by engine speed and load conditions.

22 The fuel system components include the gas tank, the fuel lines, and the fuel pump. Fuel tanks are not a source of trouble in themselves; however, they must be vented to outside air or the fuel will not be pushed from the tank to the inlet side of the fuel pump.

The lines must be clear so that fuel flow will not be restricted. Connections must be tight so that air cannot leak into the fuel flow. The fuel pump must create a vacuum on upward strokes to move the fuel from the tank to the pump and a pressure on the other downward stroke to push the fuel into the carburetor bowl. Pump pressure must be within specifications to keep the fuel level in the carburetor bowl at a predetermined level. The most important job of the air cleaner is to filter the air to the engine, and in doing this it gets dirty. When dirty, the filter can effect the calibration of the air/fuel mixture. This will lower performance and economy.

23 The purpose of the carburetor on the gasoline engine is to meter, atomize, and distribute the fuel throughout the air flowing into the engine.

24 The carburetor is a fuel metering device. It must first control air flow to the engine. Second, it must sense engine fuel requirements. This is accomplished automatically mainly by making use of the principle of differences in pressure. Third, the carburetor must meter varying quantities of air and fuel with no outside adjustment over a wide range of engine operating conditions such as various engine speeds and engine loads. Fourth, it must break up the liquid fuel into minutely small particles, (atomization) mix them with the correct amount of air, and smoothly introduce this mixture to the intake manifold.

25 The carburetor must be capable of varying the mixture from a rich (choking) mixture for cold engine starting to a lean mixture for hot starting.

26 In addition, the carburetor must vary the mixture from a rich high power mixture when the driver wants fast acceleration and full loads on the engine to a lean mixture when he wants to economize at cruising speeds.

27 The carburetor flow chart is a graphic description of an engine's air and fuel requirements through all ranges of operation. With the relationship between fuel and air expressed in pounds per minute, as shown on this chart, two radically different engines can be compared as to their relative fuel requirements. Also air/fuel ratios for one engine's various speeds and loads can be shown. The solid line curve indicates the air-fuel ratio if the accelerator were depressed to the floor and held to maximum speed. The dotted line curve shows gradual depressing of the accelerator until the engine reaches maximum speed. Notice the economy one can obtain from the engine by gradual acceleration. Air/fuel ratios are limited from an extremely lean mixture of 20 pounds of air to 1 pound of fuel to an extremely rich mixture of 8 pounds of air to 1 pound of fuel. The perfect mixture is 15 pounds of air to 1 pound of fuel. At first it would appear that the carburetor has a relatively simple job to perform. It merely has to mix 15 pounds of air to 1 pound of fuel and deliver it to the combustion chamber. Unfortunately, perfect conditions do not exist for the following reasons: First, varying amounts of exhaust gas linger in the combustion chamber and dilute the new charge. Second, variations in temperature do not allow perfect mixtures and distribution is not equal to each cylinder.

28 This flow chart shows the systems in the carburetor that operate to give the desired ratio and the approximate speeds at which they operate. The idle system supplies the entire mixture at idle and up to about 25 miles per hour. Between 25 and 40 miles per hour is a transfer range and the mixture is supplied by both the idle and the main systems. From 40 to 60 miles per hour the mixture is supplied by the main systems. Above 60 the power system enriches the main system.

29 Fluids or air will flow whenever there is a difference in pressure and the flow will be from high pressure to the lower pressure. The water in the

hose is restricted by the hose nozzle and is therefore under pressure. The water flows from the hoze nozzle under pressure into the air with no pressure. The greater the pressure difference the farther the water will spray.

30 If fuel were standing in a carburetor bowl with the engine shut off, there would be no flow of fuel because there is no difference in pressure on the fuel. Atmospheric pressure is present at the tip of the main nozzle as well as in the bowl. Atmospheric pressure is pressure exerted by the air surrounding the earth (due to its weight) on each square inch of surface. This pressure is approximately 15 pounds per square inch at sea level and decreases as altitude is increased.

31 If a tire pump were used to raise the pressure in the bowl to more than atmospheric (16 pounds per square inch, for example), there would be a difference of one pound per square inch and fuel would flow. This difference in pressure is called "effective pressure."

32 A pressure less than atmospheric is called a "vacuum." When a straw is sucked to obtain liquid from a glass a vacuum is produced in the mouth. Atmospheric pressure on the liquid in the glass will then force the liquid up the straw and into the low pressure area. Now that it has been determined what vacuum is, let's see how vacuum is measured.

33 If the left hand tube in the picture is filled with mercury and then inverted and placed in a container of mercury, the mercury in the tube will drop to a certain height and stop. As the mercury drops in the middle tube, a space with no air pressure (0 pounds per inch) is left above the mercury column. The height of the mercury column above the liquid in the container is approximately 30 inches. This means a difference in pressure between 0 and 15 pounds per square inch will support a column of mercury 30 inches high. If we opened the tube at the top to atmospheric pressure, the column of mercury in the tube would drop to 0 inches as shown on the tube in the right of the picture.

As the air is bled into the top of the tube, the pressure is increased from zero to 15 pounds while the vacuum is decreased from 30 inches to 0 inches. This means that the vacuum changes 2 inches for every pound of pressure change.

33A The chart shows this relationship. Now instead of a mercury column we generally use a vacuum gauge in actual practice to measure vacuum in the intake manifold. If a vacuum gauge reads 18 inches of mercury when the engine is idling, the chart shows that 6 pounds per square inch of pressure are in the manifold.

34 If atmospheric pressure outside is 15 pounds per square inch, the effective pressure is 9 pounds per square inch (which is equal to 1/2 the vacuum reading). Due to the fact that the throttle is practically closed, this pressure can move very little air through the carburetor.

35 The difference between (A) atmospheric pressure and (M) manifold pressure is the force which causes fuel and air to flow.

36 If the carburetor had a straight bore such as this, no fuel would flow because of insufficient pressure drop at the tip of the nozzle. In this case there would be only 3 pounds per square inch effective pressure to move the fuel.

37 The pressure at the nozzle is lowered to the point where the fuel will flow. The device used to increase speed of air is called a venturi. A venturi is a restriction in a tube. The pressure is lowest at the neck or narrowest part of a venturi.

38 Due to the venturi, fuel will flow even though the pressure difference between the manifold and outside air is a small amount.

39 Many carburetors use a primary venturi and a boost or secondary venturi within the primary. This helps lower the pressure at low speeds and still will allow a large air movement at high speed. This picture shows the bottom of the boost venturi which is located in the narrowest part of the primary venturi. This air will speed up through the boost venturi and, thereby, cause a greater drop in pressure at the main nozzle. The high air speed also helps to break up (atomize) the fuel as it comes out the main nozzle.

40 Now that it is known how the low pressure in the carburetor bore is created, it is necessary to determine how fuel in the bowl is pressurized. This is referred to as venting. Three methods of venting are used. They are external, internal, and a combination of the two. External venting can be

accomplished by merely drilling a hole in the top of the fuel bowl. Now if it were not for the air filter, this method would be a simple way of keeping the atmospheric pressure on the fuel in the bowl and also providing an outlet to release pressure developed in the fuel bowl under hot engine conditions. However, we must have air cleaners, and good air cleaners fill up with dirt. This causes restriction of air through the venturi. With external venting, the amount of pressure on the fuel does not change with this restriction, but the amount of air pressure is reduced at the tip of the high speed nozzle so that a rich mixture is obtained.

41 Internal venting when used alone can almost completely compensate for air cleaner restriction. The one main disadvantage is that under hot conditions the fuel will vaporize and, since the vent is under the filter, the vaporized gases will enrich the mixture. Under low speed driving this causes a rough running engine.

42 Since both types of venting have drawbacks, it is not surprising that a combination of the two is used on most carburetors.

43 Now let's see how the various systems in a carburetor operate. Most carburetors have a float, idle, main metering, power, a pump, and a choke system.

44 When specified fuel levels are reached in the carburetor bowl, the float pontoon and attached leverage arm exert force against a needle valve, shutting off flow. Liquid level, which is controlled by float setting, is an important factor in fuel air ratios.

45 The purpose of the idling system in any carburetor is to supply the correct air/fuel mixture to the cylinders during idle and low speed operation. The idling system consists of a calibrated idle tube, air bleeds, idle passages, secondary discharge holes, mixture screws, and idle discharge holes. The low pressure below the closed throttle valve causes fuel to flow through the idle tube into the idle passage where it is mixed with air from an air bleed. The air bleed also prevents fuel from siphoning out of the bowl when the engine is stopped. The fuel and air continues down the passage to the secondary discharge holes. These are located above the closed throttle valve; as a result more air will bleed into

the mixture at this point. The mixture flows past the mixture screw and out the idle port. The mixture screws allow adjustments of the amount of mixture which will flow out the idle port. Adjustment of the throttle stop screw, controls idle speed by allowing additional air to enter with the idle mixture.

46 Some applications have the throttle valve completely closed at idle and air is fed by a by-pass system. In this case an additional screw adjusts the amount of air allowed to pass.

47 When the throttle valve is slightly opened, the secondary discharge ports are exposed to manifold vacuum causing additional fuel mixture to discharge from them. This allows for a smoother transition between idling and cruising speeds.

48 When there is sufficient air flow through the venturi, the pressure will be low enough at the top of the nozzle to cause fuel to flow. This is known as the transfer point where the idle or low speed systems become inactive and the main or high speed systems take over the job of metering and mixing the air and fuel in the proper ratio. The main metering system consists of the main metering jet, the main feed well, and the main nozzle. In most cars the main system supplies fuel over a speed range of approximately 25 to75 miles per hour.

49 As air flow through the carburetor increases, there is a tendency for the mixture to get richer. There are a number of ways to combat this situation by the proper placement of air bleeds in the high speed nozzle. The principle shown here is the use of a perforated lower nozzle. If the part of the nozzle which lies below the level of the fuel in the main well is perforated with holes, then under increased speed the well level lowers. This allows air to enter the uncovered holes which will lean out the mixture.

End of the first hour of instruction.

The second hour lesson using the direct-and-detailed method of teaching Principles of Rochester Model BC Carburetors.

50 Under wide open throttle conditions with high engine speed or load, the main fuel system cannot supply adequate fuel. To overcome this condition an additional passageway is opened up in the main system to allow greater fuel flow. This is called the power system and includes the following parts: the power piston and spring, and the vacuum passage to the intake manifold. The power valve controls a passage from the bowl to the main well. The power piston is located above the valve and is spring loaded to push it down and open the valve. Under high manifold vacuum conditions, the low pressure above the piston will allow atmospheric pressure on the bottom to raise the piston against the spring pressure and allow the power valve to close. Under conditions of power, the pressure differential is not great enough to keep the spring compressed. The power piston is therefore pushed down by the spring and this opens the power valve.

51 When the throttle is opened rapidly, the air flow increases and manifold vacuum decreases. Because of the great difference in weight between air and fuel, any sudden change in throttle opening results in an immediate air intake, but the fuel having greater weight tends to lag behind. This results in momentary leanness. The accelerator pump provides the extra fuel necessary to overcome this problem and gives smooth operation on rapid throttle openings. This is accomplished by discharging extra fuel into the venturi air stream whenever the throttle valves are opened fast. The pump system utilizes a pump plunger that is linked to the throttle valve by mechanical linkage. As the throttle is closed, the plunger moves up in the well, creating a low pressure under the pump. An inlet ball check allows fuel to fill in the low pressure area. As the throttle is opened, the linkage forces the plunger down and exerts pressure on the fuel under the plunger. The fuel is forced out past the discharge ball check and squirts into the carburetor bore of the lower end of the venturi.

52 The necessary requirements of good fuel vaporization are missing or inadequate when starting a cold engine. This inadequacy is overcome by using a choke valve above the venturi to control the air supply while the engine is cold. The choke valve can be controlled manually or by automatic means.

Automatic chokes make use of a bimetal spring which coils up tighter as it warms up and uncoils as it gets cold. If the end of this spring is attached to the choke valve by linkage, it will push the choke closed when cold, and gradually release tension as it gets warmer. To help give more accurate control of the choke while the engine is warming up, a vacuum operated piston combines with an unbalanced choke plate to force the choke partially open against the spring trying to close it. Hot air from the exhaust manifold is pushed by atmospheric pressure through the bimetal coil and past the vacuum piston into the intake manifold. This heat helps the coil unwind and allows the choke to open gradually.

53 An automatic choke also requires a fast idle feature to give an RPM increase at idle speeds when the choke is in operation; otherwise, the engine might load up with a rich mixture and stall. A choke unloading feature is also necessary to provide a means of opening the choke if the engine becomes flooded during cranking.

Disassembly and Inspection of the Rochester BC Carburetor.

At this time each student should move over to the benches. You will find a Rochester BC Carburetor, a screw driver, a parts pan, and a clean shop towel. Please listen to the tape recording and follow only the instructions given. Do not work ahead. During certain parts of this lesson you will be asked to look at filmstrips which are flashed on the screen.

BC-1 The main parts of the Model BC Carburetor can be viewed on the screen.

Choke Disassembly

1. Loosen the 1/2 inch brass fitting on the choke vacuum tube. Invert the carburetor and notice the large vacuum hole in the inside of the throttle body.

2. Remove the three attaching stat cover screws and retainers, then the stat cover, cover the gasket and thermostat coil assembly from the carburetor. Please notice that as this coil is heated it will coil up tighter and as it cools it will uncoil. The tang on the coil pushes against the choke lever arm holding the choke valve closed.

The temperature of the coil will vary the amount of pressure against the choke valve.

3. Notice the choke baffle plate in the choke housing. Its purpose is to control the flow of heated air through the coils. Remove it from the housing.

4. Inspect the choke piston. Open and close the choke and notice the action of the piston.

5. Observe the choke housing mounting screws and the gasket. If the gasket leaks, the cold outside air instead of heated air will be drawn into the housing. This will cause excess choking on warm up of the engine.

Air Horn Disassembly

6. Remove the (4) screws holding the carburetor air horn to the bowl and lift off the air horn.

7. Place the air horn in an unended position on a flat surface. Remove the float hinge pin and float assembly. If the float pontoons were dented, they would have less volume and float lower in the fuel. This would cause a higher fuel level in the bowl.

8. Remove the float needle.

9. This carburetor is both internally and externally vented. Trace the internal venting from the spout inside the air horn above the choke valve. There are two external vents one on each side of the air horn near the top on the outside.

10. Remove the float seat and gasket with 1/2 inch bit screwdriver. Be sure to check the hinge pin and needle for grooves which are caused by wear.

11. Notice the main metering jet in the main well support. Higher elevation will require a smaller size jet because of lower atmospheric pressure.

12. Remove the main well support. The air horn gasket may now be removed carefully.

13. Remove the power piston and spring. Remember the spring is calibrated to push the power

piston down and open the power valve when the intake manifold pressure increases above a certain specified setting. Note: Do not try to remove or bend the idle tube.

Bowl Disassembly

14. Remove the pump discharge guide with a needle nosed pliers. The discharge spring and ball will fall out when you invert the carburetor bowl.

15. Remove two pin springs from the pump link and remove the pump link from the throttle lever and pump plunger arm.

16. Remove the pump plunger from the bowl and the pump return spring. Note: Do not remove the choke suction tube from the throttle body.

17. Invert the carburetor bowl and remove the throttle body and gasket from the bowl.

Throttle Body

18. Remove the idle adjusting needle and spring. Notice the small idle hole below the throttle valve.

BC-2 19. At this time let's trace the fuel and air flow through the entire idle system. Beginning at the idle tube which is extending down into the fuel in the main well, the fuel is forced up the tube and across the air horn via the nozzle bar. If you look into the top of the air horn with the choke open you can see two air bleed holes used for mixing air and idle fuel in the nozzle bar. The idle fuel and air mixture come down a passageway in the carburetor bowl to the throttle body gasket where it is directed along a slot in the carburetor bowl and through a passageway in the throttle body, past the idle adjusting needle and out into the bore of the carburetor below the closed throttle valve.

BC-3 20. Now let's trace the fuel and air through the main or high speed system of this carburetor. Pick up the main well support and set it in place temporarily on the air horn. Remember about two-thirds of this support is immersed in the fuel in the bowl. Now with the throttle valve partly open, atmospheric pressure moves air down through the venturi. A transfer from idle to high speed occurs as effective pressure decreases at the idle discharge port and increases in the vicinity of the high speed nozzle.

BC-4 21. The power valve on this carburetor is on the lower end of the main well support. When the power piston is pushed down by the spring, it forces the spring loaded ball out of the opening and additional fuel from the bowl will enter and add to the fuel which is already flowing through the main jet. With the throttle valve almost wide open thereis very little difference in the pressure or either end of the power piston so that the spring forces the piston down and opens the power valve. Assemble thepower piston spring and main well support to the horn.

22. Replace the needle, seats, float, and hinge pin to the air horn.

23. Replace the choke baffle plate. Replace the thermostat coil assembly and cover, being sure to hook the end of the coil under the choke piston linkage. Rotate the cover clockwise until the single mark on the cover lines up with the middle mark on the choke casting. Replace the three lock screws. The choke should be in the closed position and you may test it for any binding by depressing it with your finger. If it binds, remove the stat cover and check the shaft for freedom.

24. Float adjustment should be made at this
BC-5 time. With the air horn inverted, place the float gauge into position and bend the float tang so that the top edge of the float just touches the gauge.
BC-6 Check to see that the sides of the float do not touch the gauge legs. Next turn the air horn in the upright position and check the amount of float drop.

25. Invert the bowl, place the throttle body gasket into position, and attach the throttle body. Note: Be sure the gasket holes are lined correctly with the vacuum holes in the body and the bowl.

BC-7 26. Now before assembling the accelerator pump system, let's trace the fuel flow through this system. Most models of these carburetors have no inlet ball check for the pump. Fuel comes in between the pump piston and the wall on the upward stroke. Notice the vapor vent ball check in the pump piston in the picture. Notice also the steel ball and spring in the pump discharge cavity. On the downward stroke of the pump, fuel is forced past the ball and out the small hole in the venturi near the top of the cavity. Find this hole on your carburetor. Assemble the plunger, spring, and retainer and install the assembly in the pump well. Replace the linkage from the pump to the throttle shaft.

27. Install the air horn to the throttle body and connect the choke rod and choke suction tube.

BC-8 28. Notice that with the choke closed the choke rod holds the highest step on the fast idle cam against the idle speed adjusting screw. This holds the throttle valve open slightly so that the engine will idle faster when the choke is closed. If you push the choke plate open the fast idle cam will swing to a lower step and the throttle valve will close completely. This setting is adjusted by bending the choke rod.

BC-9 29. Observe that when the throttle is opened wide a tang on the throttle lever contacts the fast idle cam and pushes the choke partially open. This is called the unloader. The operator can open the choke to redice flooding by pushing the accelerator to the floor. This completes the lesson on Rochester BC Carburetors.

End of second hour of instruction.

The first hour lesson using the directed-discovery method.

INTRODUCTION TO CARBURETION

Students, this lesson is concerned with the fundamentals of carburetion. Please listen carefully to what is being said while you are studying each slide. You will find throughout this lesson that questions are asked and clues are given to help you to gain greater understanding. Short intervals of time are allowed after each question. Please try to answer the questions silently in your own best judgment.

Slide #

1 Engine performance is dependent upon how efficiently the air/fuel mixture can be moved into the cylinder, compressed, burned, and the exhaust gases removed so that the cylinder is clear for the next charge. This is sometimes referred to as engine "breathing ability."

2 The internal combustion engine in a sense is nothing more than a vacuum pump. Just how can an engine be compared to a vacuum pump?

What is vacuum anyway?

3 Most piston type automotive engines have four strokes in one complete cycle of operation. Beginning with the intake stroke, the piston moves down in the cylinder. This causes a low pressure or partial vacuum within the cylinder. Can you explain why the piston moving down in the cylinder on the intake stroke will create a partial vacuum? During this stroke, air is forced through the carburetor where it picks up a proper portion of fuel and continues on to fill the cylinder with a combustible mixture. What is the force causing the air to move into the cylinder?

4 When the intake stroke is completed, the piston moves up, squeezing the fresh charge upward into the combustion chamber where both valves are now closed. This is called the compression stroke. The reason that the fuel/air mixture is compressed is that the energy released by burning can be captured more efficiently. Can you determine the reasons for this?

5 As the piston ends the compression stroke, an electrical charge is released in the combustion chamber

at the spark plug. This causes the air/fuel mixture to ignite and burn. Rapid generation of heat within the cylinder causes an expansion of gases which pushes or forces the piston down. This turns the crankshaft and is called the power stroke. Desired combustion is the complete burning of all gases across the combustion chamber. This should be a carefully controlled combustion, not a sudden explosion. What would be some of the results as far as engine operation and failures are concerned if the mixture burned too fast? How about too slow a burning time?

What effect would fuel/air ratios have on burning time?

6 Can you think of any reasons why most engines have trouble getting the exhaust gases out and consequently will usually allow more time for this last stroke? Consider friction and inertia in your answer.

7 Can you think of reasons why each of the different strokes would <u>not</u> start and end on top and bottom dead center?

This is a diagram of the actual valve timing of a high performance engine. Why do you think this engine would run rough at idle and low speeds?

Notice the length of the intake stroke in crankshaft degrees. The compression stroke begins when the intake valve closes and only uses 106° of crankshaft rotation. Can you visualize how the principle of inertia is used here in respect to filling the cylinder?

The power stroke only requires 98° of crankshaft rotation. The exhaust stroke begins when the exhaust valve opens at 82° before bottom dead center and has a duration of 293° of crankshaft rotation. Notice both valves are open near top dead center for 60° of crankshaft rotation.

8 Intake manifolds must be a compromise between a large bore size necessary for high speed breathing and a small bore size necessary for low idling speed. How would intake manifold restriction affect high speed and power?

How would no restriction in the intake manifold affect low speed and idle?

9 Good distribution of mixture to each cylinder is difficult on an in-line engine due to the variation in distances the mixture must travel. Can you think of possible answers to this problem?

10 In a V-8 engine, the manifold is designed to give the same distance to each cylinder, thereby giving better distribution between cylinders. By using two or four barrel carburetors each bore feeds four cylinders. Notice the black arrows indicate the four cylinders fed by one carburetor bore and the white arrows indicate those fed by the other bore. What are some possible reasons for dividing V-8 manifolds in this particular way?

11 The purpose of the exhaust passage in the intake manifold is to heat the intake gases so that they vaporize when the engine is cold. Will water vaporize when we boil it?

What seems to be one important requirement for vaporization of a liquid?

How will variations in the atmospheric pressure affect vaporization?

The manifold heat control valve is much like a damper in a stove pipe. This valve is set in one exhaust pipe and when closed will block off the exhaust from the one side and force it to cross over past the carburetor to the other exhaust pipe. A thermostatic spring controls the valve keeping it closed when the engine is cold and open when the engine is warm. If two strips of metal with different expansion rates are laminated together as one strip, what would you expect would happen if you heated this strip?

12 The exhaust system has the important job of carrying away the exhaust gases and promoting quiet operation while still allowing good engine breathing. What would be the effect on engine speed and power with too much back pressure in the exhaust system?

Can you think of some possible causes of back pressure in the exhaust system?

Most automotive engines will not idle if they have no tailpipe or muffler. Can you determine a reason for this?

13 Now let's see what ignition timing has to do with basic carburetion and the proper functioning of the engine.

14 No matter what the speed or load on any modern engine the fuel/air mixture should be completely burned by the time the crankshaft has moved approximately 10° past top dead center. Can you suggest why there would be a tremendous loss in power if the fuel were allowed a burning time of the full length of the power stroke?

If the burning time of the gas mixture is approximately .003 of a second, an engine running at 1000 RPM (revolutions per minute) would travel through 18° of crankshaft rotation during this time. To completely burn the mixture by 10° past top dead center, the spark timing must occur at 8° before top dead center. Now at 2000 RPM this same engine with the same burning time would require what spark advance setting?

15 Here is a typical centrifugal advance curve. Notice the tolerance. Can you think of any reasons why the spark advances more rapidly from 500 RPM to 1500 RPM than it does from 1500 to 3500 RPM?

16 The distributor centrifugal weights shown here move out against spring tension as speed increases. As the weights move out, they cause the breaker cam on the distributor to move with rotation. This causes the ignition points to open earlier which fires the fuel charge earlier. Can you visualize how this same centrifugal weights principle might be used as a mechanical governor to control engine speed?

17 The vacuum advance unit consists of a spring loaded diaphram connected through a linkage to the distributor breaker plate. Manifold vacuum, when applied to the diaphram, overcomes the spring tension and causes the breaker plate to rotate opposite distributor rotation. A reduction in vacuum produces a retarded spark and an increased vacuum advances the spark. When the throttle valve in the carburetor is closed, does the engine vacuum go up or down?

18 This chart shows a typical vacuum advance curve. Variations in intake manifold vacuum cause the vacuum advance unit to operate. Can you determine what causes this variation in intake manifold vacuum?

19 For maximum economy, under cruising speeds (part throttle), the spark has to be advanced farther than for full power at the same RPM because lean mixtures burn slower. Why do you think a lean mixture will burn slower?

20 Initial timing is a basic spark timing position, usually a few degrees before top dead center. It is always set at a specific RPM at idle speed.

21 Total spark timing is the sum of initial, centrifugal, and vacuum advance and is derived by engine speeds and engine load conditions. Do you think the total spark advance would be high, medium, or low in the following conditions:

Low speed full load?

High speed part load?

High speed full load?

Low speed part load?

22 Now let's look at the fuel system components.

A. The fuel tank provides storage for the fuel. What do you think would happen if the air vent in the fuel tank became closed up?

B. The fuel lines carry fuel from the tank to the pump and then to the carburetor. What do you think would be the effect of a loose fuel line connection between the tank and pump?

C. The fuel pump must create a vacuum on upward strokes to move the fuel from the tank to the pump and a pressure on the downward stroke to push the fuel into the carburetor bowl. If a special cam on the camshaft supplies the force on the upward stroke of the pump to create the vacuum, what supplies the force for the downward stroke to push fuel to the carburetor? <u>Cue</u>: Keep in mind that if the pump pressure is too high, it will overcome the float pressure on the fuel inlet needle and raise the fuel level too high in the carburetor bowl. Do you think a spring could be used to supply the force on the downward stroke of the fuel pump?

D. The most important job of the air cleaner is to filter the air entering the carburetor. In doing this, the cleaner gets dirty. You will see later that a dirty air filter can effect engine economy and performance.

23 The purpose of the carburetor on the gasoline engine is to meter, atomize, and distribute the fuel

throughout the air flowing into the engine.

24 The carburetor is a fuel metering device. First, it must control air flow to the engine. Can you determine how air is controlled from this picture?

How do you think engine speed might affect air flow to the engine?

Second, it must sense engine fuel requirements. Could you explain how this sensing is accomplished automatically through the use of differences in pressures?

Third, it must break up the liquid fuel into minutely small particles. This is called atomization. Cue: This is done in the same way that a garden sprayer breaks up the spray liquid. Can you explain the action of a garden sprayer?

25 When it's cold the carburetor must enrich the fuel/air mixture because some of the particles of atomized fuel are lost on the way to the combustion chamber. Can you account for this loss of fuel particles when the engine is cold? How is this adjustment of fuel/air mixture controlled by the carburetor automatically?

How can this be accomplished manually?

26 In addition the carburetor must vary the mixture to a rich power mixture when the driver wants fast acceleration and full loads on the engine, and lean out the mixture when he wants to economize at cruising speeds.

27 The carburetor flow chart is a graphic description of an engine air and fuel requirements through all ranges of operation. The solid line curve shows the air fuel ratio when the driver depresses the acceleratorto the floor and holds it until maximum speed is attained. The dotted line curve shows gradual depressing of the accelerator until maximum speed is attained. Can you explain why there is such a great difference in fuel economy between the top and bottom curves?

Would a high performance engine ever show less difference in these two curves than a low performance engine?

Air/fuel ratios are limited from an extremely lean mixture of twenty pounds of air to one pound of fuel to an extremely rich mixture of eight to one. Can you give any reasons why fuel/air mixtures will not burn in the combustion chamber sufficient to allow the engine to run if they are too lean or too rich? Cue: Think of the fuel as many little "specks" which are distributed throughout the air.

Under perfect conditions of engine operation, what are some reasons as to why we don't have perfect conditions for engine operation?

28 This flow chart shows the systems in the carburetor that operate to give the desired ratio and approximate speeds at which they operate. The low speeds and high speeds require the richest mixtures. Is it possible to improve this obvious waste of fuel by introducing some new ideas in the fuel system design?

Would injection of fuel into each cylinder improve either low speed or high speed?

How about supercharging or blowing?

29 What makes the water flow from the hose nozzle? If you removed the nozzle the water would not shoot out of the hose as far. Why not?

30 There is no pressure differential between the fuel in the fuel bowl and the fuel in the nozzle; consequently, there is no fuel flow. How much pressure is there on the fuel?

What is atmospheric pressure?

31 If a tire pump were used to raise the pressure in the bowl above atmospheric, fuel would flow. The difference between the two pressures is called the effective pressure. How is this effective pressure obtained in actual practice?

32 What makes it possible to drink the liquid by sucking on a straw?

Suppose the straw develops a crack in it above the liquid level? What would happen?

Atmospheric pressure is approximately 15 pounds per square inch at sea level. Pounds per square inch refers to the force per unit area. Can you explain this last statement?

33 If a tube closed at one end is filled with mercury and then inverted and placed into a container of mercury, the mercury in the tube will drop to approximately 30 inches at sea level. Can you explain what keeps the mercury at 30 inches in the inverted tube at sea level?

What would happen to the column of mercury if you placed it on top of a mountain?

If the specific gravity of mercury is 13.6 times that of water, how high would atmospheric pressure at sea level support a column of water?

33A This chart shows a relationship between gauge pressure in yellow and inches of mercury which can be supported by the corresponding gauge pressure in red. How much does the vacuum reading in inches change for every one pound per square inch pressure change?

Five pounds negative pressure supports 20 inches of mercury, whereas 5 pounds positive pressure supports 40 inches of mercury. Can you explain this?

34 The pressure difference of 15 pounds atmospheric pressure and 6 pounds manifold pressure is maintained because of what conditions in this picture?

Suppose you opened the throttle wide. What would you expect would happen to the intake manifold pressure?

35 The difference between (A) atmospheric pressure and (M) manifold pressure is the force which causes fuel and air to flow. Can you see the relationship in this case with the principles under which most pumps and compressors operate?

How about the principle used in vacuum type windshield wipers and windshield washers?

What about the home vacuum cleaner?

36 If the carburetor had a straight bore such as this, why wouldn't fuel flow from the bowl out through the nozzle?

37 In order to lower the pressure at the nozzle so that fuel will flow we use a device called a venturi. It works on the following principle: the higher the

velocity the lower the pressure drop. If air is made up of tiny particles, can you visualize a greater space between these particles at the smallest points in the venturi?

If we have fewer particles in a space, aren't we approaching a perfect vacuum which is nothing in a space?

Can you visualize why there is a partial vacuum created immediately behind a fast moving train?

38 Can you explain why fuel will flow even though there is very little pressure differential between atmospheric and manifold?

39 A secondary or boost venturi is used on most carburetors for two reasons. It helps atomize the fuel and it lowers the cut-in speed of the main system. Can you explain why the boost venturi does this?

40 If atmospheric pressure were not allowed into the fuel bowl, fuel would not flow out of the nozzle regardless of how low the pressure drops in the venturi. Why not?

There are three methods of venting - external, internal, and a combination of the two. External venting alone can cause high mixtures if the air filter on the top of the carburetor becomes dirty. Can you see why this would happen?

How would a dirty air filter affect the pressure difference between the fuel bowl and the high speed nozzle?

41 Internal venting when used alone can almost completely compensate for air cleaner restrictions. One main disadvantage is that under hot conditions the fuel will vaporize and since the vent is under the filter the vaporized gases enrich the mixture. This condition causes a rough running engine at low speeds.

42 Since both types of venting have drawbacks, it isn't surprising that a combination of the two is used on most carburetors.

43 Now let's see how the various systems in a carburetor work. Most carburetors have a float idle, main

metering, power accelerator pump, and choke system.

44 When specified fuel levels are reached in the carburetor bowl, the float pontoon and attached leverage arm exert force against a needle valve shutting off flow. The fuel level is the most important setting in the carburetor. Fuel pump pressure and float pontoon size as well as the mechanical advantage of the float lever arm are inter-related. Can you identify this relationship?

The purpose of the idle system in any carburetor is to supply the correct air/fuel mixture to the cylinders during idle and low speed operation. The idle system consists of a calibrated idle tube, air bleeds, idle passages, secondary discharge holes, mixture screws, and idle discharge holes. Can you explain what causes the fuel and air mixture to come out of the idle discharge holes when the throttle valve is closed?

Why do we have the secondary discharge holes and when do they begin to operate?

What is the purpose of the idle mixture screws?

What do we adjust to get more air into the idle mixture?

46 On some applications the throttle valve is closed and additional air is fed by a by-pass system. An additional screw adjusts the amount of air allowed to pass. Can you think of any advantages to this method?

47 The secondary discharge ports are exposed to manifold vacuum as the throttle valve is slight opened. Can you recognize the purpose of these ports under a slightly opened throttle valve?

The secondary discharge ports also have a purpose when the throttle is closed. Can you identify this purpose?

48 When there is sufficient air flow through the venturi, the pressure will be low enough at the top of the nozzle to cause fuel to flow. Do you know why the idle system decreases and finally stops feeding as the throttle valve opens wider and the main system takes over?

The main metering system consists of the main metering jet, the main feed well, air bleeds, and the main nozzle. This supplies fuel over a speed range of approximately 25 to 75 miles per hour. Suppose the car were being used in Denver, Colorado, which has an altitude of over 5000 feet above sea level. Would the jet size be smaller or larger in size to allow more fuel or less fuel to the air at this altitude? Cue: Will the effective pressure be more or less?

49 As air flow through the carburetor venturi increases, there is a tendency for the mixture to get richer. Can you suggest a method for the increased air bleed compensation required when more fuel is used at higher speeds?

Cue: One method is to perforate the lower end of the high speed nozzle. As fuel is used faster it will lower the level in the feed well and uncover the perforated holes to outside air.

End of the first hour lesson.

The second hour lesson using the directed-discovery method.

50 Under wide open throttle conditions and high engine speed and load, the main metering jet cannot supply adequate fuel. To overcome this condition an additional passage is opened up in the main system to allow greater fuel flow. This is called the power system and includes the following parts: the power valve, the power piston and spring, and the vacuum passage to the intake manifold. The difference in pressure holds the long stem on the power piston from opening the power valve. What is the force which pushes the power valve open when the vacuum drops off?

What are the possibilities of using a diaphram instead of a piston to operate a power valve?

51 Any sudden increase in throttle opening, such as might happen in moving away from a stop sign, will result in an immediate increase in the air to the engine, but the fuel, having greater weight, tends to lag behind. This results in engine hesitation and lean fuel mixtures.

The accelerator pump overcomes this problem by spraying fuel into the lower half of the carburetor whenever the accelerator is pushed down. The accelerator pump system includes the piston type pump, a pump cylinder, an inlet valve, a discharge valve, and a pump jet. Can you explain how the pump operates?

Begin with the piston moving up on the inlet stroke.

52 We have already indicated that fuel must be atomized and vaporized to ignite and burn effectively in an engine. Can you explain why fuel will not vaporize in a cold engine?

The choke cuts off most of the air supply and causes the fuel/air mixture to be very rich. However, by the time the fuel/air mixture arrives in the combustion chamber, it is much leaner. What do you suppose caused this leaning out and where did the fuel go?

Almost all automatic chokes use a bimetal spring which coils up when warm and uncoils when cold. This spring pushes on the choke linkage holding the choke closed when cold and gradually releases this tension when it warms up.

As the engine is warming up, a vacuum piston combines with an offset choke valve to force the choke partially open which works against the bimetal spring trying to keep it closed. Air heated by the exhaust manifold is drawn up around the bimetal spring and past the piston and finally into the intake manifold.

The automatic choke has almost completely replaced the manual choke on modern automobiles. Can you suggest reasons for this other than convenience?

53 The automatic choke requires an unloader linkage accessory so that the driver can stop the choke from overchoking and flooding the engine at times. How would you expect this unloader to operate?

The fast idle cam is another necessary feature to increase the engine idle speed when the choke is being used; otherwise, the engine might stall with the rich mixture at low speed.

Disassembly and Inspection of the Rochester BC Carburetor

At this time each student should move over to the benches. You will find a Rochester BC Carburetor, a screwdriver, a parts pan, and a clean shop towel. Please listen to the tape recording and follow <u>only</u> the instructions given. Do not work ahead. During certain parts of this lesson,
BC-1 pictures will be projected on the screen. They may serve as clues to the answers to certain problem situations.

<u>Choke Disassembly</u>

1. Loosen the brass fitting on the choke vacuum tube. How does the intake manifold vacuum reach the top end of this tube?

What is the purpose of this vacuum?

2. Remove the automatic choke cover and gasket. Place a pencil mark on the plastic choke cover in line with the tang of the coil. Invert the coil and hold a lighted match about 2 inches away. What causes the coil to tighten when heated?

3. Notice the choke baffle plate inside the choke housing. What is its purpose?

Remove it.

4. How does the choke piston operate?

Can you see how the choke piston can control the amount of heated air through the choke coil? Cue: Replace the baffle plate and move the choke open and closed.

5. Notice the gasket which seals the choke housing to the carburetor. What would the consequences be if it leaks?

Air Horn Disassembly

6. Remove the air horn from the bowl.

7. Remove the float hinge pin, the float assembly, and the float needle. How would the fuel level be affected if the float pontoons were crushed to give a smaller volume?

8. Notice the tang on the float and the float needle have curved surfaces. What would be the effect on fuel level if the surfaces were flat?

9. Can you trace out the internal and external venting on this carburetor?

10. Remove the float seat and gasket with 1/2 inches bit screwdriver.

11. Notice the main metering jet in the main well support. Under what conditions would the jet size be smaller than normal? Cue: How does elevation affect the amount of atmospheric pressure?

12. Remove main well support and gasket.

13. The power piston and spring can now be removed. If you stretched the spring what effect would it have on the power system? Note: Do not try to remove or bend the idle tube.

Bowl Disassembly

14. Remove the pump discharge guide. Be careful not to lose the spring and ball when you remove them after pulling out the guide.

15. Remove the pump link.

16. Remove the pump and return spring from the pump well. Note: Do not remove the choke suction tube from the throttle body.

17. Remove the throttle body and gasket.

Throttle Body

18. Count the number of turns required to tighten the idle adjusting screw. Remove the screw and notice the small hole below the throttle valve. Can you determine the purpose of the several small holes just above the throttle plate? Cue: Notice where they lead.

BC-2 19. At this time let's trace the fuel and air flow through entire idle system beginning at the idle tube in the air horn. Why does the fuel and air mixture cross the nozzle bar to the opposite side of the carburetor bore and not drop down through the high speed nozzle opening? Cue: Under idling conditions with the throttle closed how much vacuum is there at the high speed nozzle opening?

Notice the two fine holes on the top of the nozzle bar as you look through the air horn. What is the purpose of these holes?

BC-3 20. Now let's trace the fuel and air through the main or high speed system. Replace the main well support temporarily in its proper position on the air horn. How much of this support would be in the fuel under normal float setting?

The transfer from idle to high speed is controlled by the driver. Can you explain what takes place to cause this transfer?

Notice the air bleeds in the top of the nozzle bar. If you enlarged these holes what would the effect be on engine operation?

BC-4 21. Inspect the power valve on the lower end of the main well support. By placing your pencil tip through the small hole you can push the ball down. Can you trace the fuel through the power valve?

Now let's look at the power piston and spring. Why are the grooves cut on the outside of the power piston? Cue: There are at least two places where atmospheric pressure can push on the power piston. Can you locate these places? Cue: Another reason for the grooves has to do with reducing of binding and friction on walls where the power piston rides. Can you determine how grooves will help these two problems?

Suppose the power piston spring were shortened. How do you think this condition would affect the power valve operation?

You may now assemble the power piston, spring, and main well support to the air horn.

22. Replace the needle, gasket and seat, float, and hinge pin to the air horn.

23. Replace the choke baffle plate. Replace the thermostat coil assembly and gasket. How can you be sure the thermostatic spring is hooked to the tang and the choke valve shaft? Cue: Under room temperature is the choke plate held closed or open?

How can binding of the choke assembly be checked?

Set the choke tension at normal and lock the three screws which hold the thermostat cover.

BC-5 24. Float adjustment should be made at this time. With the air horn inverted, place the float gauge into position and bend the float tang so that the top of the float just touches the gauge. Check to see that the sides of the float do not touch the
BC-6 gauge legs. Next turn the air horn in the upright position and check the amount of float drop.

25. With the bowl inverted, place the throttle body gasket into position and attach the throttle body. Note: Be sure the gasket holes are lined correctly. Can you think of any method by which you can test the alignment of this gasket?

BC-7 26. Before assembling the accelerator pump system let's trace the fuel flow.

In the basic lesson, remember the pump had an inlet valve and a discharge valve. Can you find the inlet valve in this carburetor? Cue: Notice the fuel in the bowl would be higher than the pump well. Does this suggest why an inlet ball check is not required?

Can you point out where the pump discharges the fuel into the venturi? Most carburetors have some method of prolonging the fuel discharge over a longer period of time than the pump movement. Can you determine how the prolonged discharge is handled on this carburetor? Cue: Notice the slot in the upper end of the pump shaft. Reassemble the pump system and raise your hand when you have completely assembled and replaced the pump circuit.

27. Install the air horn to the throttle body and connect the choke rod and choke suction tube.

BC-8 28. With the choke closed, would you expect to see the idle speed adjusting screw on the high step or on the low step of the fast idle cam?

On what step of the fast idle cam is the idle speed adjusting screw on your carburetor?

Is the throttle valve slightly open?

Now push the choke valve open with your finger. Did the throttle valve close?

With the choke plate still half open, observe what step the idle speed adjusting screw is setting. How can the fast idle setting be adjusted?

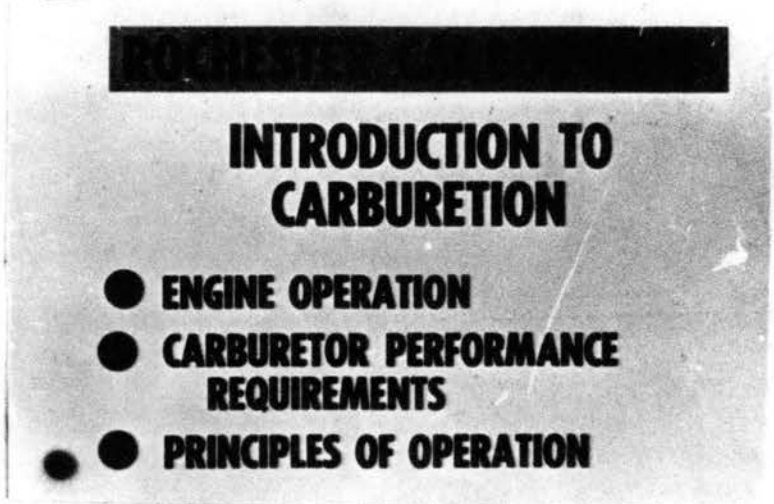
BC-9 29. Notice when the throttle is opened wide a tang on the throttle lever contacts the fast idle cam and pushes the choke partially open. This is called the unloader. Can you determine the purpose of the unloader and under what conditions it would be used?

This completes the lesson on the BC Carburetor. End of second hour.

Appendix B

Visual Part of the Lessons

Filmstrip



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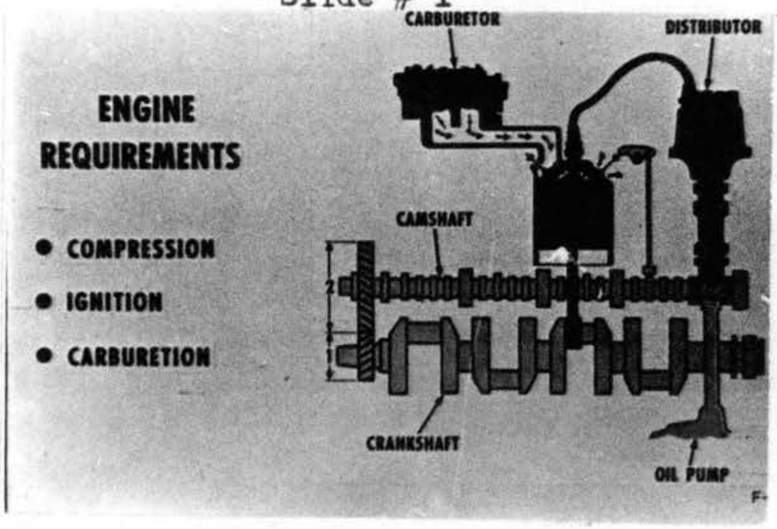

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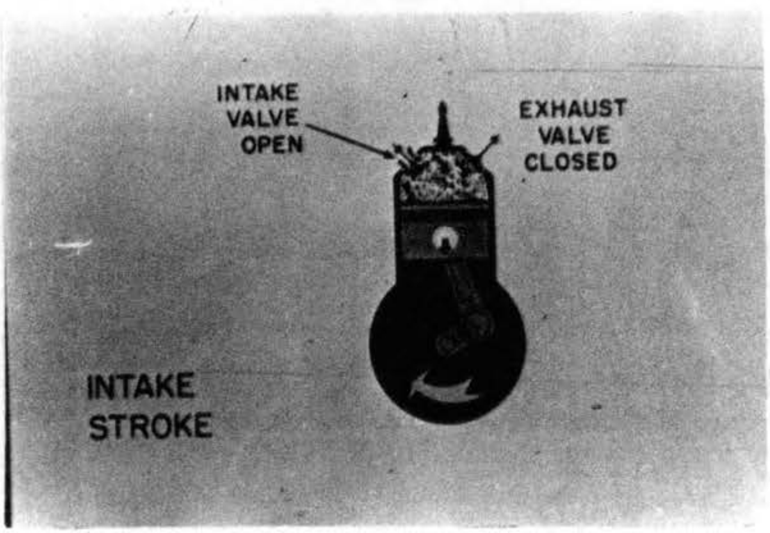

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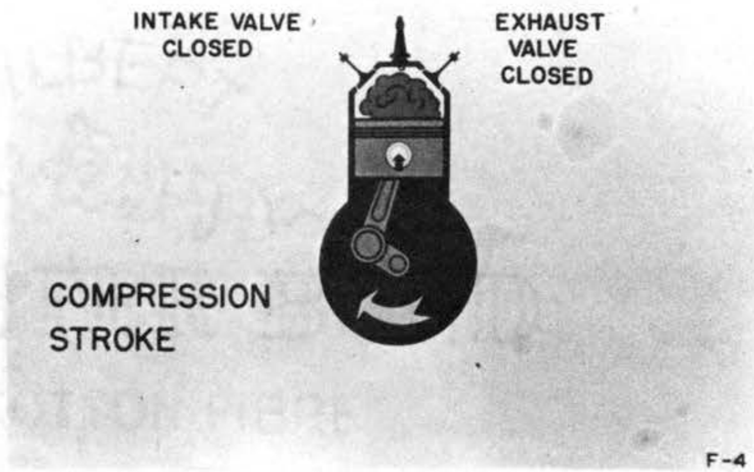

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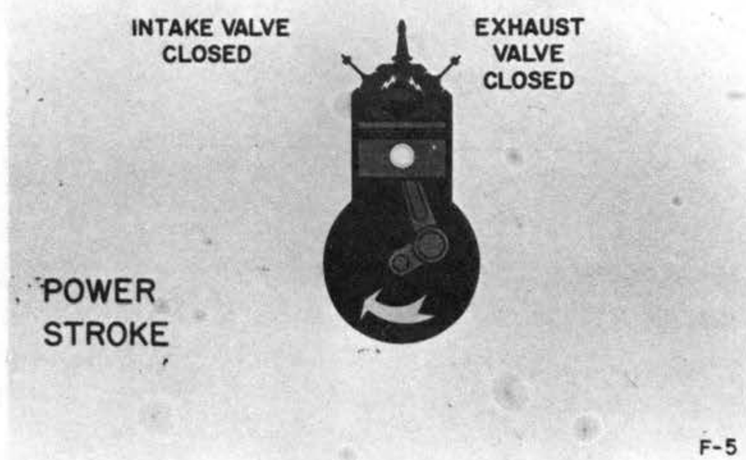

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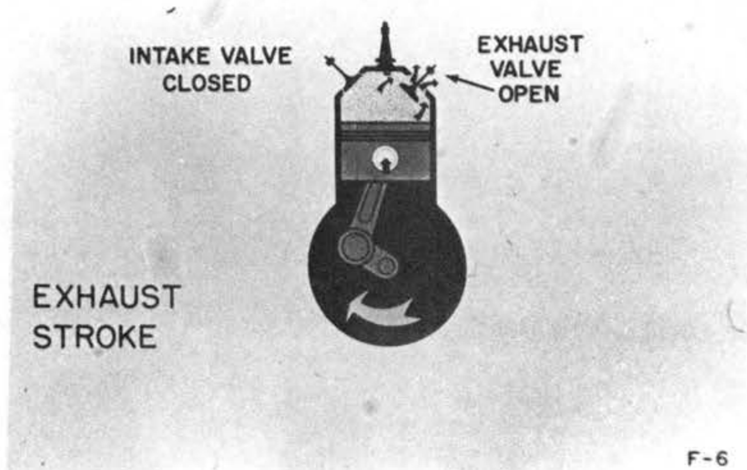

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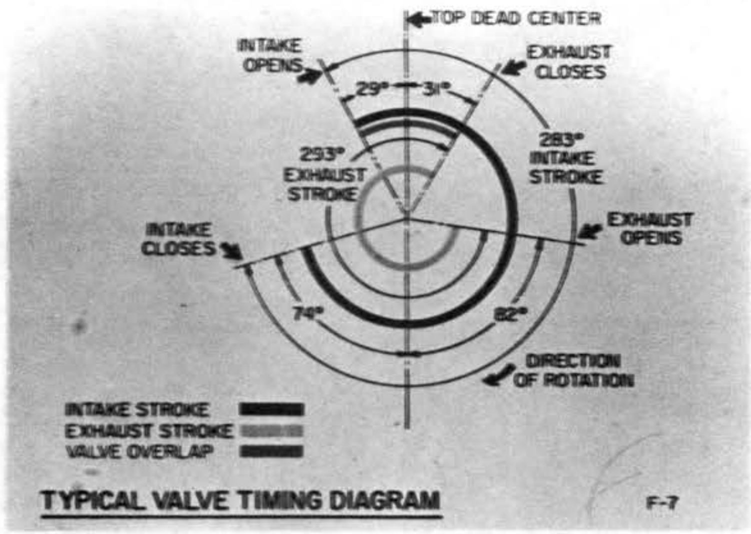

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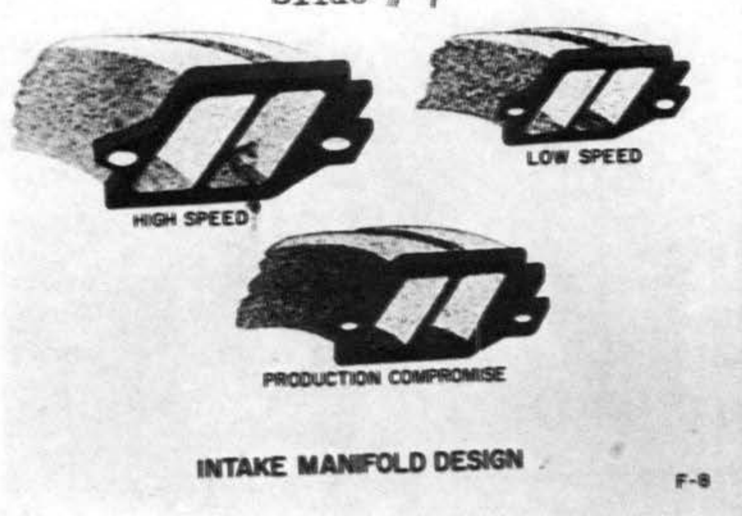

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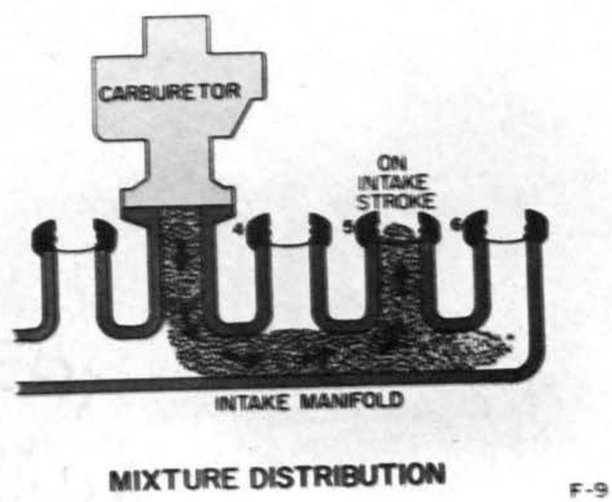

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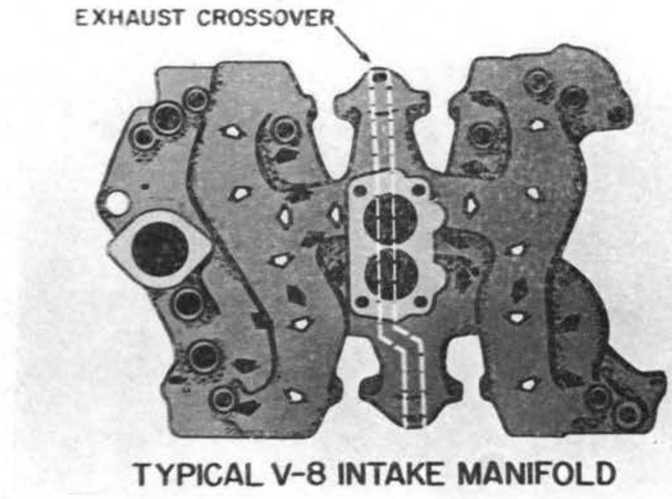

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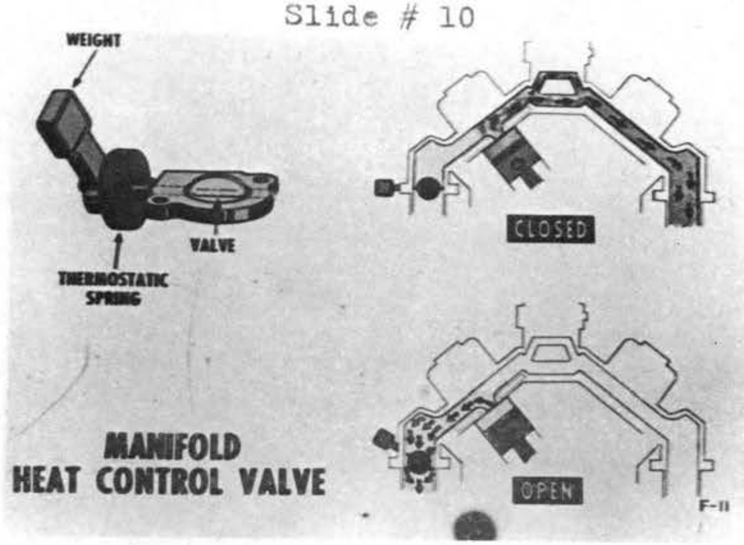

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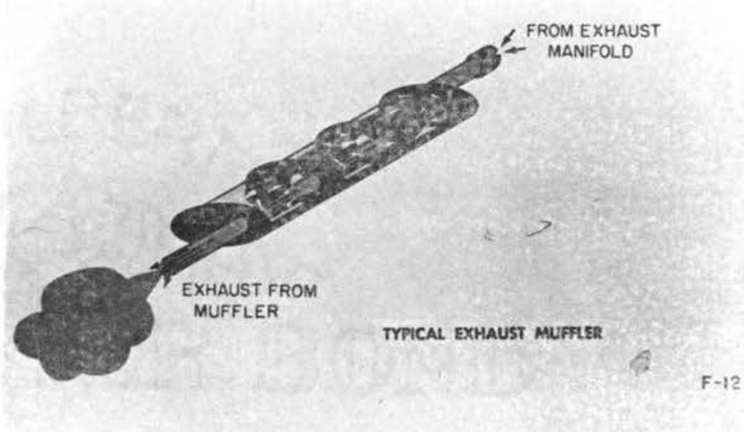

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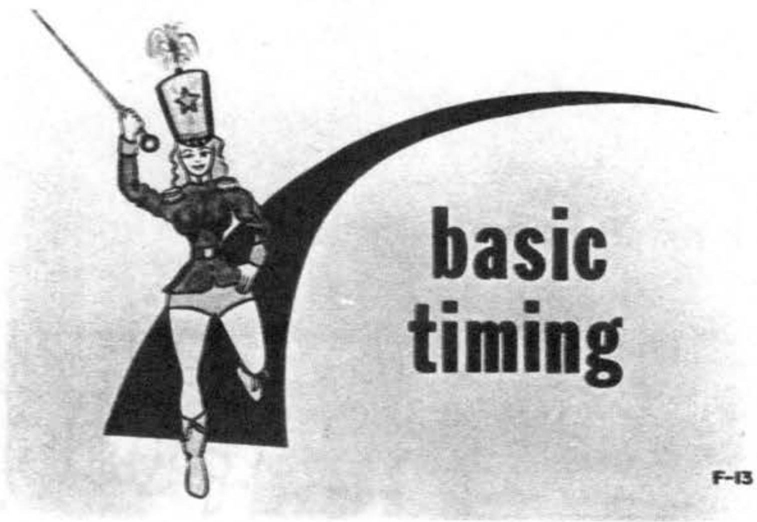

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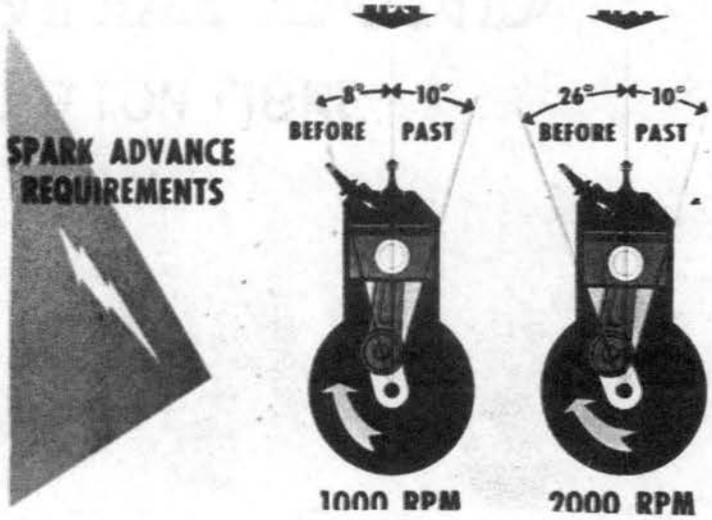

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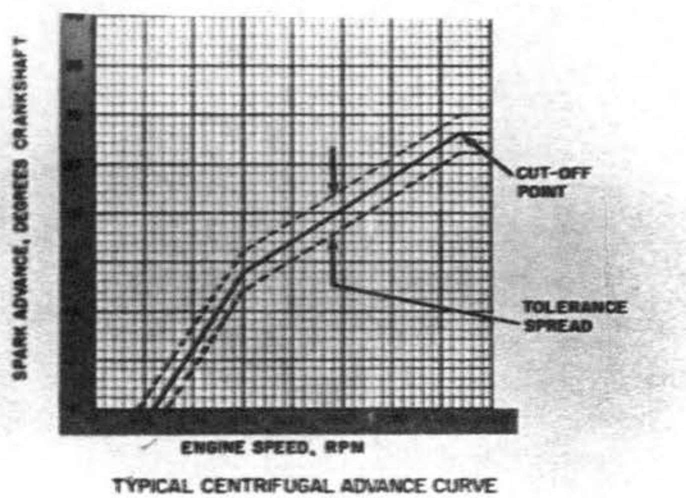

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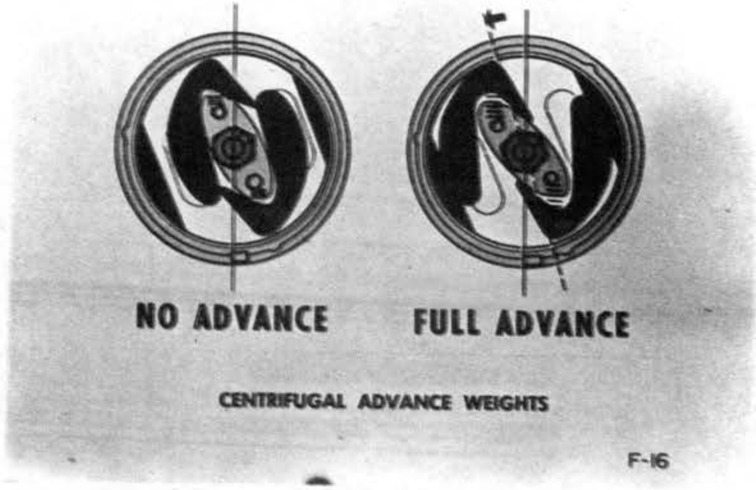

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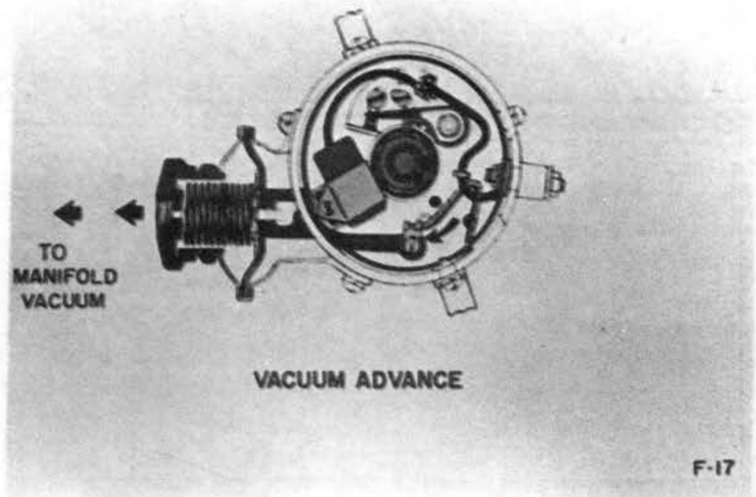

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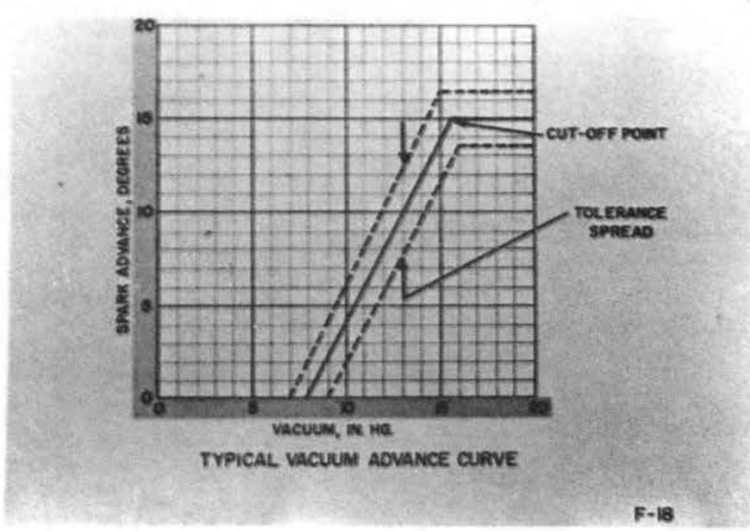

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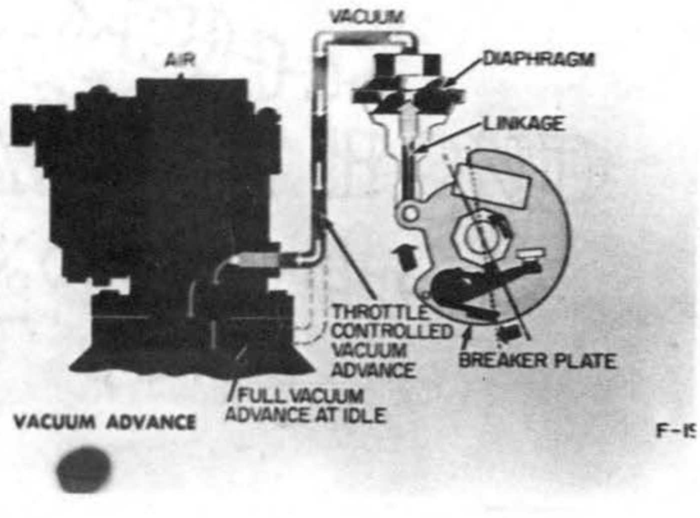

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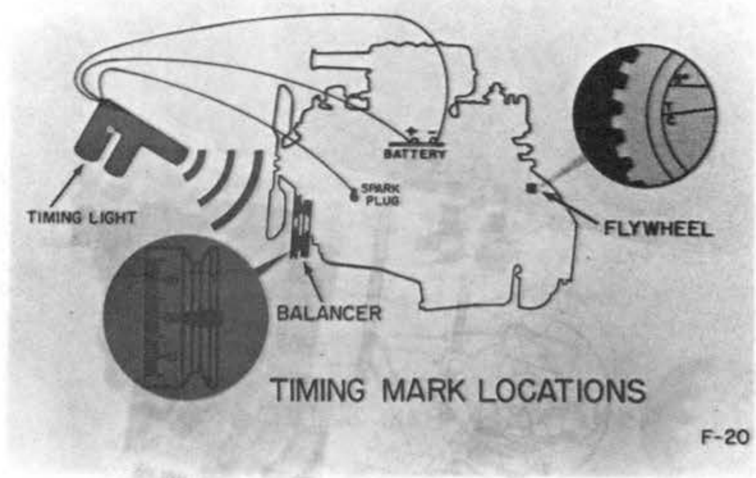

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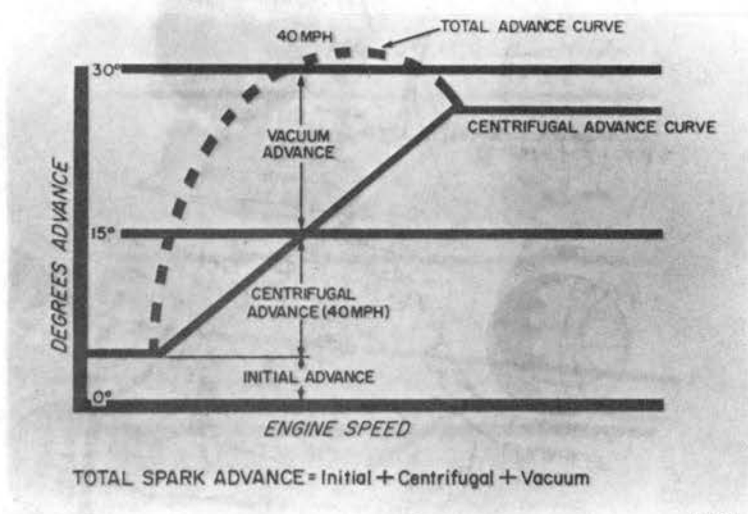

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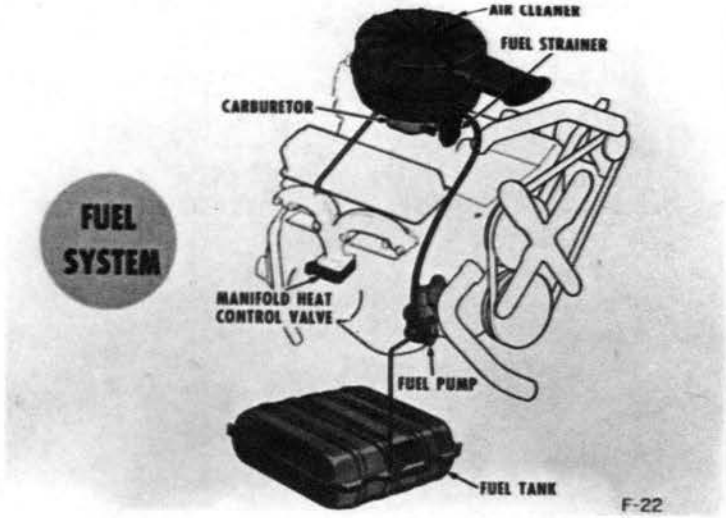

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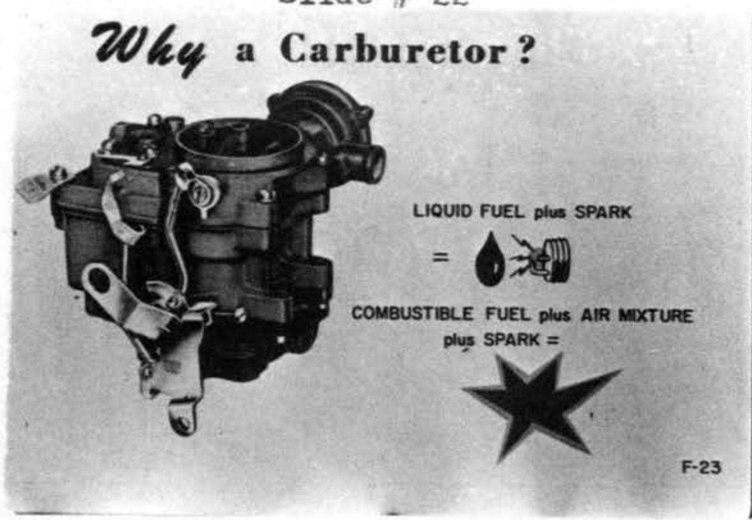

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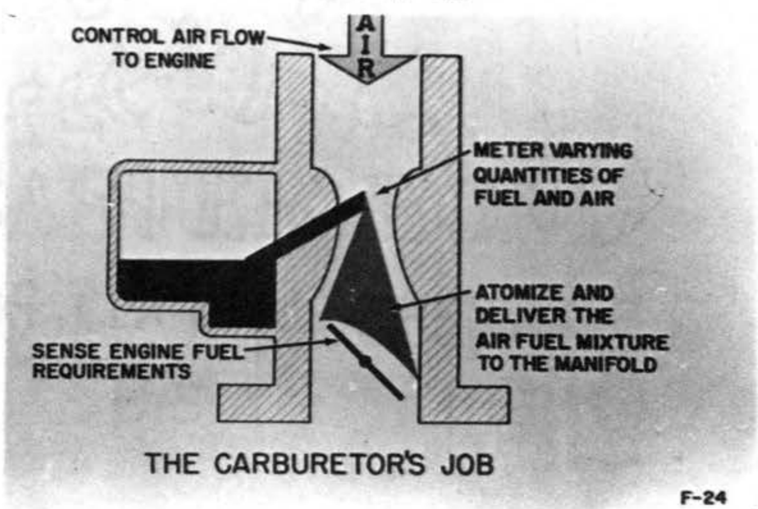

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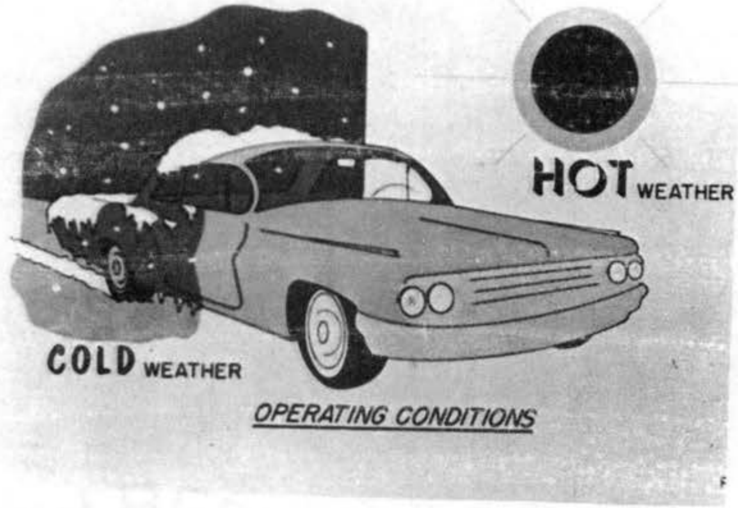

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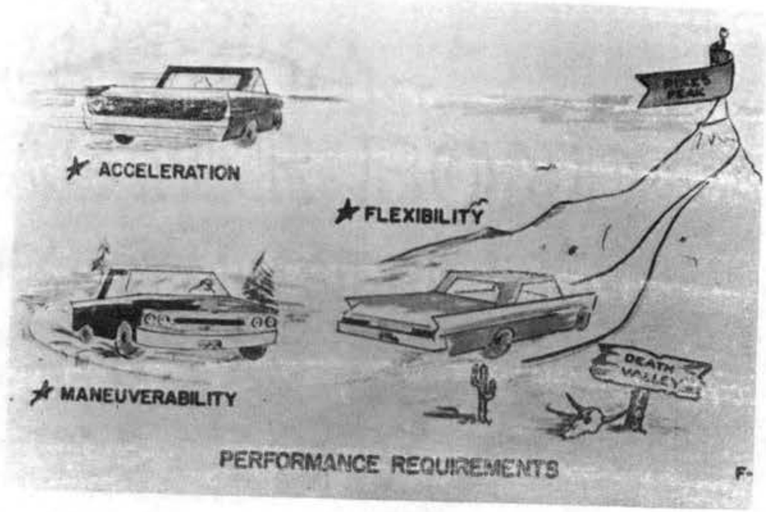

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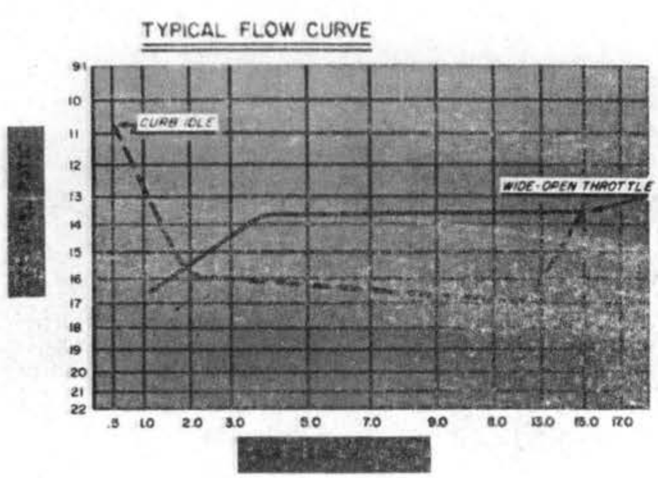

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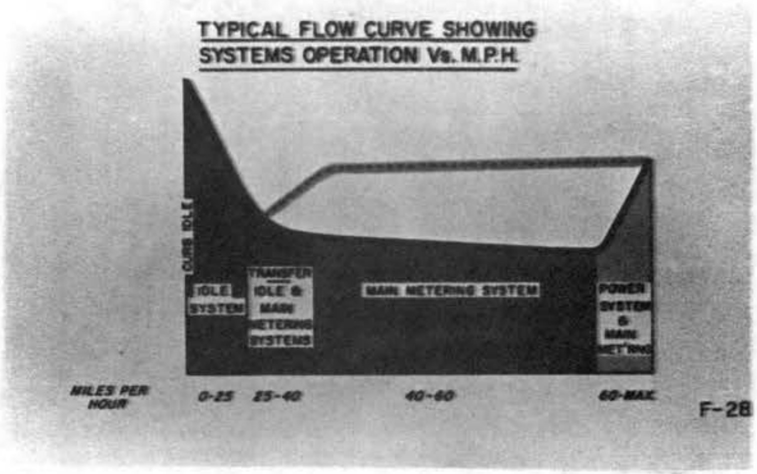

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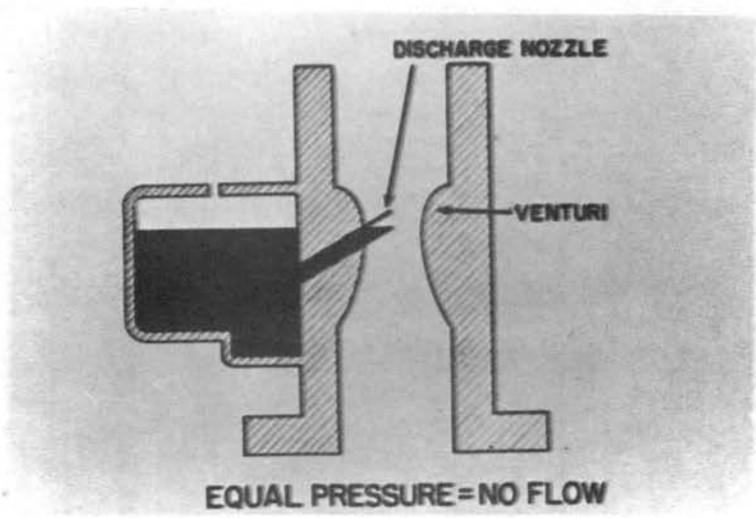

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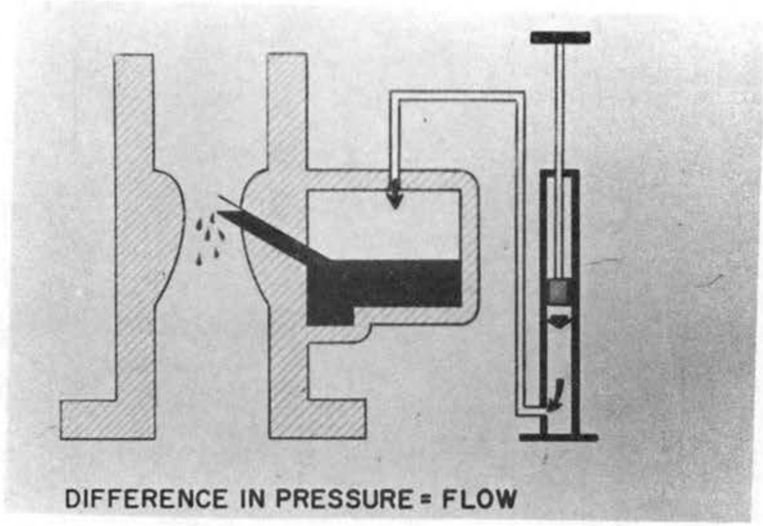

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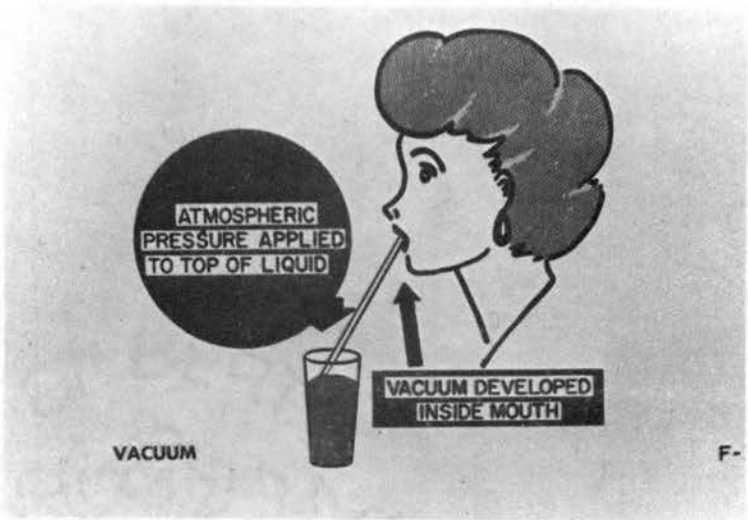

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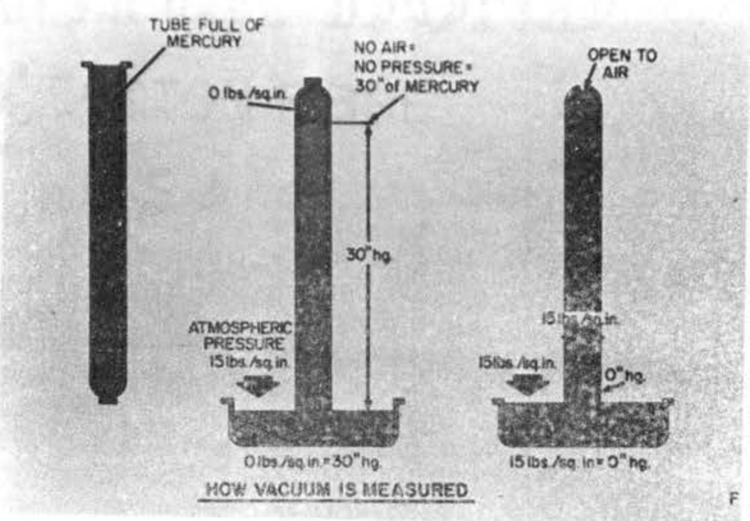

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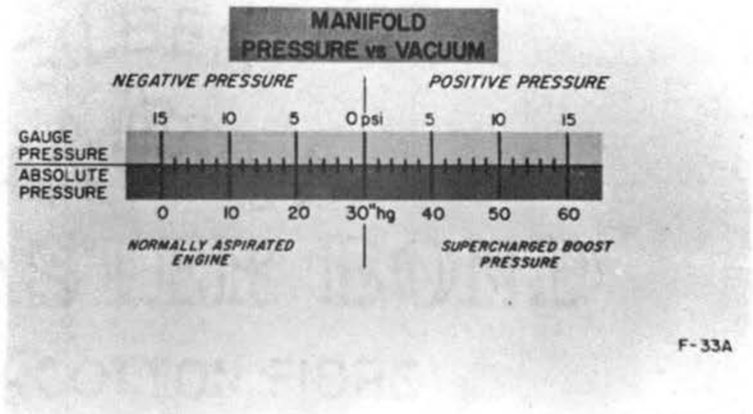

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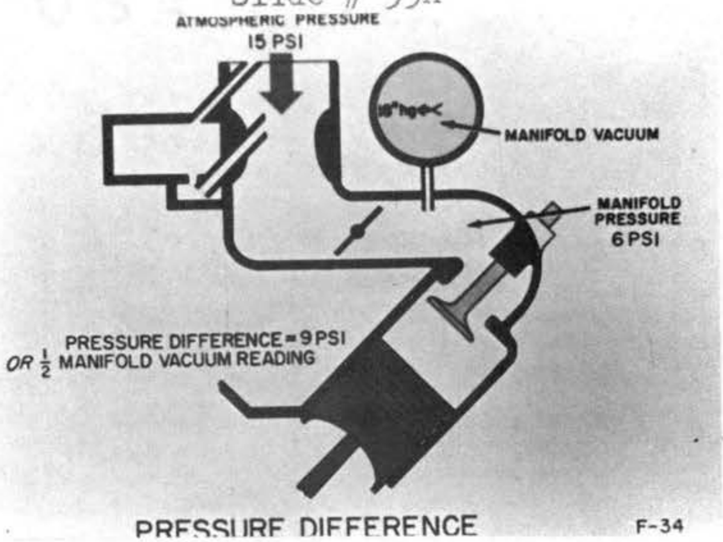

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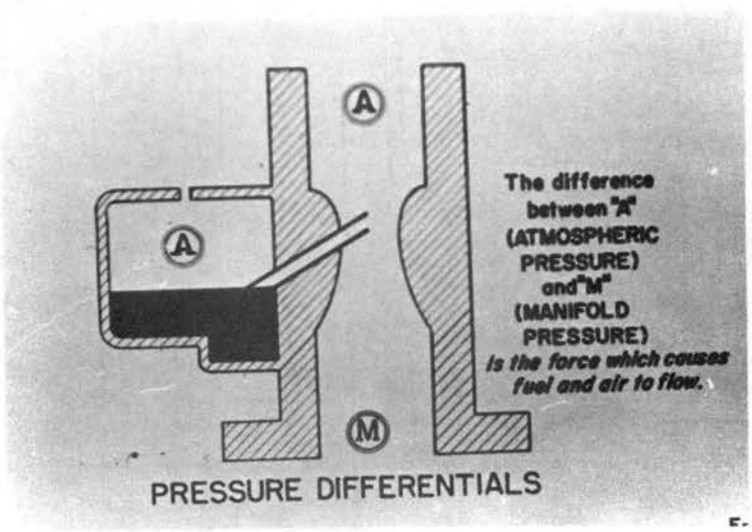

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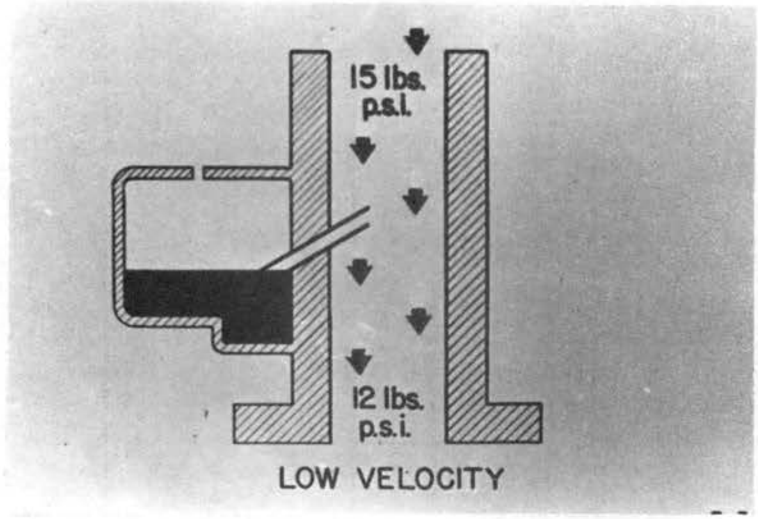

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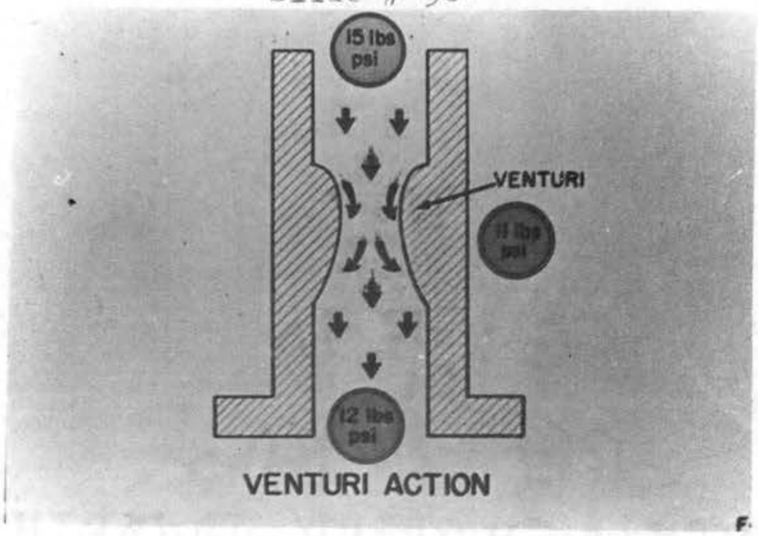

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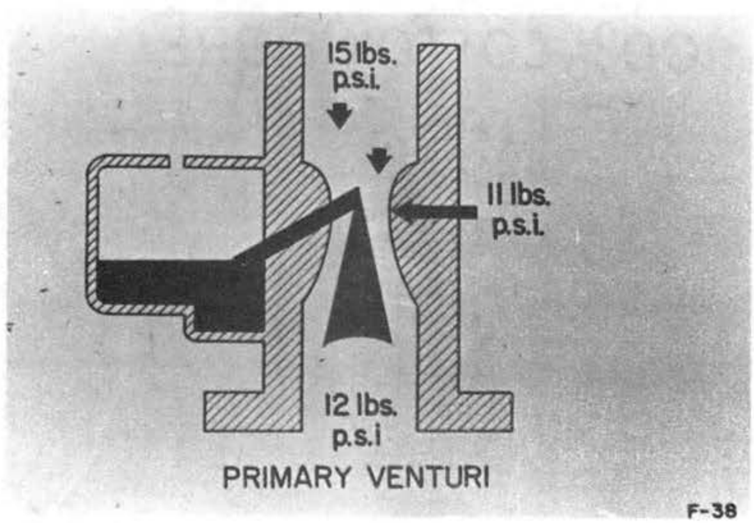

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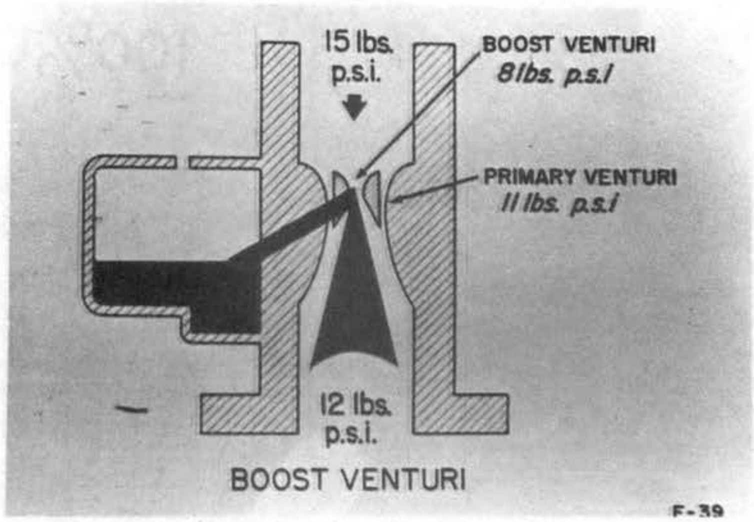

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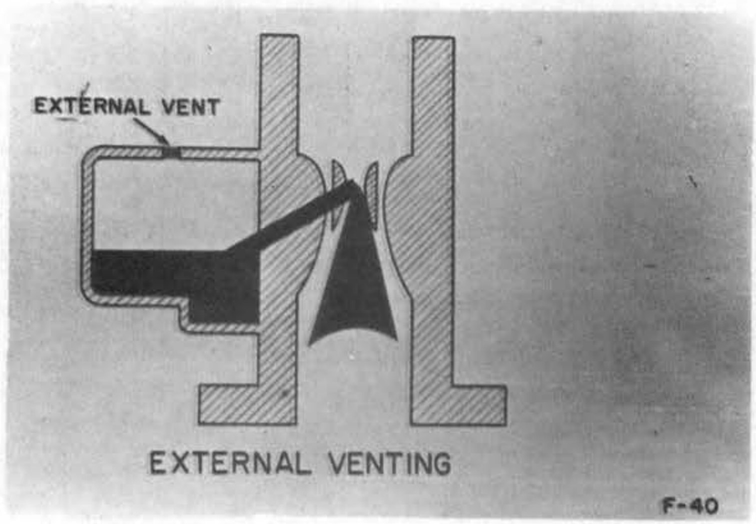

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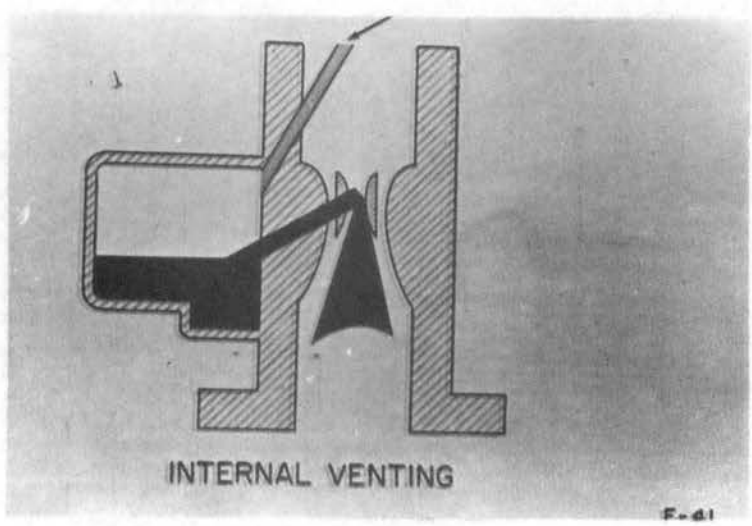

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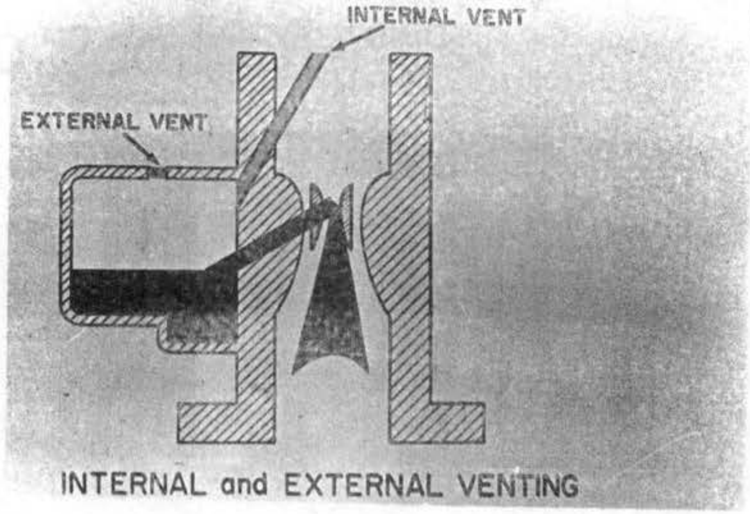

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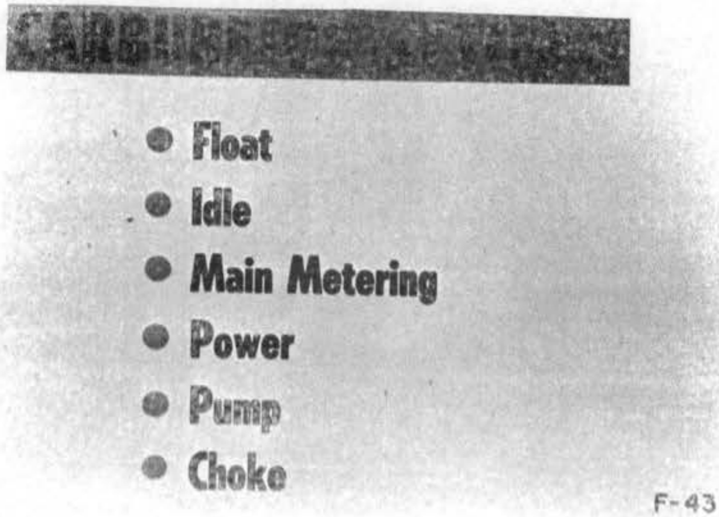

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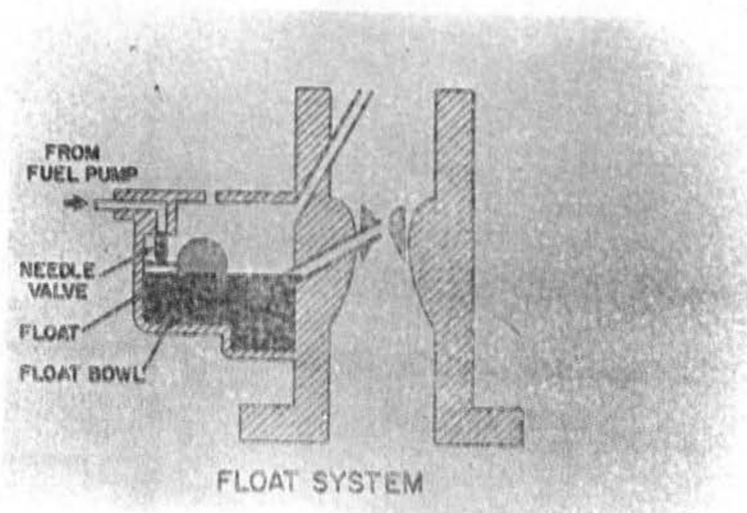

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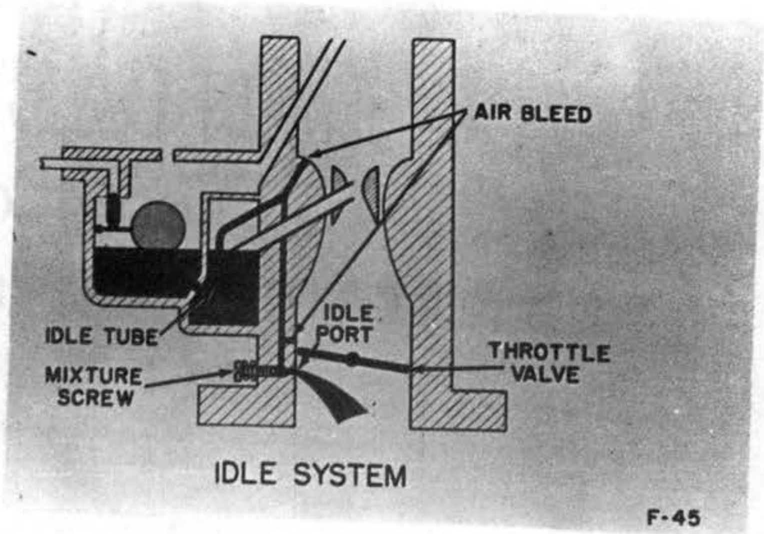

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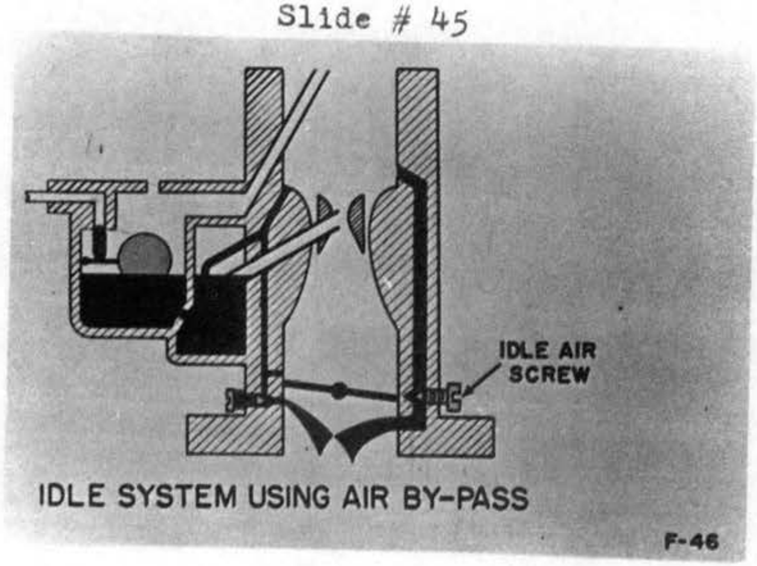

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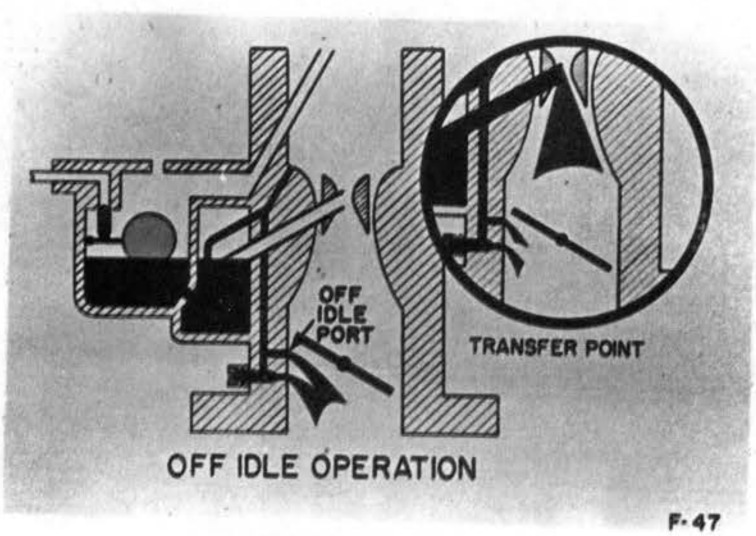

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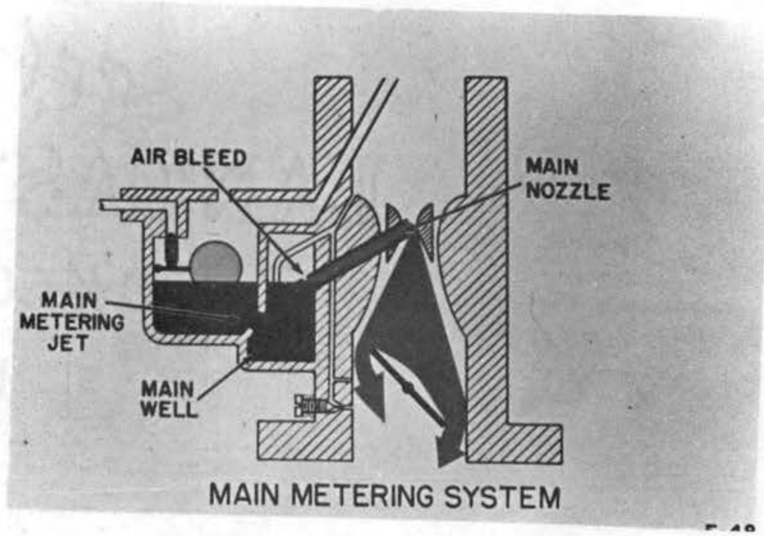

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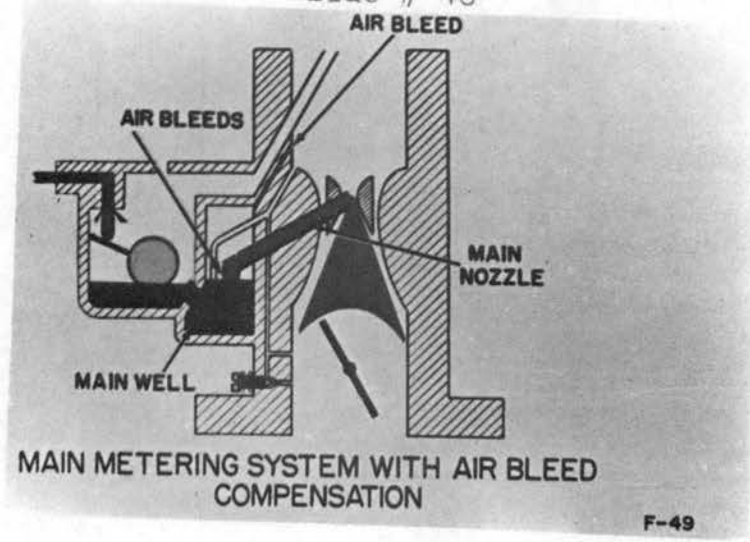

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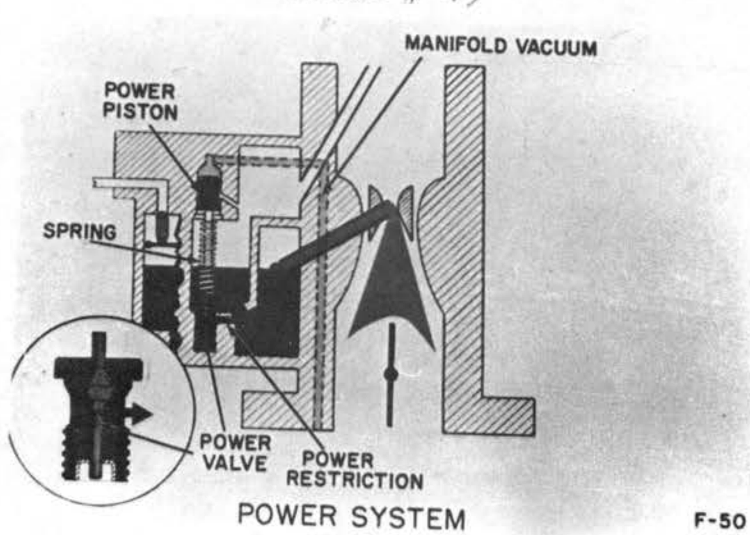

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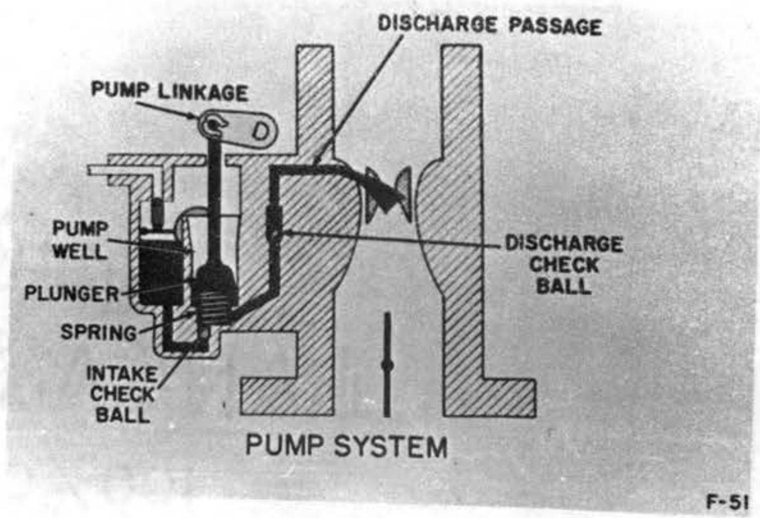

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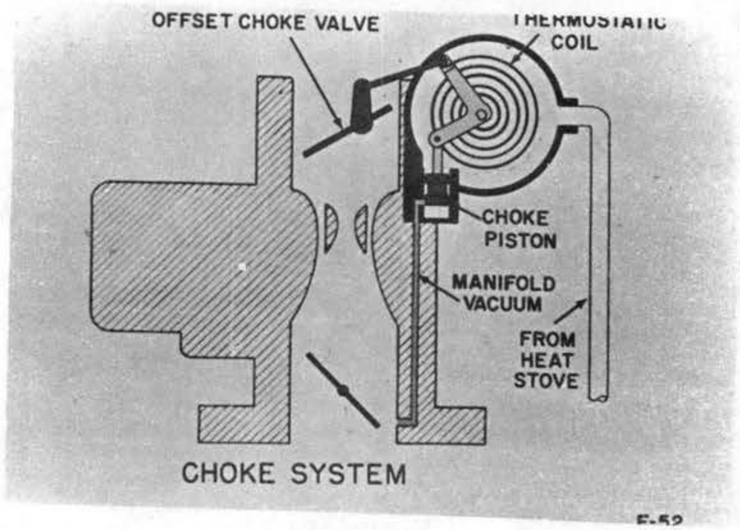

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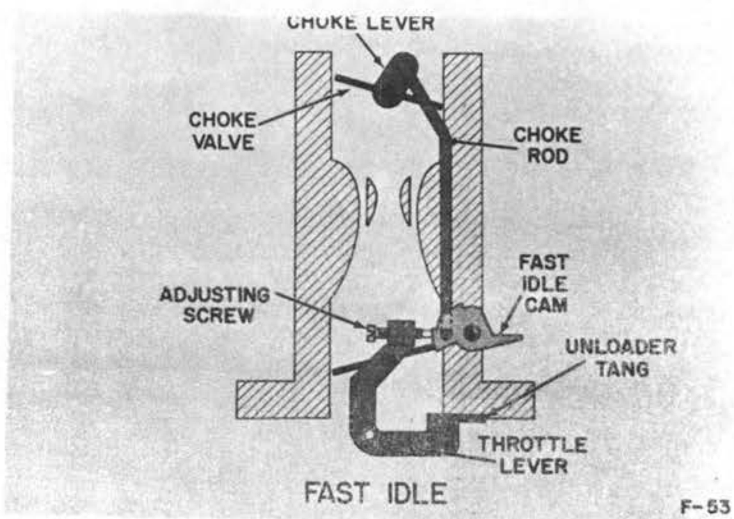

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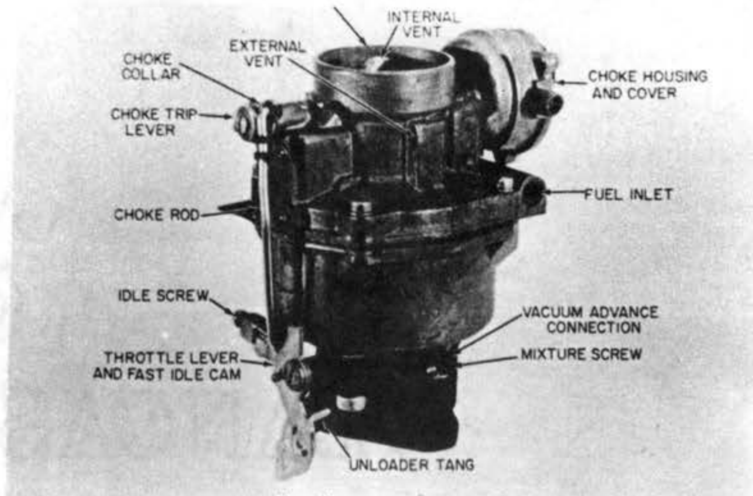
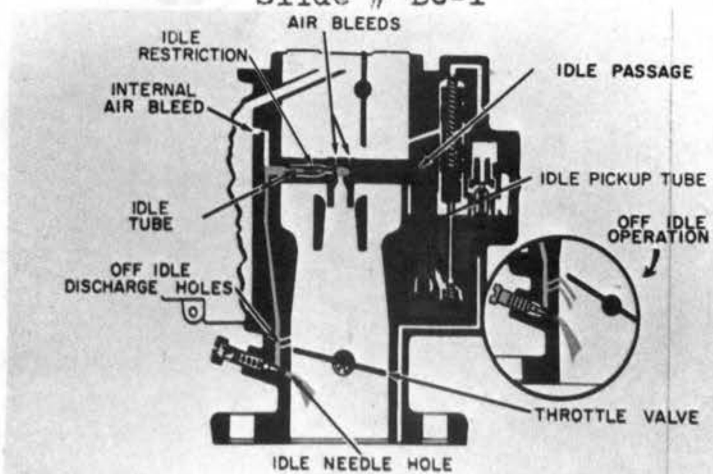


MODEL "BC" CARBURETOR (EARLY)

Slide # BC-1



IDLE SYSTEM

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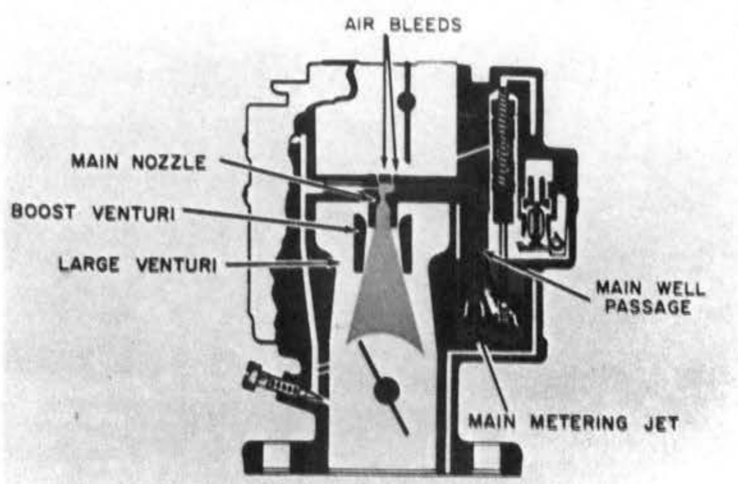
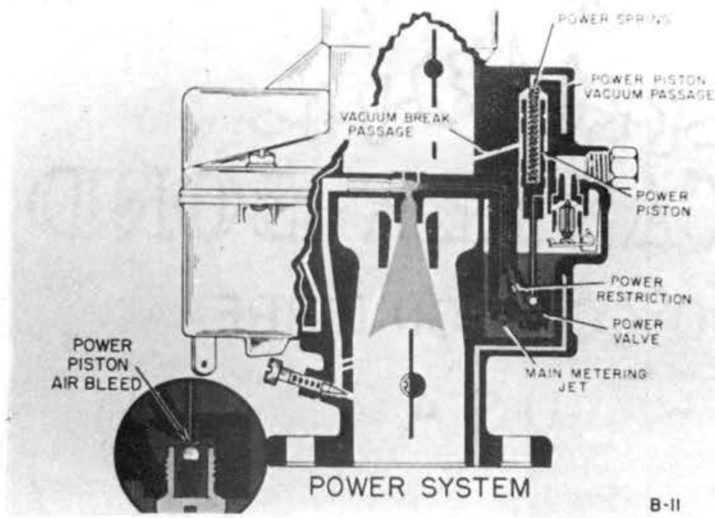


MAIN METERING SYSTEM

B-10

Slide # BC-3



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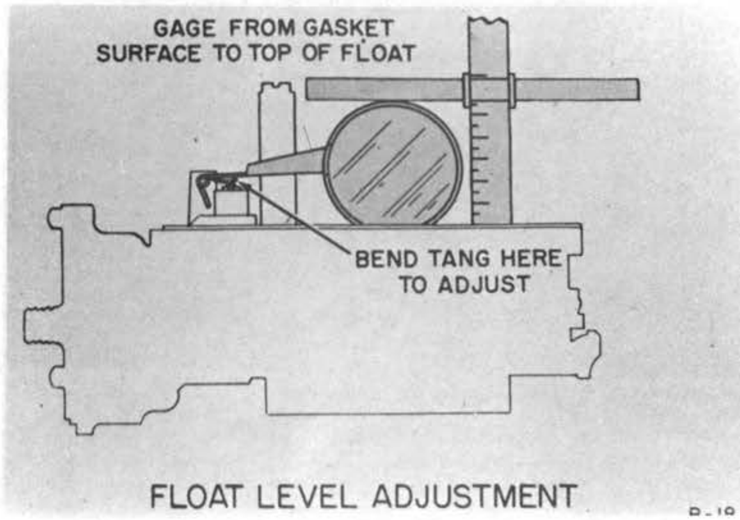

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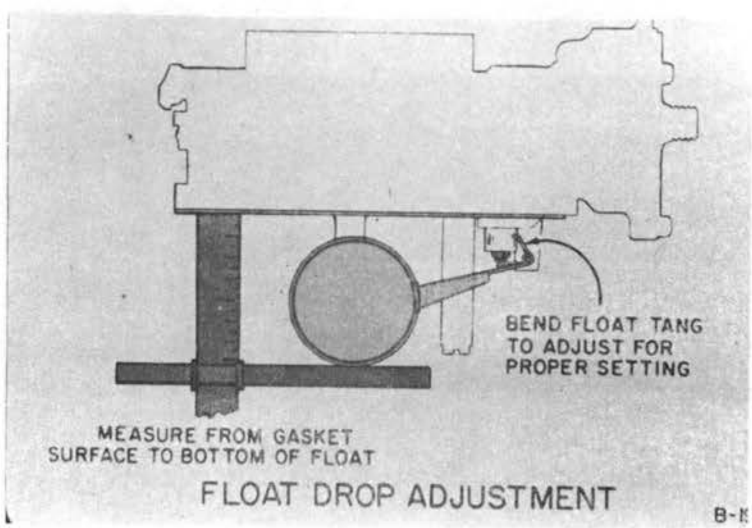

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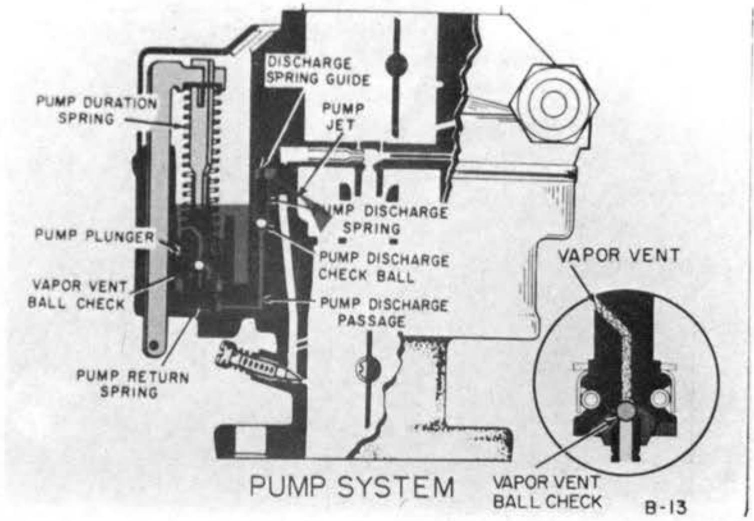

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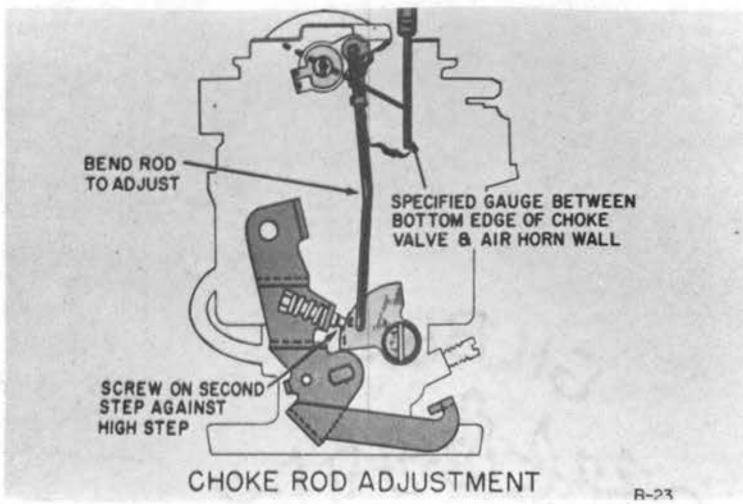

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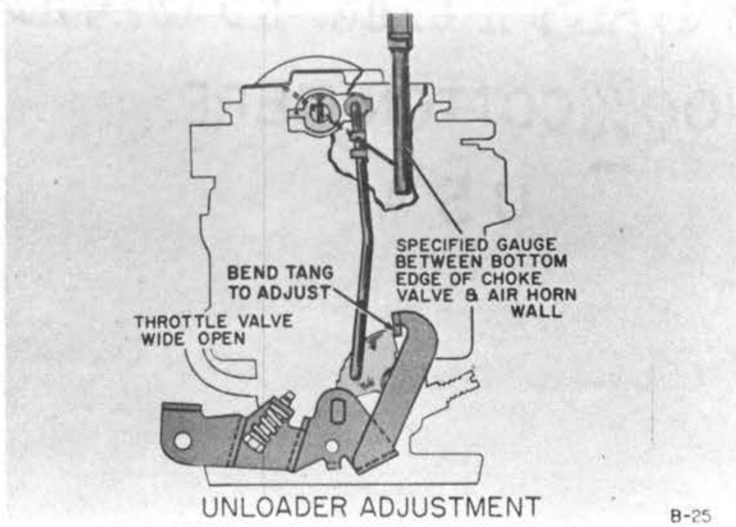


Slide # BC-9

Appendix C

Objective tests

Initial learning test

Transfer of learning test

Initial Learning

Test #1

Fundamentals of Carburetion

Directions: One of the answers listed below each question or incomplete statement is correct. Select the answer you believe to be correct and circle its identifying letter on the answer sheet.

1. The low speed circuit in the downdraft carburetor delivers fuel:
   a. below the throttle valve.
   b. at bottom of venturi.
   c. at top of venturi.
   d. at center of venturi.

2. The high speed circuit in the downdraft carburetor delivers fuel:
   a. below the throttle valve.
   b. above the venturi system.
   c. to the venturi system.
   d. to the accelerating pump circuit.

3. The purpose of the accelerator pump is to:
   a. retain the proper level in the carburetor fuel bowl.
   b. keep the high speed circuit amply supplied.
   c. counteract too much fuel pump pressure.
   d. furnish additional fuel for quick pick-up.

4. The purpose of an air vent in a carburetor is to:
   a. prevent low pressure area.
   b. eliminate fuel locks.
   c. limit the flow of fuel.
   d. increase vacuum capacity.

5. The purpose of a choke circuit in the carburetor is to:
   a. restrict the amount of fuel flowing in all circuits.
   b. increase the air velocity in the venturi.
   c. aid in the warming-up period of an engine.
   d. enrich the fuel mixture when starting an engine.

6. The purpose of the air bleeds in a carburetor is to:
   a. aid in the atomizing of fuel.
   b. create high pressure areas.
   c. prevent low pressure areas.
   d. create atmospheric pressure.

7. The basic function of a carburetor is to:
   a. atomize the fuel by varying the air speeds.
   b. meter the air and fuel in varying percentages.
   c. vaporize the fuel by means of heat.
   d. force air and fuel into engine cylinders.

8. The three methods used to vaporize fuel are:
   a. spray, vacuum, combustion.
   b. vacuum, combustion, compression.
   c. spray, vacuum, heat.
   d. heat, compression, combustion.

9. The fuel mixture in carburetors is enriched at high speeds by the:
   a. accelerator pump.
   b. power jet or metering rod.
   c. change in float levels.
   d. air velocity in the venturi.

10. The accelerating pump in a carburetor is controlled by the:
    a. amount of vacuum in the venturi.
    b. automatic spring tension on the metering rod.
    c. low pressure area in carburetor throat.
    d. throttle linkage or vacuum loss in manifold.

11. Air vents as applied to carburetors must be:
    a. large enough to eliminate a low pressure area.
    b. drilled to a definite size.
    c. small enough to create vacuum.
    d. large enough to allow fuel flow.

12. A venturi is used in a carburetor to:
    a. offer less restriction to the air.
    b. offer more restriction and more velocity.
    c. offer more restriction and less velocity.
    d. balance pressure and velocity.

13. The point of the lowest pressure in the venturi is at the:
    a. smallest point.
    b. largest part.
    c. top end.
    d. lower end.

14. The starting mixture of the engine is semi-automatically controlled by the:
    a. idle adjustment screw.
    b. choke plate.
    c. poppet valve.
    d. idle discharge port.

15. The purpose of the secondary or boost venturi is to:
    a. change the RPM by increasing the air pressure.
    b. increase pressure and decrease velocity.
    c. lower the cut-in speed of the high speed circuit.
    d. raise the cut-in speed of the high speed circuit.

16. A "loaded" float condition in the carburetor will cause:
    a. a lean fuel mixture.
    b. a rich or flooding condition.
    c. needle valve to remain closed.
    d. increased fuel pump pressure.

17. Volatility of a fuel is:
    a. ability of fuel to vaporize.
    b. octane rating of fuel.
    c. volume of fuel used.
    d. pressure of fuel.

18. A lean fuel mixture will cause the engine to:
    a. run normal.
    b. run at high RPM.
    c. overheat.
    d. operate too cold.

19. When air pressure is reduced in a cylinder by the action of the piston the area in the cylinder is known as:
    a. high pressure area or vacuum.
    b. low pressure area or compression.
    c. low pressure area or vacuum.
    d. equalized pressure or balance.

20. A hot spot in the intake manifold is to:
    a. regulate the temperature of the manifold.
    b. aid in the vaporization of fuels by heat.
    c. eliminate heat expansion.
    d. preheat the air entering the carburetor.

21. Crank case dilution is caused by:
    a. a lean mixture.
    b. low compression.
    c. vaporized fuel.
    d. unvaporized fuel.

22. The float circuit maintains the correct level in the fuel bowl and supplies fuel to:
    a. the high speed circuit only.
    b. the low speed circuit only.
    c. all the circuits.
    d. accelerating pump circuit only.

23. The purpose of a choke circuit in the carburetor is to:
    a. restrict the amount of fuel flowing in all circuits.
    b. increase the air velocity in the venturi.
    c. aid in the warming-up period of an engine.
    d. enrich the fuel mixture when starting an engine.

24. The fuel mixture in carburetors is enriched at high speeds by the:
    a. accelerator pump.
    b. change in float levels.
    c. power jet or metering rod.
    d. air velocity in the venturi.

25. Vapor locks in fuel is caused by:
    a. atomization of fuel.
    b. fuel pressure too high.
    c. excessive heat in fuel lines.
    d. failure of fuel pump.

26. Vaporization of fuel:
    a. causes a drop in surrounding area temperature.
    b. has no influence upon temperatures.
    c. generates heat for the surrounding area.

27. Gasoline has a specific gravity of approximately:
    a. 13.6.
    b. 0.7.
    c. 1.3.
    d. 0.2.

28. Atmospheric pressure at sea level of 14.7 P.S.I. will support a column of mercury approximately:
    a. 21 inches high.
    b. 7 inches high.
    c. 29.92 inches high.
    d. 34.14 inches high.

29. As the velocity of air increases through a carburetor venturi the pressure:
    a. increases.
    b. remains the same.
    c. reduces.

30. Breaking up of fuel into small particles of liquid is called:
    a. vaporization.
    b. atomization.
    c. evaporization.
    d. boiling.

31. Heated air:
    a. expands and becomes heavier.
    b. expands and becomes lighter.
    c. contracts and becomes heavier.
    d. does not change.

32. Volumetric efficiency of an engine is increased by:
    a. moisture.
    b. inertia.
    c. heat.
    d. speed.

33. The automatic choke uses manifold vacuum:
    a. to close the choke valve.
    b. toopen the choke valve.
    c. has no control of the choke valve.

34. The thermostatic spring on the automatic choke tends to:
    a. open the choke valve when engine is cold.
    b. close the choke valve when engine is cold.
    c. open the choke valve when engine is hot.

35. The purpose of the unloader on the carburetor is to:
    a. open the choke when the engine floods.
    b. enrich the air/fuel mixture.
    c. increase the idle speed when the engine is cold.

36. When the carburetor is used at high altitudes the air/fuel ratio tends to:
    a. decrease.
    b. stay the same.
    c. increase.

37. Engine torque drops off at high speed because the:
    a. fuel/air ratio gets richer.
    b. fuel/air ratio gets leaner.
    c. engine breathes better.
    d. volumetric efficiency is lower.

38. Lean fuel/air mixtures burn more slowly than rich fuel/air ratios because:
    a. of the lack of oxygen.
    b. the molecules of fuel are farther apart in lean mixtures.
    c. the fuel does not vaporize as easily in lean mixtures.

39. The fuel/air mixture must be completely burned by the time the crankshaft moves from 10 to 18 degrees past top dead center because the:
    a. increase in volume in the cylinder multiplies the increasing pressure.
    b. push on the piston must be a swift hammer like blow.
    c. exhaust valve opens and you lose the pressure.

40. Intake manifold size must be a compromise between:
    a. a large bore allows for high velocity of mixture flow and a small bore allows for low velocity flow.
    b. a large bore size to allow high speed breathing and a small bore size necessary for smooth idle.
    c. a large bore to get ram effect to the mixture flow and a small bore to reduce this effort.

41. A mercury manometer will register 30 inches high when the:
    a. atmospheric pressure is 14.7 P.S.I.
    b. gauge pressure reads 0 P.S.I.
    c. absolute pressure reads 0 P.S.I.

42. Internal venting when used alone will almost completely compensate for air cleaner restriction. One main disadvantage to internal venting is:
    a. the possibility of causing a rough idling engine at low speed.
    b. the possibility of reducing the top output speed of the engine.
    c. the possibility of causing rich mixtures when the air cleaner is dirty.

43. In addition to allowing air to mix with the fuel the purpose of the idle air bleeds at the top end of the idle circuit is to:
    a. control the maximum amount of fuel passing through the idle system.
    b. enrich the idle mixture.
    c. prevent siphoning of fuel from the bowl when the engine is stopped.

44. If the float level is high the following systems will be affected by:
    a. rich high speed and low speed.
    b. lean high speed, accelerator pump and idle speed.
    c. lean idle and high speed.

45. If the power piston spring were stretched longer the power valve would open:
    a. at a higher engine load.
    b. at a lower engine load.
    c. at the same load as before.

46. The centrifugal weights advance mechanism varies the spark according to:
    a. engine load.
    b. spark knock.
    c. engine speed.

47. Ignition advance should be varied with engine load:
    a. inversely.
    b. directly.

48. To time an engine accurately, the distributor should be set so that the ignition spark occurs when the piston is near the:
    a. top of the exhaust stroke.
    b. bottom of the intake stroke.
    c. top of the compression stroke.
    d. bottom of the power stroke.

49. The spark is automatically advanced as the speed of the engine increases by the:
    a. centrifugal advance governor.
    b. manual spark control.
    c. breaker point spring tension.
    d. vacuum.

50. The purpose of the ignition contact points in the distributor is to:
    a. complete and interrupt the primary circuit.
    b. complete the secondary circuit.
    c. take the place of the ignition switch.

TRANSFER OF LEARNING - TEST - 2

Directions: One of the answers listed below each question or incomplete statement is the most correct answer. Select the answer you believe to be most correct and circle its identifying letter on the answer sheet. Be sure to use the correct figure or diagram indicated in the questions.

1. An engines maximum power and speed have a limit because:
    A. of lack of time to fill the cylinder.
    B. the air/fuel ratio gets too rich.
    C. the air/fuel ratio gets too lean.
    D. ignition of the air/fuel ratio mixture is slower.

2. A necessary change in automotive carburetors which are used at high altitudes continuously is to:
    A. reduce the size of the main speed jet in the carburetor.
    B. increase the size of the main speed jet.
    C. increase the idle mixture amount.
    D. lower the float setting.

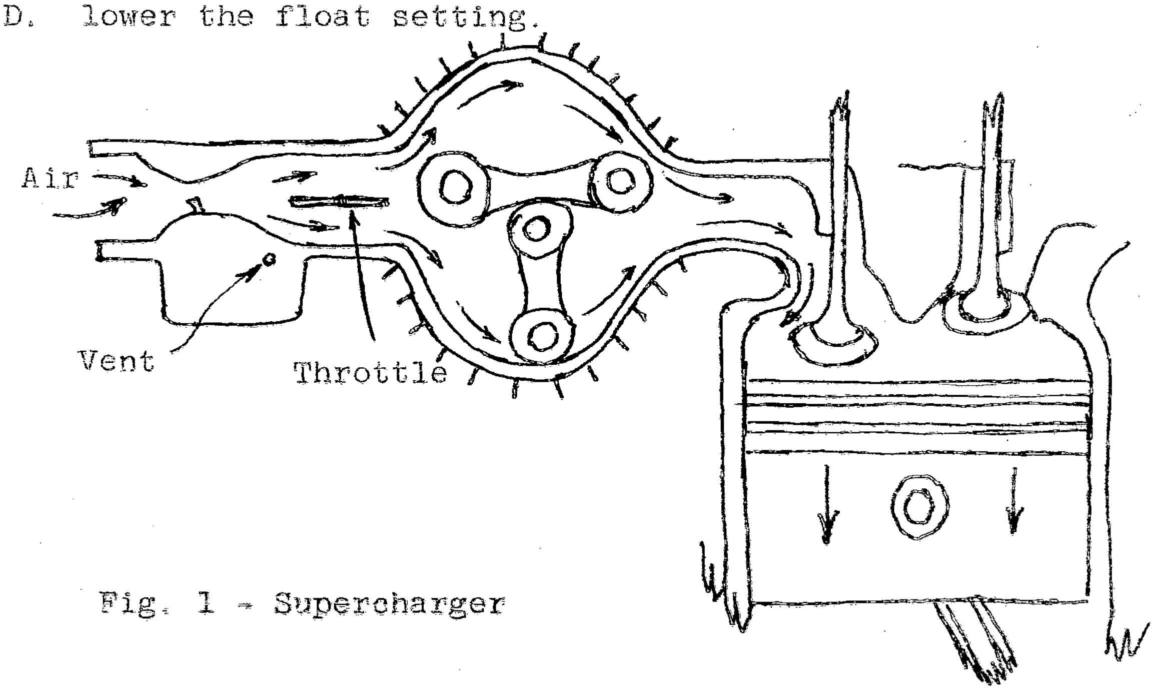


Fig. 1 - Supercharger

3. The supercharger in fig. 1 used on an engine will increase the amount of air/fuel mixture in the cylinders because of the following principle:
    A. as velocity of gases increase friction reduces.
    B. the increased pressure caused by the blower moves the mixtures faster.
    C. the pressure difference is greater between atmospheric and inside the cylinder.
    D. none of the above answers are correct.

4. If the supercharger in fig. 1 were placed in front of the carburetor instead of where it is, the effect would be:

A. leaner mixtures.
B. no change in mixtures.
C. richer mixtures.
D. none of the above answers.

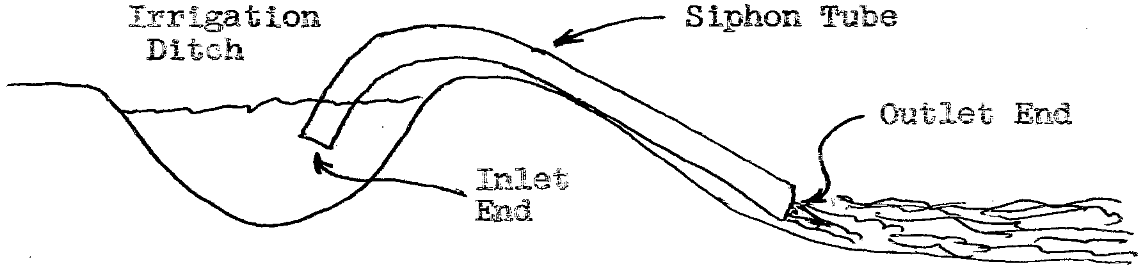


Fig. 2 - A siphon in operation

5. How do we get the water in Fig. 2 started to run in the hose?
   A. It will start by itself.
   B. It creates a vacuum at the outlet end of the siphon.
   C. It creates a vacuum at the inlet end of the siphon.
   D. It creates a pressure on the outlet end of the siphon.

6. The water will continue to run through the siphon tube once it has started because:
   A. of gravity.
   B. friction inside the tube becomes less.
   C. water moving out of the tube continually creates a vacuum.
   D. of the weight of the water compared to the weight of air.

7. On a high performance four-stroke internal combustion engine, the intake and exhaust strokes will require almost 600 degrees of crankshaft rotation out of the 720 degrees because:
   A. as air velocity increases friction is reduced.
   B. friction causes air/fuel mixtures and exhaust gases to slow down.
   C. of exhaust back pressures.
   D. the intake gases lack inertia.

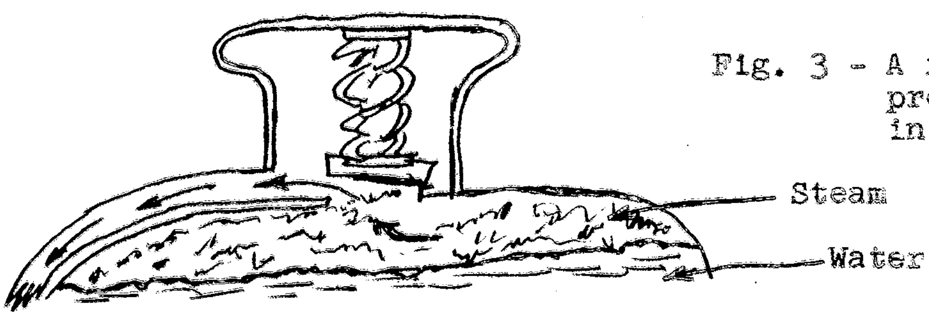


Fig. 3 - A radiator pressure cap in operation.

8. Water (boils) changes from a liquid to a gas at 212 degrees fahrenheit (at sea level). With a pressure cap as shown in Fig. 3, the boiling point can be raised. This principle could be applied in the fuel system to prevent:
   A. fuel surging.
   B. vapor lock.
   C. atomization of fuel.
   D. oxidation of fuel.

9. If boiling points can be increased by pressurizing as shown in Fig. 3, then boiling points can be reduced by lowering pressures. This principle is used to an advantage in the:
   A. venturi of the carburetor.
   B. float bowl.
   C. accelerator pump well.
   D. fuel pump outlet side.

10. The principle stated in (question 10) that boiling points can be lowered by lowering pressure, will also operate to a disadvantage in the fuel system and is the reason for:
    A. percolation.
    B. vapor locks.
    C. pressurized areas.
    D. rich mixtures.

11. If an automatic choke over-chokes the engine whether it is cold or warm and there is <u>no</u> evidence of a binding choke shaft or that the choke setting is too rich, a possible cause is:
    A. the heat tube is blocked.
    B. the unloader linkage is too long.
    C. the choke piston is gummed up or filled with carbon.
    D. none of the above answers are correct

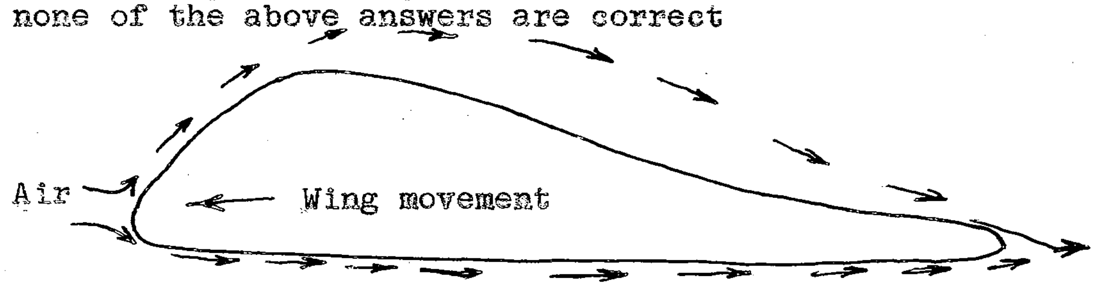


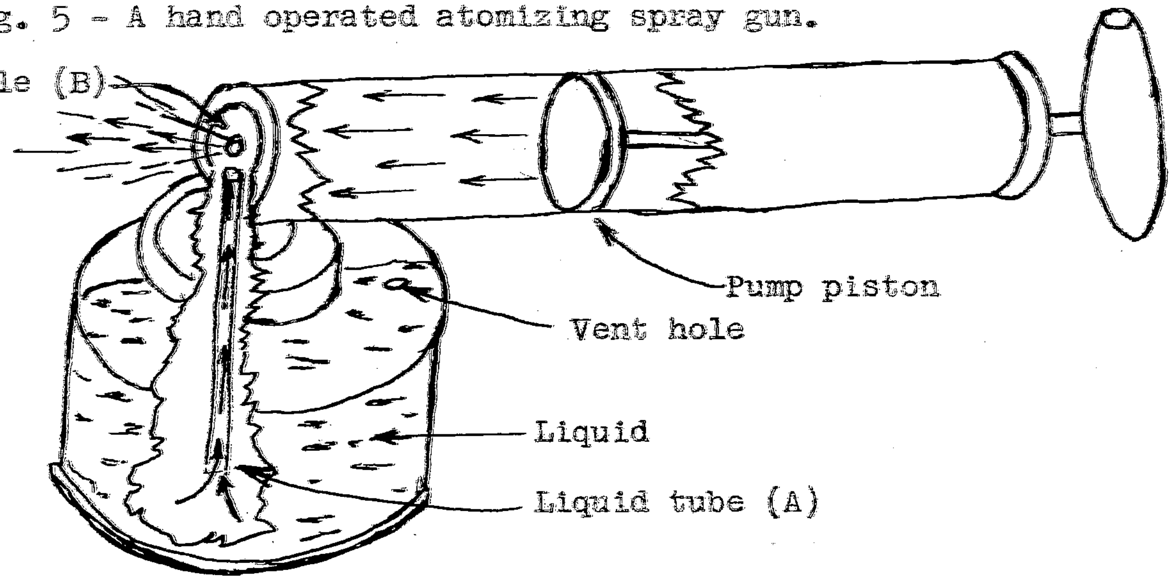
Fig. 4 - Cross section view of an airplane wing.

12. <u>Why an airplane flies.</u> If the airplane wing in Fig. 4 is moving through the air very fast, a comparison of the relative pressures on the top and on the bottom of the wing would be:
    A. low pressure on top and high pressure on the bottom.
    B. high pressure on top and low pressure on the bottom.
    C. no pressure difference between top and bottom.

13. In Fig. 4, what effect would roughness on the wing surface have on the air flow around the wing?
    A. There would be an increase in the speed of air over the wing surfaces.
    B. There would be no effect.
    C. The lifting ability would be reduced due to turbulence.
    D. There would be an increase in pressure difference between the two sides.

14. If the initial ignition timing is advanced, the distributor body is always turned:
    A. with rotation of the breaker cam.
    B. opposite rotation of the breaker cam.
    C. clockwise.
    D. counter-clockwise.

Fig. 5 - A hand operated atomizing spray gun.



15. In Fig. 5 the liquid moves up the tube (A) and out the top because:
   A. the pump piston compresses the air in the can which forces the liquid up the tube.
   B. a vacuum is created at the upper end of the liquid tube and atmospheric pressure forces the liquid up.
   C. the high velocity air coming out of the air hole creates a pressure in the liquid tube.
   D. the pump piston creates a vacuum within the can.

16. If the air hole (B) in the pump part of Fig. 5 were made larger, the effect on the sprayer would be to:
   A. make a finer mist of the liquid particles.
   B. increase the vacuum in the liquid tube which would cause more liquid to flow.
   C. reduce the pressure difference which would allow less liquid to flow.
   D. have no effect.

<u>Note</u>: The function or action of parts in the hand sprayer in Fig. 5 can be related to certain similar functions or action of parts in the carburetor. In questions 16, 17, and 18 select the one best relationship in each question.

		<u>Hand sprayer</u>	<u>Carburetor</u>
17.	A.	Liquid tube (A) ----------------	High speed nozzle
	B.	Air hole (B) ------------------	Main jet
	C.	Vent hole in the can ----------	Main jet
18.	A.	Hand pump stroke --------------	Accelerator pump stroke
	B.	Vacuum at air hole (B) --------	Intake manifold vacuum
	C.	Velocity at air hole (B) ------	Velocity at small part of venturi.
19.	A.	Air hole size (B) -------------	Main jet size
	B.	Spray from air hole (B) -------	Fuel/air mixture entering engine.
	C.	Vent hole in spray can --------	Idle air bleeds

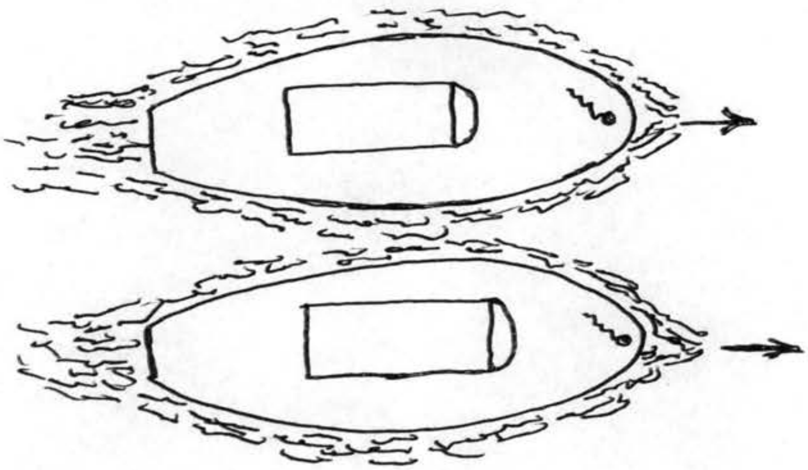


Fig. 6 - Two speed boats running at the same speed very close together.

20. How will the speed boats in Fig. 6 affect each other?
    A. They will have no significant effect on each other.
    B. They would have a tendency to collide because of lessened pressure between them.
    C. They would have a tendency to move away from each other because of increased pressure between them.
    D. They would tend to hold their course with greater steering ease.

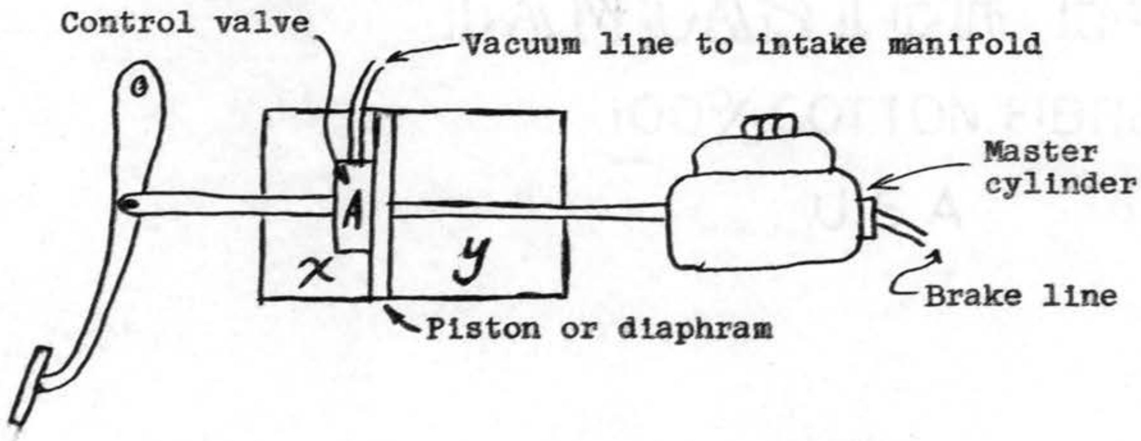


Fig. 7 - Schematic view of a power brake. The control valve can apply either vacuum or atmospheric pressure to (y) side.

21. The power brake unit in Fig. 7 has 12 inches of vacuum on (y) side and atmospheric pressure on side (X). What is the approximate pressure differential between the two sides at sea level?
    A. 5.7 pounds per square inch.
    B. 7.0 pounds per square inch.
    C. 8.7 pounds per square inch.
    D. 6.3 pounds per square inch.

22. In the power brake unit in Fig. 7, if the area of the diaphram is 20 square inches, how much would it assist in pushing the brake down? (Use the same pressure differential as in problem 21).
    A. 174 pounds of force.
    B. 138 pounds of force.
    C. 72 pounds of force.
    D. 114 pounds of force.

23. The following groups of carburetor troubles which are most likely to cause carburetor flooding are when the:
    A. choke is set too rich and the power piston is too weak.
    B. float is set too high and fuel pump pressure is too high.
    C. choke piston is gummed up and the float setting too low.
    D. needle and seat are damaged and accelerator pump outlet valve is blocked open.

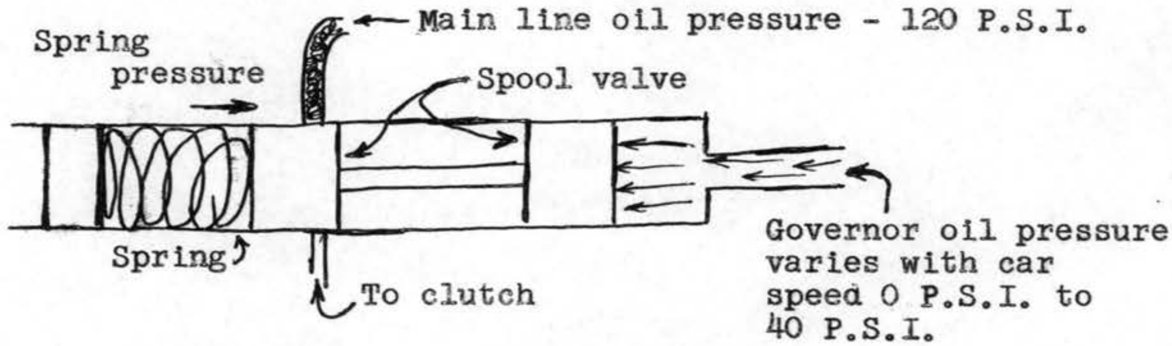


Fig. 8 - This is a spool valve in an automatic transmission. When the governor oil pressure gets high enough in pounds per square inch, it will overcome the spring pressure pushing the spool valve to the right. The spool valve will move, compressing the spring and opening the main line oil pressure to the clutch.

24. If the end of the spool valve open to governor pressure is one-half square inches in area, how high will the governor pressure be required to go if the spring pushes with 10 pounds of force against the other end?
    A. 5 pounds per square inch.
    B. 20 pounds per square inch.
    C. 10 pounds per square inch.
    D. 15 pounds per square inch.

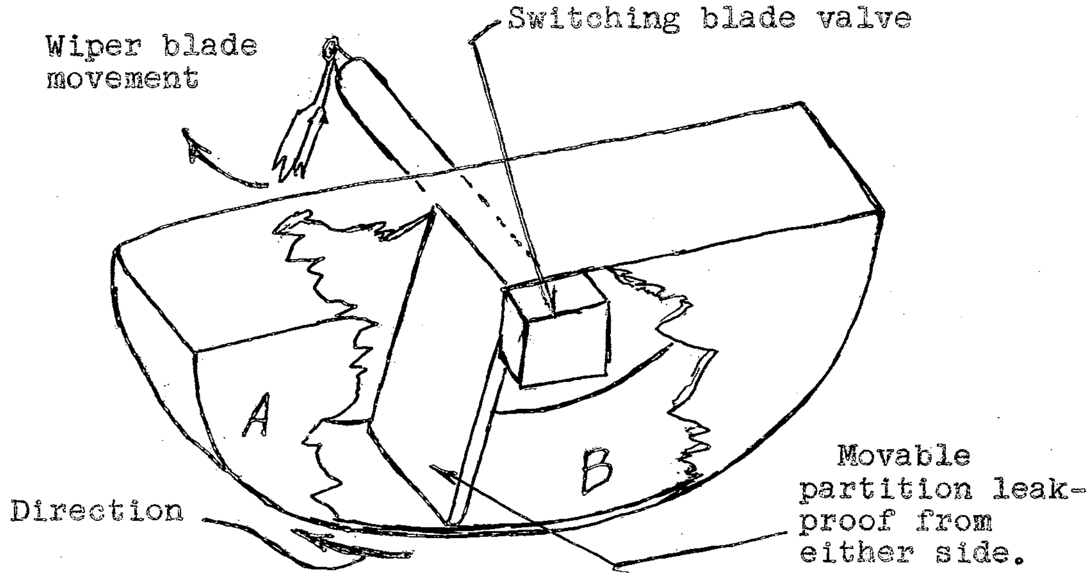


Fig. 9 - Vacuum operated windshield wiper motor.

25. In this windshield wiper shown in Fig. 9, the intake manifold vacuum is on the:
    A. (A) side
    B. (B) side
    C. neither side
    D. both sides

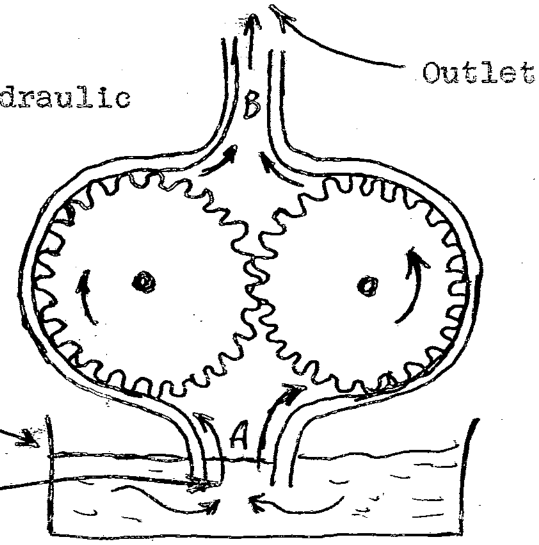
26. If the wiper in Fig. 9 were on an automobile being operated at sea level, side (B) would have approximately:
    A. 13 pounds per square inch of air pressure.
    B. 14.7 pounds per square inch of air pressure.
    C. 9 pounds per square inch of air pressure.
    D. 18 pounds per square inch of air pressure.

27. If the carburetor float were dented in on the side or end, the effect would be to:
    A. enrich the high speed air/fuel ratio.
    B. lean out the high speed air/fuel ratio.
    C. to have no effect on the air/fuel ratio.
    D. cause the float to float higher in the liquid.

28. If the power piston spring on the carburetor was accidently stretched longer, the power valve would:
    A. open with less accelerator pedal depression.
    B. open with more accelerator pedal depression.
    C. have no effect.
    D. never open at any speed.

29. The fuel/air ratio mixture must be completely burned by the time the crankshaft moves 10 to 18 degrees past top dead center because the:
    A. push on the piston must be a swift hammerlike blow.
    B. exhaust valve opens and the cylinder pressure is lost.
    C. increase in volume in the cylinder, nullifies the increasing pressure.
    D. gasoline engine is a constant pressure engine.

Fig. 10 - Gear type hydraulic pump.



30. The gear pump in Fig. 10 has a larger inlet opening (A) than the outlet opening (B) because the:
   A. pressure differential available at point (A) is greater than at (B).
   B. gallons per minute needs are more at (A) than at (B).
   C. pressure difference available at point (A) is less than at point (B).
   D. friction at (B) is less than at (A).

31. The pressure could be increased in the outlet lines on the gear pump in Fig. 10 by:
   A. speeding up the pump.
   B. restricting the outlet line.
   C. pressurizing the tank above atmospheric.
   D. increasing the size of the outlet line.

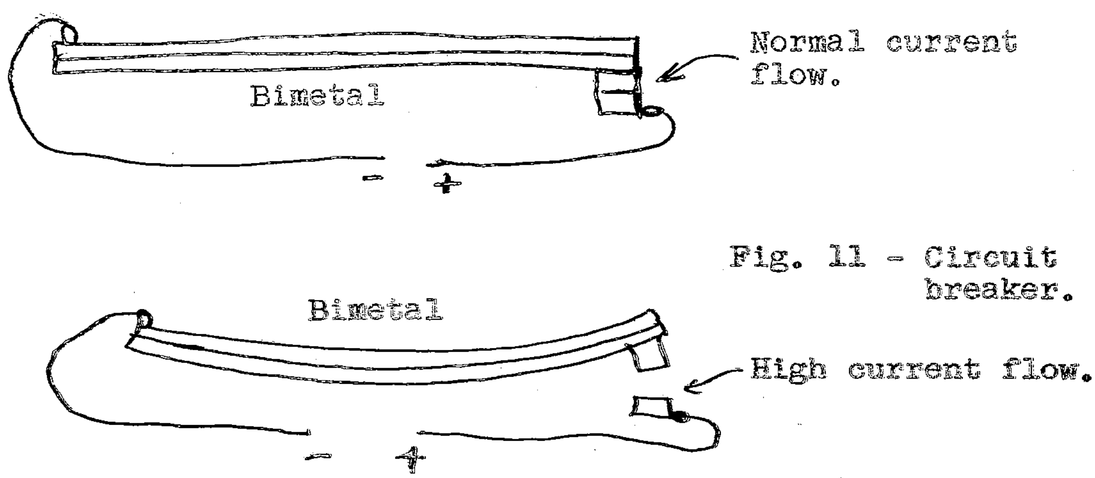


Fig. 11 - Circuit breaker.

32. The side of the circuit breaker in Fig. 11 which has the high expansion metal is:
   A. neither side.
   B. the bottom side.
   C. the top side.
   D. both sides.

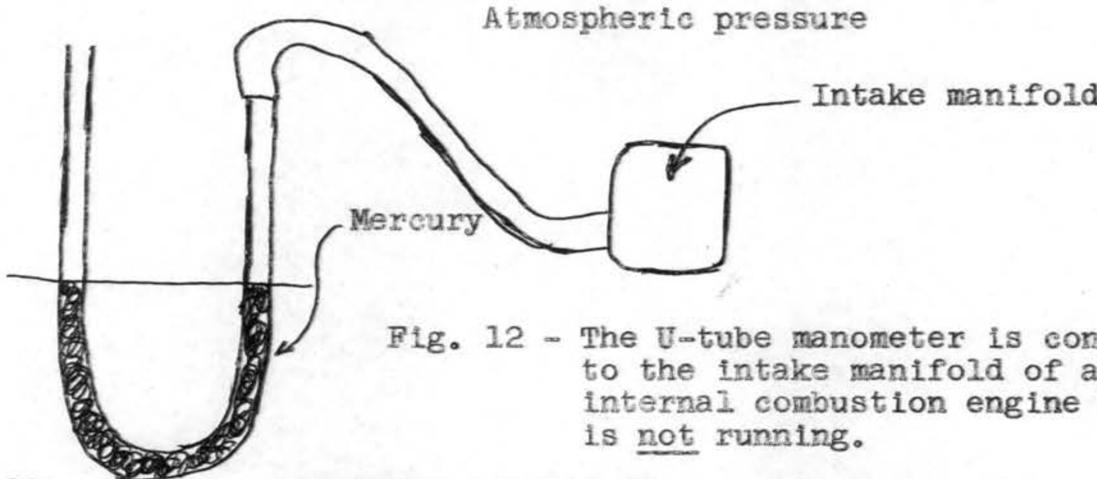
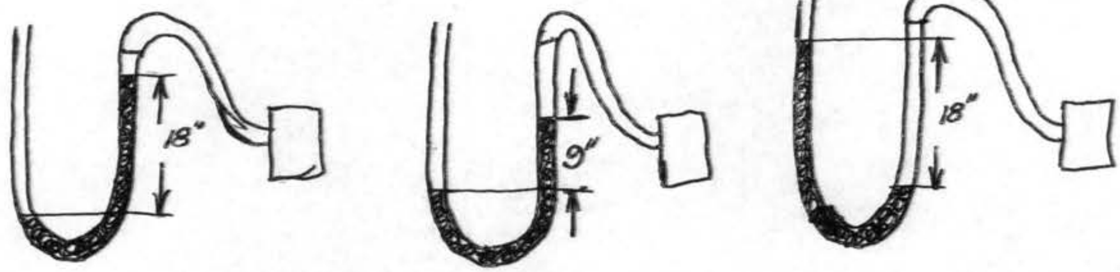


Fig. 12 - The U-tube manometer is connected to the intake manifold of an internal combustion engine which is not running.

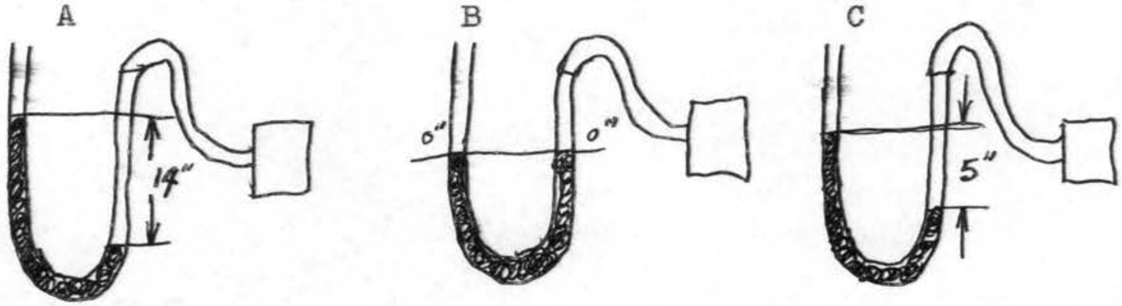
33. If the engine were idling, the mercury in the U-tube would be approximately like:

A B C



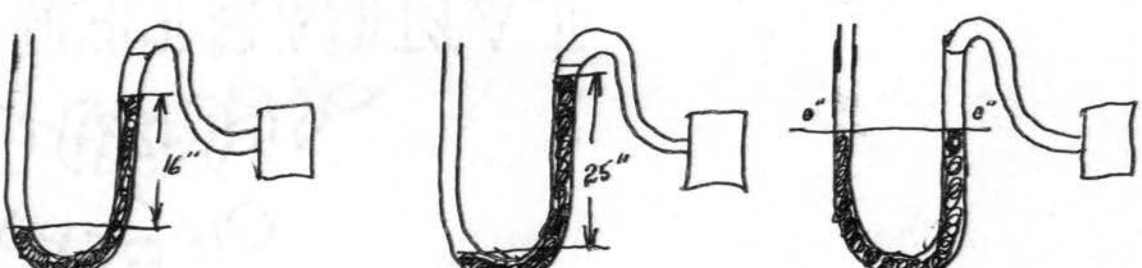
34. If the engine were running with open throttle under full load, the U-tube manometer would be approximately like:

A B C



35. If the engine is in good condition and it is operating with a fully open throttle, what will the U-tube manometer look like just after the operator suddenly closes the throttle?

A B C



36. If ignition timing is advanced too far for the type of fuel (octane rating) used in an engine, uncontrolled burning takes place in the combustion chamber. The two most characteristic effects of this uncontrolled burning are:
    A. high temperatures and an increase in push on the crankshaft throw.
    B. high pressures and temperatures and a decrease in torque on the crankshaft throw.
    C. high temperatures and pressures and high power output.
    D. none of the effects above.

37. If fuel burns in the combustion chamber too slowly, it will cause:
    A. detonation and bearing failures.
    B. high heat and pressure.
    C. the pressure on the piston to be lost because the volume above the piston increases as the piston moves down.
    D. decreased engine temperature and a loss in power.

38. If the diameter of the piston is 4 inches and the maximum pressure in the cylinder is 600 pounds per square inch, what is the total force on top of the piston? (Area of a circle = $.7854\ D^2$ or πR^2)
    A. 3460 pounds.
    B. 8220 pounds.
    C. 7540 pounds.
    D. 5152 pounds.

39. An idling engine requires a rich mixture of fuel and air because:
    A. the rich mixtures burn faster and give a quicker push on the piston to keep the engine running at slow speed.
    B. the mixture is moving so slowly in the manifold at idle that the heavier fuel molecules drop out of the mixture before it reaches the combustion chamber.
    C. the idle system cannot be adjusted leaner at low speed, however, rich mixtures are not required.
    D. the above answers are all incorrect.

40. If the idle air bleed was blocked with dirt, the result would tend to:
    A. enrich the idle mixture and cause siphoning of fuel from the bowl when the engine is stopped.
    B. lean out the idle mixture and cause a rough running engine at idle speed.
    C. raise the idle to high speed and increase economy.
    D. indicate that the above answers are all incorrect.

Matching questions: Each of the following questions are problems which are located in one of the particular carburetor circuits from the list below. You are to select the one circuit in which you would look for the problem. Identify each circuit by the letter in front of it.

Problems		Carburetor Circuits	
41.	A bad "flat spot" as the automobile moves from idle to high speed.	A.	Idle circuit
		B.	High speed circuit
42.	No power at top speed.	C.	Choke circuit
43.	Engine will not run unless the accelerator is depressed part way down.	D.	Accelerator circuit
		E.	Float circuit
44.	Fuel mixture is too rich at all speeds.	F.	High speed or power circuit.

Appendix D

Special Bibliography of Physical Principles

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Appendix E

Test for disproportionality

A COMPARISON BETWEEN THE ORIGINAL ANALYSIS OF VARIANCE OF INITIAL LEARNING TEST SCORES AND THE ADJUSTED SCORES FOLLOWING A TEST FOR DISPROPORTIONALITY

Source of Variation	Unadjusted Sum Squares	Adjusted Sum Squares	Unadjusted Variance	Adjusted Variance	Degree Freedom	F-Value	F-Value
Between (X) Levels	1911	1745	955.50	872.50	2	26.90*	24.55*
Between (A) Treatments	1821	1655	910.50	827.50	2	25.70*	23.30*
X x A	53	219	13.30	54.80	4	.37	1.65
Within	6181		35.50	35.50	173		
Total	9966				181		

Appendix F

Student questionnaire

PERSONAL DATA QUESTIONNAIRE

Name in full______________________________________ Age____

Grade in school _________________________

List the courses you have taken in Industrial Arts below:

1. ____________________________________
2. ____________________________________
3. ____________________________________
4. ____________________________________
5. ____________________________________

List any specialized automotive instruction other than high school courses. Include the name of the courses and the approximate length of time in hours.

1. ___________________________________ Hours _________
2. ___________________________________ Hours _________

List the <u>Job Titles</u> and the approximate <u>months</u> of work experience which can be related to the automotive field.

1. ___________________________________ Months_________
2. ___________________________________ Months _________
3. ___________________________________ Months _________

List father's main occupation below:

____

List mother's main occupation below:

____

VITA

William Ernest Luck

Candidate for the Degree of

Doctor of Education

Thesis: AN EXPERIMENTAL COMPARISON OF DIRECT-AND-DETAILED AND DIRECTED-DISCOVERY METHOD OF TEACHING SELECTED AUTOMOTIVE TOPICS TO SENIOR HIGH SCHOOL INDUSTRIAL ARTS STUDENTS

Major Field: Higher Education

Biographical:

Personal Data: Born at Rhame, North Dakota, April 15, 1917, the son of William F. and Mary Luck.

Education: Attended grade school in Rhinelander, Wisconsin; graduated from Rhinelander High School in 1935; received the Bachelor of Science degree from Stout State University, Menomonie, Wisconsin, with a major in Industrial Education, in June, 1948; received the Master of Science degree from Stout State University, with a major in Industrial Education, in August, 1954; completed the requirements for a Doctor of Education degree in May, 1966.

Professional experience: Entered the teaching profession as an industrial education teacher in the Richland, Washington Public Schools in 1948 and remained in this position for five years. Accepted the position as Head of Mechanical Technology (a two-year engineering technical program) at Oklahoma State University in 1953 and remained at this position until 1962. Since 1962 has been a professor in the Industrial Arts and Technology Department at the State College of Iowa.