

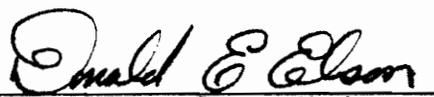
THE DEVELOPMENT AND VALIDATION OF A
PAPER AND PENCIL ACHIEVEMENT
TEST, IN AUTOMOTIVE MECHANICS

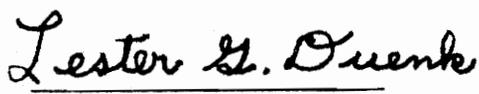
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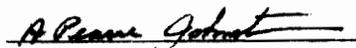
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DOCTOR OF EDUCATION
in
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TABLE OF CONTENTS

	Page
LIST OF TABLES	vi
LIST OF FIGURES	vii
CHAPTER I	
INTRODUCTION	1
PURPOSE	1
PROBLEM	3
RESEARCH QUESTIONS	3
LIMITATIONS	3
DEFINITION OF TERMS	4
JUSTIFICATION	5
CHAPTER II	
REVIEW OF LITERATURE	8
CHAPTER III	
METHODOLOGY	18
INTRODUCTION	18
JURY OF EXPERTS	18
POPULATION	19
PERFORMANCE TEST CONSTRUCTION	20
PAPER AND PENCIL TEST CONSTRUCTION	23
PILOT STUDY	30

	Page
COLLECTION OF DATA	32
TEST ADMINISTRATION	32
Performance Test Administration	32
Paper and Pencil Test Administration	33
TEST SCORING	34
TREATMENT OF DATA	35
 CHAPTER IV	
TEST INSTRUMENTS AND DATA ANALYSIS	39
THE PERFORMANCE TEST INSTRUMENT	39
THE PAPER AND PENCIL TEST INSTRUMENT	46
ANALYSIS OF TEST DATA	59
 Chapter V	
SUMMARY, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS	68
SUMMARY OF THE STUDY	68
Purpose	68
Methodology	69
Summary of Data	71
CONCLUSIONS	72
IMPLICATIONS	73
RECOMMENDATIONS	74
Recommendations for Administration of Performance and Paper and Pencil Achievement Tests	74
Recommendations for Further Study	75
SELECTED BIBLIOGRAPHY	77

APPENDICES	Page 81
A. Counties of Virginia	82
B. Performance Test Instrument Checklist	83
C. Paper and Pencil Test Instrument	84
D. Letter to School Divisions	111
E. Optical Scan Answer Sheet	113
VITA	114

LIST OF TABLES

	Page
Table 1: Number of Items Answered Correctly per Test on Paper and Pencil Test and Performance Test	61
Table 2: Listing of Comments Concerning the Paper and Pencil Test	67

LIST OF FIGURES

	Page
Figure 1: Automotive Mechanics Problem Solving Approach	25
Figure 2: Scatterplot of the Correlation Between the Paper and Pencil Test and the Performance Test	62
Figure 3: Scatterplot of the Correlation Involving Split- Half Odd-Even Scores of the Performance Test	64
Figure 4: Scatterplot of the Correlation Involving Split- Half Odd-Even Scores of the Paper and Pencil Test	65

CHAPTER I

INTRODUCTION

In this age of rapid technological advancement there exists increasing employment opportunities for the person with less than a baccalaureate degree. Because completion of a certified automotive mechanics program may not be required for employment, successful completion of a competency test may be desired. Traditionally such testing has been conducted on a one-to-one basis; the examiner dictates a certain series of tasks to be completed and the examinee proceeds to perform these tasks in a laboratory setting. The examiner then judges the work to be either satisfactory or unsatisfactory. The time required in this type of testing situation is great due to the nature of the tasks assigned and the degree of proficiency exhibited by the examinee. Further, only one person is being tested and therefore the man hours of examiner time expended as related to the number of subjects tested is substantial.

PURPOSE

The purpose of this study was to develop and validate a paper and pencil automotive mechanics achievement test and determine the feasibility of using this instrument rather than a traditional performance test to measure the competence of mechanics. Paper and pencil tests have many advantages over performance tests. They are more efficient

inasmuch as one examiner can test several subjects at a time and the potential for high reliability is greater. Given a fixed time for testing, many more items can be administered from a paper and pencil test than a performance test. "In most cases, the objective test will clearly provide a distinctly more complete and representative coverage of the universe of situations that might have been sampled in the testing period" (Wood, 1960:22). The scoring of paper and pencil tests is more objective. A much broader content space can be sampled, as indicated by Toops.

The chief value in using any written trade test method, is, of course, the saving that results both in the actual examination time and in the time required to score the subject's replies. One examiner can examine five hundred men by written methods almost as quickly as a single man by oral methods. . . . Again, if the questions have been adequately standardized before administration, a definite, predetermined set of answers eliminates all subjective judgment on the part of the scorer.

One further advantage, only slightly used in school examinations, is the possibility of examining large numbers of persons at one time, allowing all who are evidently well above the minimum basis, to pass without further question and reserving those who make low marks for further detailed individual examination by oral or other methods (1972:30-31).

If paper and pencil test items can be developed with validity comparable to similar performance test items, construction of an improved examination would be possible.

In performance testing of automotive mechanics, the time required for various tasks will naturally vary widely. Installation of distributor contact points, for example, requires about twenty minutes while the installation of a manual transmission clutch assembly will take several hours. In the same time, hundreds of paper-pencil items could

be administered, thus providing a broader base for assessment of the subjects' realm of understanding and ability.

PROBLEM

The problem was to determine whether or not it is possible to devise a paper and pencil test which will measure a performance skill.

RESEARCH QUESTIONS

The research questions posed for this study were:

1. Can a sample of accepted performance items used in testing automotive mechanics trainees be selected by a jury of experts?
2. Can a paper and pencil achievement test be developed which can measure performance skills?
3. Can the paper and pencil achievement test developed during this study be validated?
4. Can a correlation corrected for attenuation between an accepted performance test and a like paper and pencil test be achieved which would account for 50 percent of the variance?

LIMITATIONS

The limitations of this study were:

1. Only a cross section of the possible number of test items was covered due to both time and special equipment constraints.

2. No attempt to be comprehensive in scope was made since competency measures were not attempted.
3. No attempt was made to predict on-the-job success inasmuch as this study involved only a comparison of two sample test instruments.
4. No attempt was made to measure the competence of the subjects involved inasmuch as this was not a part of this study.
5. The population was not randomly selected inasmuch as it involved only students in specific automotive mechanics classes in Virginia.
6. The study involved only selected schools in the state of Virginia that agreed to participate by allowing the students enrolled in automotive mechanics to complete two necessary tests.
7. The performance test was not administered by the researcher.
8. Photographs used in constructing the paper and pencil test were limited to those available in current automotive service manuals.

DEFINITION OF TERMS

Definition of terms used in this study were:

1. Examinee: A student currently enrolled in the public schools of Virginia and a member of either the first or second year class in automotive mechanics.

2. Performance Test: An exercise requiring the examinee to complete a specified number of tasks in the laboratory or shop setting while being observed and scored by an examiner.
3. Paper and Pencil Test: An exercise requiring the examinee to complete a specified number of questions involving a test booklet, an answer sheet, a pencil, and proper instructions.
4. Automotive Mechanics Instructor: A person meeting Virginia State Trade and Industrial Education Teacher Certification Requirements in the field of automotive mechanics and currently teaching at the secondary level.
5. Employed Mechanic: A person currently employed as an automotive mechanic having worked in his present position for the preceeding five years.

JUSTIFICATION

There exists among vocational educators a subtle controversy regarding the question of whether or not certain performance skills such as those possessed by automotive mechanics can be adequately tested by using a paper and pencil instrument. Also there is a move towards licensing such mechanics on the basis of satisfactory performance on an examination. While at the present there is no mandatory certification and licensing program in effect, there is a voluntary test series administered by the

National Institute for Automotive Service Excellence (NIASE) which mechanics can take and receive certification in any one of, or all eight specialized service areas. The NIASE test series is justified because:

Good mechanics are hard to find. Neither vehicle owners nor vehicle service employers can tell easily which mechanics are competent to diagnose and repair vehicle problems. The NIASE Certification Program offers a practical way to provide qualified mechanics with the recognition and improved status they deserve (1972:5).

The NIASE test series requires a high degree of verbal proficiency on the part of the examinee. The paper and pencil test utilized in this study attempts to reduce to a minimum the requirement of verbal proficiency. Hopefully, this test will replace the traditional performance test which is administered in the shop environment.

Many arguments have arisen over the use of any test procedure other than an actual performance test administered to the subjects in a shop or laboratory setting. This was pointed out by Butler in discussing the merits of the performance test:

Performance tests emphasize the non-verbal; that is, they require the student to do something instead of just telling how to do it - "show and tell" rather than just "tell." Of course, all jobs require some use of verbal communication; for example, an automobile mechanic must be able to read repair manuals and parts lists. A performance test for this job could involve the student's ability to locate, read, understand, and follow certain technical materials. The fact that a certain task involves the use of words does not keep it from being a performance test as long as it is job-like and is derived from the training objectives. Under certain conditions, multiple-choice, completion, and short-answer test items can be performance test items; usually, however, they do not approximate activities that are job-like. Many times these kinds of test items are concerned with telling about a job instead of performing tasks required as part of a job (1972:217).

It has been pointed out by the proponents of the performance test that any other method merely tests ones' ability to read or to memorize a

series of facts and procedures which he simply is able to recall for a short period in order to answer the questions posed, while not necessarily having the necessary mechanical ability required in the trade. In other words, the subject will be able to explain how a certain repair job is done, but if confronted with the actual situation he could not necessarily perform the indicated repair in a manner which would meet industry standards. There would be no guarantee that a person passing such a written test possessed the skill required to function in the capacity of automobile mechanic. Also, because of the reading and general intelligence levels required to successfully complete the test, a person failing it might still be able to function satisfactorily as an automobile mechanic. Toops supports this assumption:

. . . 'a man may be able to tell about his trade, but not be able to write about it.' One can readily see that this is but an extension of the belief of such persons that a workman may be able to do a job, but not to talk about it. Statistics would probably show that there is a high correlation not only between trade skill and ability to talk about the trade, if the proper questions are used, but also between trade skill and ability to write about the trade, if, again, the proper questions are used (1972:20).

The paper and pencil test developed for use in this study attempted to eliminate the faults which have caused similar instruments to have low validity. There is a very definite need for a test which can assess a performance skill and at the same time be economical to administer from a standpoint of time and test administration personnel involved. A high correlation between the paper and pencil test used in this study and a traditional performance test will indicate that such a testing approach is not only possible, but practical.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this study was to determine the feasibility of using a paper and pencil achievement test to assess true performance of manipulative skill abilities. A general overview of the pertinent available literature relating to paper and pencil testing and performance testing is presented in this chapter.

Attempts are continually being made to adequately test actual performance in order to rate or assign a score which reflects a demonstrated degree of ability or resulting success in solving a problem. Ryans and Frederiksen pointed out that "the validity of a performance test will depend to a large extent on the particular tasks which are chosen to be included in it to represent the more general abilities which the test is designed to measure" (1951:467). Most of these attempts involve a certain amount of subjective judgment, and consequent margin for error, on the part of the examiner. The rating scale and the checklist are two widely used instruments for determining performance involving trade skills. The rating scale is used in many performance testing situations, but a question is raised concerning which is actually being scored, the procedure employed or the final product achieved. Gronlund indicated that there are instances where two ratings are desirable:

Where pupil performance results in some type of product, it is frequently more desirable to judge the product rather than the procedures. . . . In some areas . . . it might be most desirable to rate procedures during the early phases of learning and products later, after the basic skills have been mastered. In any event, product ratings provide desirable evaluative information in many areas (1967:318).

Thus, the conventional rating scale provides the examiner with a subjective method of evaluation if he reasons that the student should pass the test even though the student's demonstrated ability faltered during the performance test. On the other hand, the examiner could legitimately fail an individual who may have blundered into the correct solution, by producing an acceptable answer to the problem posed through using a non-sequential or unconventional procedure.

The checklist method for evaluating a performance skill allows far less margin for personal judgment on the part of the examiner as indicated by Gronlund:

A checklist is similar in appearance and use to the rating scale. The basic difference between them is in the type of judgment called for. A rating scale provides an opportunity to indicate the degree to which a characteristic is present or the frequency with which a behavior occurs. The checklist, on the other hand, calls for a simple 'yes-no' judgment. It is basically a method of recording whether a characteristic is present or absent, whether an action was taken or not taken (1967:325).

It therefore becomes clear that, in testing a performance skill, one's ability to perform the task is more easily measured by using an easy-to-defend "yes or no" checklist which states whether the subject could or could not perform the appointed task.

In any situation, whether the test is of a written or performance nature, it must be administered with a maximum amount of forethought and planning concerning the test environment and its potential effect on the subject. Furthermore, as indicated by Butler, opinions are mixed concerning the feasibility of attempting to utilize a paper and pencil test while trying to access a performance skill.

Written tests are often termed poor measures of proficiency, while performance tests are thought to constitute the only real measures of performance. This is not necessarily true. Some paper and pencil tests are indeed job-like and thus are performance tests. . . . The real requirement is that the test situation make demands of the student that are as similar as possible to the demands of the task when it is done on the job. It is what is measured that counts in a performance test - not just the procedure by which it is measured. . . . All tests that have the student perform are not necessarily good tests. The final test may not be a good measurement device because time considerations may force cutting the test; equipment considerations may limit testing; and the test procedure itself may make it impossible to test whether the student knows how to go about the task being tested. . . . The performance test really measures 'doing' and not just 'knowledge about doing', which can be measured better in other ways (1972:218).

A variety of attempts have been made to measure performance ability in the past and many of these have been of the paper and pencil type while others required the examinee to manipulate tangible objects, look at pictures, or listen to recordings. This researcher located none of these, either in the aptitude or achievement form, which approached the problem of attempting to measure a true performance skill in a manner similar to the approach utilized in this study.

The Aptitude Test of Mechanical Comprehension Form AA developed by George K. Bennett (1940) utilized a variety of line drawings depicting various mechanical situations. It was designed, however, to determine the examinee's ability to perceive the results of mechanical operations relative to normal daily occurrences. The results of such a test, as to the examinee's performance or score, is of use only as an aid in determining whether the individual would be likely to succeed in certain industrial capacities or in definite trade school programs. Bennett's test in no way attempted to narrow its prediction to success in a single trade area.

Another aptitude test, the Stenquist Mechanical Aptitude Tests, requires the examinee to pair items shown in the figure to the left with the corresponding item or part shown in the figure to the right. This test is useful only in determining the ability of the examinee to demonstrate his mechanical aptitude which might prove helpful in certain occupations or future training. It in no way attempts to measure achievement, which is the purpose of the test developed for use in this study.

Many of the paper and pencil achievement tests currently available seem to fall into the highly verbal knowledge oriented category, which in no way could hope to replace the true traditional performance test. The average automotive mechanic taking such a test form would probably know the answers to the questions posed but due to the wording of the distractors presented is unable to correctly differentiate between them. Several of these achievement tests were selected for brief discussion.

An Achievement Test for Automotive Mechanics was developed by the Achievement Measures Project at North Carolina State University (1967). This test, however, approached the testing problem in the traditional paper and pencil manner at the knowledge level of the cognitive domain. Another similar achievement test was located, also titled Achievement Test for Automotive Mechanics, which consists of 295 multiple-choice four distractor items of the traditional knowledge level paper and pencil type (Baldwin, 1968).

The Auto Mechanics Trade Competency Examination consists of 300 four distractor multiple-choice items containing no illustrations. This test is in the form of a computer printout compiled from an item

pool on demand and is of the traditional knowledge level variety (Department of Industrial Education, Mich., 1969). Automotive Mechanics, Ohio Trade and Industrial Education Tests offer 306 multiple-choice items concerning the basic automotive systems (Ohio Trade and Industrial Service, 1972). This test is also one of traditional design inasmuch as it consists largely of knowledge level items.

The Examination in Automotive Mechanics (The State Department of Education, N.Y., 1971) consists of 150 four distractor multiple-choice items of traditional knowledge level design. This test is revised yearly and may be varied by the individual instructor to suit his needs. This test is commonly referred to as the New York Regents Examination in Automotive Mechanics.

The Short Occupational Knowledge Test for Auto Mechanics designed by Campbell and Johnson (1969) involves 20 five distractor multiple-choice items, again of the traditional knowledge level type.

The National Institute for Automotive Service Excellence (NIASE) and Educational Testing Service (ETS), (1972) have produced an eight part mechanics certification test consisting of about 400 questions. This test involves some actual photographs and diagrams and requires a high degree of verbal ability for successful completion. It consists basically of four distractor multiple-choice answers largely at the knowledge level of the cognitive domain.

The paper and pencil instrument which came the closest to approaching the problem of testing a performance skill in a manner attempted by this researcher was a unique test published by

Van Valkenburgh, Nooger and Neville, Incorporated (1960). This test involved the troubleshooting TRAINER TESTER^R device for a six cylinder valve-in-head engine (GMC Type 302). The examinee is presented with a problem and is given troubleshooting results by erasing a hidden "symptom" on the test sheet. He continues this process, numbering each erasure, until he feels he knows the answer, or in effect has located the problem. He now erases a hidden "remedy" and is scored by analysis of his troubleshooting sequence following his numbering of each erasure. Four such problems have been produced involving only one engine and it would appear difficult to adapt this design to many automotive service areas.

The Ohio Trade and Industrial Education Services (1972) has a two part Automotive Mechanics test consisting of 335 items covering all of the basic automotive systems. This test is largely a knowledge level test designed in the traditional paper and pencil manner.

There are many achievement test available, but these are nearly always of the traditional knowledge level type requiring verbal proficiency in order for the examinee to comprehend the questions. In an effort to approach the testing of automotive mechanics in a different manner, Swanson (1968) developed the AAMDAT (Auditory Automotive Mechanics Diagnostic Achievement Test). In taking this test the examinee listens to both normal and abnormal prerecorded engine sounds through headphones and selects an answer response to each sound as presented. Having administered this test to 269 examinees and realizing a correlation of .249 Swanson concluded that "In its present

form the AAMDAT cannot be considered a [sic] sufficiently reliable to make fine discriminations in auditory diagnostic ability. . . ."

The researcher attempted to locate information involving a paper and pencil test similar to the design planned for use in this study. A computer search of both DATRIX (Direct Access to Reference Information) and ERIC (Educational Resources Information Center) produced no instruments in a form which could be utilized. It, therefore, became necessary to design the test instrument used in this study in its entirety.

There exists some debate concerning the true definition of a performance test. Webster's Third New International Dictionary defines performance as "the act or process of carrying out something; the execution to determine factual knowledge or mental proficiency . . ." (1969:2361-2).

The performance test is seldom viewed as the best possible means of assessing performance ability. As indicated by Butler, "Often a portion of what the performance test measures could be measured better by an objective written test" (1972:218). Some researchers indicate that the term "performance" when used in discussing tests, denotes a distinctly different type of measuring instrument. There are others such as Fitzpatrick and Morrison, however, who see the performance tests in the same class with all other tests:

There is no absolute distinction between performance tests and other classes of tests - the performance test is one that is relatively realistic. Since performance tests tend to involve special problems and to require decisions and procedures not usually required for conventional tests, it is useful to distinguish the performance test from other classes of tests. . . (1971:237-8).

The performance test may be classified as to type, depending upon the purpose of the test. Ryans and Frederiksen (1951) indicate three major categories: 1) recognition, 2) simulated conditions, and 3) work sample. The first category, that of "recognition" requires that the examinee recognize or identify desired features or components of an assembly or piece of equipment. The second category, "simulated conditions," involves the use of one or more of a combination of hypothetical situations produced through the use of models, mock-ups, and other similar aids which are designed to approximate the real-life situation. The advantage of this category of test is its economy and safety. One disadvantage is the fact that the examinee is well aware that it is not a "real" situation confronting him so the psychological approach will vary considerably from what it would be if the actual situation existed. The third category involved the "work sample" which places the examinee in a true employment situation. Rather than working with a simulator in a hypothetical situation, the subject is faced with the actual task and must perform realistically. A typical example might be the person applying for an airplane pilot's license who is required to actually pilot the aircraft with the examiner on board as opposed to merely performing in a flight simulator. Performance tests of this nature follow training from a designated course of study and require a prescribed degree of proficiency in the area. The type of performance test employed in this study is of the work sample type as described by Ryans and Frederiksen (1951).

The paper and pencil test has most frequently been used to measure general intelligence, aptitude, achievement, attitude or to predict suitability for certain types of industrial employment. Tiffin, in discussing written achievement tests, indicated that the Purdue Vocational Tests ". . . comprise a series of pencil-and-paper tests that measure achievement in technical information related to various areas of training" (1952:166). Tiffin stated that these tests were originally developed for vocational instructors, but are now largely used by industry to determine job applicants qualifications as related to the various trades (1952:166).

The vocational teacher tends to utilize the true performance test or psychomotor tasks for actual assessment of his student's abilities. He typically uses the paper and pencil test merely to satisfy the requirement that some form of written test be administered to his students. When such tests are used they rarely test beyond the lowest or knowledge level of the cognitive domain. According to Cronbach, however, "all psychomotor tasks involve intellectual abilities such as are found in pencil-paper tests" (1949:301). It follows then that it should be possible to formulate a paper and pencil test which will tap the examinee's performance or psychomotor ability. Cronbach in discussing paper and pencil measures of psychomotor performance indicated:

We have seen in the GATB Mark Making Test an example of a pencil-paper psychomotor test. Some psychologists are convinced that with sufficient ingenuity other important motor abilities can be reduced to group pencil-paper tests (1949:309).

The difficulty in attempting to use a paper and pencil test in assessing a performance skill is that little success has been realized in past

efforts toward this end. Cronbach pointed out, however, that: "It is nevertheless obvious that testers would gladly substitute pencil-paper tests if these would measure the same aptitudes" (1949:309). It, therefore, follows that research is necessary in order to make a further case for paper and pencil testing of psychomotor domain achievement.

CHAPTER III

METHODOLOGY

INTRODUCTION

The purpose of this study was to determine whether a paper and pencil test could be developed which would measure a manipulative skill to the same degree as a traditional performance test.

A general discussion of the jury of experts, population, development of the data gathering instruments, pilot study, collection of data, test administration, test scoring, and treatment of data is presented in this chapter.

JURY OF EXPERTS

It became evident very early in the study that the aid of experts in the automotive field would be required. The first step in instrument design dictated that a suitable sample of performance test items be collected. Selection of these items was left to a group of ten automotive instructors and four employed automotive mechanics available to the researcher as a jury of experts. Initial contact with the ten instructors was made while they were attending a workshop for the purpose of writing behavioral objectives and related achievement test items at Virginia Polytechnic Institute and State University. Each of these instructors met the Virginia State Requirements for Vocational Trade and Industrial Education Teachers. The four employed automotive

mechanics selected were chosen on the basis of: 1) recommendation of their employer's service manager, 2) having worked for their present employer for the preceding five years, and 3) regular attendance at automotive service schools.

These instructors and employed automotive mechanics provided the expertise necessary to form a jury of experts capable of selecting suitable performance test items. This process of selecting performance test items as described by DuBois involved an empirical rather than a statistical approach to assess content validity of the test (1965:403).

POPULATION

The population of students was chosen from the school divisions in the counties of Amherst, Augusta, Giles, and Henry (Appendix A) which represented four geographic locations in Virginia. The four school divisions were chosen because five of the original ten automotive mechanics instructors who assisted in this study by serving as part of a jury of experts taught at these locations. This group of five instructors agreed to further aid the study by administering the performance test to each of their students. The students at these four locations in both the first and second year automotive mechanics classes totaled 124.

PERFORMANCE TEST CONSTRUCTION

Modern automobile diagnosis and repair presents a vast area for possible test item construction. It was necessary first to choose the areas from which to select the test items. One approach to selecting test items was to limit them to only one specific area of the automobile such as the engine, the suspension system, or the drive train. A second approach was to choose items at random from the total vehicle, thus including the total possible areas from which automotive test questions could be made in a performance setting. Questions utilized as performance items must be redesigned in a paper and pencil form so that both the performance test and the paper and pencil test measure the same objective. The decision was made with the aid of the jury of experts that the test should not attempt to be comprehensive, but rather include selected items from the total field of diagnosis and repair.

The idea of developing a series of questions which could be tested in a performance setting was first explored. Each participating instructor and group of students would then be provided with these items for administration purposes. It was discovered, however, that the variety of equipment utilized in the different school laboratory settings differed so markedly that this seemed an impractical approach. It was determined that the best approach was to consult collectively with all ten participating automotive mechanics instructors as well as the four employed automotive

mechanics serving as a jury of experts concerning the best approach to take in formulating the actual performance test. As a result of this consultation, a large number of performance test items were listed by each member of the jury of experts which were utilized universally in performance testing of automotive mechanics. The individual lists of items were compiled in a one-way outline as suggested by Wood (1961:34). This process ranks all potential items from most to least important and those items receiving the highest count were then selected for use in the performance test.

This listing was not meant to be comprehensive in any way, although it included in excess of three hundred items. A major point of consideration was the time element. The instructors could only devote a reasonable amount of time to each of the test items in a typical automotive mechanics class setting. It, therefore, became necessary to rule out certain lengthy performance test items which require an excessive amount of time.

Items retained in the test were discussed and agreed upon by all automotive mechanics instructors and employed automotive mechanics participating as a jury of experts. This process required a job analysis which: 1) involved a direct observation by the investigator, and 2) involved judgment by individuals other than the researcher (Bechtoldt, 1949:1248). The latter method was employed in this study for determining the items to be included in the performance test. The time factor cut the list by approximately 67 percent, leaving

about one hundred usable performance test items which the jury considered usable in constructing the actual performance test. Further consultation with the participating automotive mechanics instructors suggested that no single performance test item should require in excess of 25 minutes to complete from the time the student first began the test operation until the total operation was completed. This factor reduced the total number of items to approximately 50.

It had been initially anticipated that between 20 and 30 performance test items would be utilized in this study. Further discussion with the participating automotive mechanics instructors indicated that some of the 50 listed items were impossible for utilization inasmuch as they did not have certain basic equipment available in their shops or they could not provide necessary test conditions which could be readily set up for student use in performance measurement. As an alternative it was considered that certain of these conditions be simulated by the researcher and transported from one school laboratory setting to another for purposes of testing the students. The approach would have utilized cutaways and other automotive component parts with predetermined mechanical problems. The student would merely determine the problem area and select the proper corrective measure to be followed to restore this particular component part to normal acceptable operating condition. Thus, he would have determined the actual problem, checked with

manufacturer's specifications and arrived at a corrective procedure which restored the defective component to normal operating condition or to a condition meeting manufacturer's specifications. This approach, however, was later rejected as providing a nonrealistic situation and therefore could not be a valid performance test. After consideration of all aspects of the test requirements, the jury of experts ultimately agreed upon a total of 26 performance test items which they considered could be administered in a laboratory setting to individual students within a three month period of time.

The items required the student to approach the work station, comprehend the problem, interpret manufacturer's specifications, select any required special tools or equipment, and supply the correct answer or solution to the test item in question within the allotted time. The examinee's performance was then indicated by the examiner in the space beside that item on the checklist as:

1) Performed With Success or 2) Could Not Perform (Appendix B).

PAPER AND PENCIL TEST CONSTRUCTION

The paper and pencil test developed for use in this study (Appendix C) incorporated various pictures, diagrams, and factory specifications which duplicated all aspects of the performance test items. The diagrams and pictures used deleted any mechanical aspects which were not of major importance in solving the obvious problem. Although the grease, oil, and actual feel associated with

normal analysis of the component parts were missing, the competent and conscientious examinee or mechanic experienced little difficulty in solving the problems presented. The performance test and the paper and pencil test were purposely constructed as nearly identical in each concept presented as possible, and yet be two distinctly different test types.

At the outset it was decided by this researcher to utilize diagrams whenever feasible to produce as nearly as possible, a non-verbal test form. In many instances, however, some written descriptions became necessary and factory specifications had to be included for some items. The individual paper and pencil items making up this achievement test were designed to duplicate the content of the performance test items. It, therefore, became necessary for the jury of experts to consider each performance task relative to areas of knowledge required for successful test item completion. This culminated in a series of required knowledge plateaus as indicated in flow chart form in Figure 1.

The flow chart indicates the two most common procedures employed by the mechanic to determine the cause of a vehicle malfunction. In either instance he is presented with the automobile, appearing as 1 on the flow chart. He, through prior schooling, study and/or on-the-job experience, is thoroughly familiar with its theory of operation, 2. He carefully listens to the nature of the given complaint, 3, as presented by the customer or reads this information directly

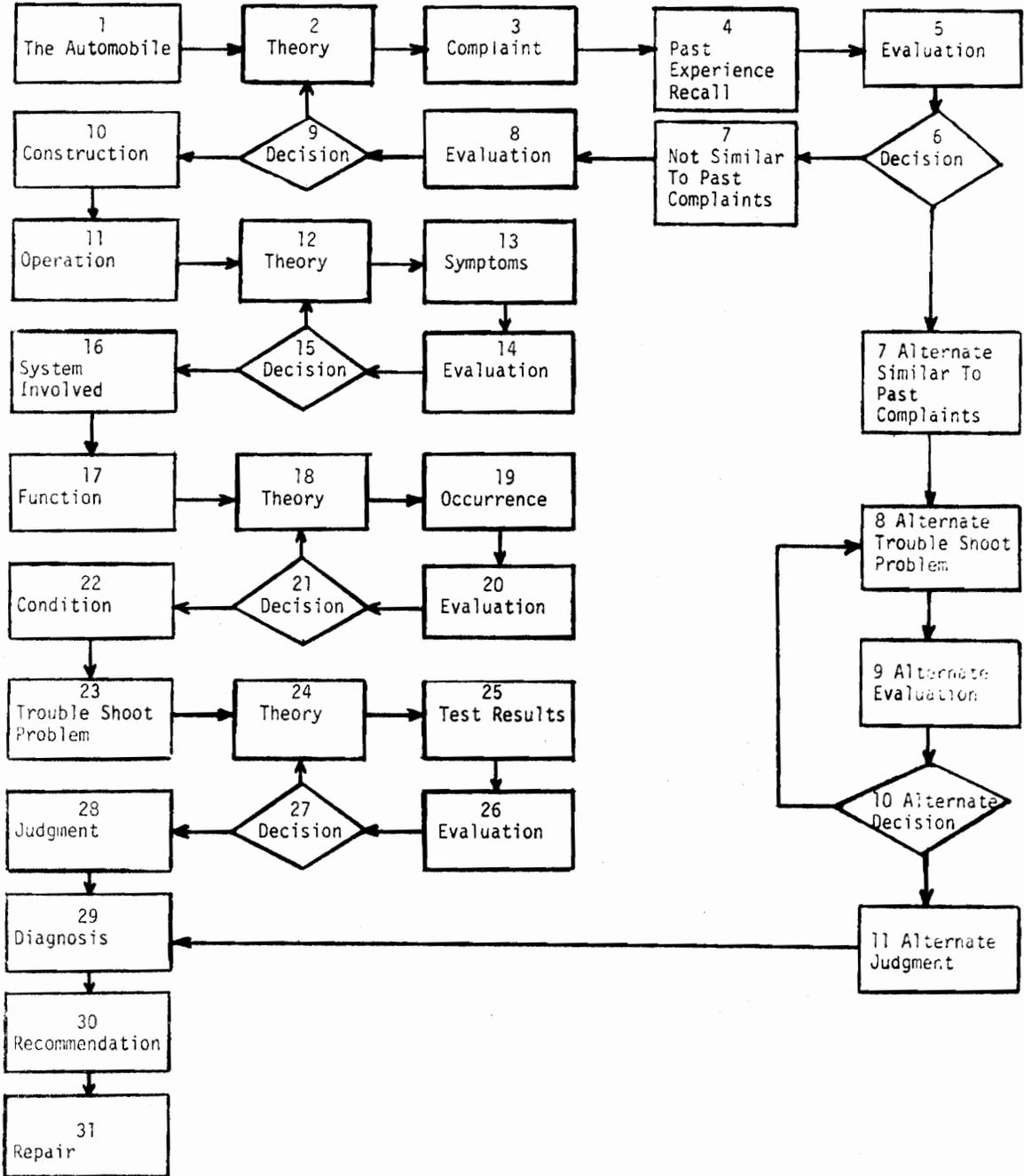


Figure 1. Automotive Mechanics Problem Solving Approach

from a work order written by a person such as a service writer. This person is also skilled in complaint diagnosis and received the complaint directly from the vehicle owner/operator. The mechanic, having heard the complaint, relies on past experience recall, 4, to compare the symptoms evident to those encountered previously on like vehicles with similar or identical owner/operator complaints. He evaluates, 5, the given set of complaints after careful analysis against those from past recall and is therefore able to reach a decision, position 6 on the flow chart. The mechanic concludes that the symptoms presented in the complaint are either not similar to past complaints, appearing as 7 on the chart, or similar to past complaints shown as 7 alternative.

Considering first, position 7, not similar to past complaints, the mechanic must further evaluate all evidence presented, 8, with the fact in mind that this is a totally new situation which he has not encountered before. He, therefore, must make a decision, 9, as to whether he should reconsider the initial complaint thus repeating steps 2 through 8 or consider his thinking correct and proceed immediately to 10 on the chart, the actual construction of the vehicle. In either instance, if he ultimately arrives at this section, his past experience and schooling will have acquainted him with an extensive knowledge of automotive construction which will allow a narrowing down process to limit the parameters within which this given complaint might be isolated.

The mechanic is now able to move to 11 on the chart or the operation block. This allows him to consider the normal operation of the total vehicular system in reference to the complaint or problem presented. Logically and systematically he goes through the theory, 12, relating to the operation of each component and considers each possible set of symptoms, 13, which might exist with a complaint or problem like the one with which he finds himself confronted. He evaluated his thinking to this point, 14, and makes a decision as to whether or not to reconsider and repeat steps 12 through 14 or proceed directly to 16 and narrow his possible problem area down to one specific system involved. Again, if he ultimately arrives at this section, the mechanic must either already be cognizant of the function, 17, of the individual system operation or will immediately consult reference material in the form of service bulletins, overhaul manuals, or similar sources of information. He will then again, logically and systematically, go through the theory, 18, involving the function of the questionable system and attempt to determine the occurrence, 19, of this function. Is the function occurring properly or improperly in relation to manufacturer's specifications? This question leads to area 20 of the chart, that of evaluation. If some question arises, a decision, 21, must be made concerning whether to repeat steps 18 through 20 or proceed directly to the condition, 22. If the mechanic ultimately arrives at the condition, he has a total mental picture of the complaint or problem in mind at this point in time. He knows

the construction, operation, symptoms of the system involved as well as its function as related to overall vehicle performance. He knows when the symptoms relating to the function occur and now can conclude the actual operating condition(s) during which they occur. Often this condition or set of conditions is difficult to produce or reproduce in the shop setting so the vehicle in question may be taken out on the road in an attempt to cause the symptoms to reappear. This process as well as the in-shop testing is collectively referred to as troubleshooting the problem, 23.

The mechanic draws upon his knowledge surrounding the total theory, 24, concerning all aspects of operation and testing of the suspect system and records his test results, 25. Having compiled all information surrounding the troubleshooting phase, he evaluates, 26, the test results and the original complaint. If there is some question as to whether the test results bear out the actual problem location, a decision, 27, is made to again repeat steps 24 through 26. If, on the other hand, the test results do indeed point to problem location, a judgment, 28, is made concerning whether the actual problem has been isolated in its entirety or if additional investigation is warranted in this instance. If all evidence points toward one or more component parts causing the difficulty leading to the original complaint or problem, a diagnosis, 29, is made by the mechanic who may or may not consult with another mechanic concerning his findings. He next makes a recommendation, 30, concerning the

feasibility of either component repair or replacement, unless the customer specifically indicated that the vehicle should be repaired in any case to serviceable condition based solely on the mechanic's judgment. The customer is notified, vehicle condition is explained, an estimated cost and time projection is made, and the repair is or is not authorized.

If at step 6, the decision indicated that the complaint was similar to past complaints, 7 alternate, the mechanic proceeds to troubleshoot the problem, 8 alternate. With the troubleshooting test results compiled, the mechanic evaluates, 9 alternate, with respect to the original complaint. If there is some question concerning whether the test results bear out the actual problem location, a decision, 10 alternate, is made to again repeat steps 8 and 9 alternate. Next the mechanic makes a judgment, 11 alternate, concerning whether the source of the difficulty has been isolated. If no further doubt exists, a diagnosis, 29, is made. The remainder of the chart follows the same steps as previously described.

It is assumed that the automotive mechanic possesses a sound basic knowledge of theory, construction, and operation as they are related to his field of expertise. A valid automotive mechanic test situation should trigger the same sequence of events in the mind of the examinee as presented in Figure 1.

It was with these basic concepts in mind that each of the paper and pencil achievement test items were formulated. It has been previously indicated that mere knowledge concerning the subject of

automotive mechanics is not sufficient for passing the performance test. The researcher reasoned that the design of the paper and pencil test must be such that the same knowledge should be prerequisite for successfully completing the paper and pencil test as for the manipulative performance test.

PILOT STUDY

It was realized that the degree of difficulty among the selected 26 performance and matched paper and pencil items varied greatly, therefore, it was decided to administer the 26 paper and pencil items to a group of students in Montgomery County (Appendix A). This group of students consisted of two Automobile Mechanics II classes totaling 25 students. An item analysis was performed on these two sets of test scores and, as a result, the paper and pencil items were ranked in order from those items most easily answered to those answered with most difficulty. The 26 performance test items were also ranked in this order. The paper and pencil test was administered to 10 experts in the field in order to determine if any changes in verbal or picture aspects might be required. These experts were selected according to: 1) recommendation by their employer's service manager, 2) having worked the preceding five years for the same employer, 3) regular automotive service school attendance, and 4) willingness to take the time required for completion of the test instrument. These 10 currently employed automotive mechanics completed the achievement test and all 10 selected the correct answer to each question. Their

statements indicated that they considered it to be a very clear and a fair test with highly realistic answer choices.

An additional 10 individuals, known by this researcher, were selected. These individuals had read extensively in various publications such as tune-up guides, factory service manuals, and high performance automotive guides, and did limited automotive tune-up and repair work for themselves and associates. They were asked to aid in this study by answering the 26 paper and pencil test items. The results indicated that this group was unable to successfully complete the test inasmuch as the average number of correct answer responses was 10.4 or 40 percent. These self-proclaimed automotive mechanics readily admitted to having guessed at many of the answers and were not sure of others. Their reasoning was that while they had studied a great deal of pertinent material they had not actually performed half of the jobs around which these test items were designed. The point is thus established that if these paper and pencil items were merely at the knowledge level in the Cognitive Domain of the Taxonomy of Educational Objectives (Bloom, 1965), then it is reasoned that this latter group would have probably achieved a high score since they had an exceptional speaking knowledge of the trade. This researcher reasoned that the aforementioned group of individuals would probably score higher on a strictly cognitive examination than would the employed automotive mechanics due to the verbal nature of the traditional multiple-choice achievement test.

COLLECTION OF DATA

The first step in data collection was to contact the division superintendent and the director of vocational education of each locality involved. A copy of the letter of request was also sent to each principal involved and to the cooperating automotive mechanics instructors (Appendix D). All division superintendents, vocational directors, and principals unanimously agreed by letter to participate in the study, but added that they would in no way try to influence their respective instructors either in favor of or against participating in the study. It would be strictly up to the instructors to participate if they felt it would not interfere with their regular planned programs, and were willing to devote some additional time to this investigation.

Each instructor was then contacted by telephone during the last week of November 1973 to confirm his participation in the study. All instructors were visited in their respective schools and were given a supply of performance test checklists (Appendix B). Each participant was instructed on the administration of each item and any questions or points raised were discussed and resolved without difficulty.

TEST ADMINISTRATION

Performance Test Administration

Ten automotive mechanics instructors assisted in this study by serving as a jury of experts during the development of the performance test items. Of these ten, five agreed to administer the 26 performance

items to each of their students in the first and second year automotive mechanics sections.

Paper and Pencil Test Administration

The paper and pencil test covering each performance item was administered by the researcher during the month of May, 1974, to all students involved in the study. The normal procedure followed by this researcher involved arrival at the participating school at 8:30 a.m. on the test date and meeting with the instructor who had informed the principal of the researcher's planned visitation in the class. In each case provision had been made for testing in one of the vacant classrooms, if the instructor did not have one of his own. Following placement of all materials in the classroom, the students arrived, roll was taken, and the researcher was introduced to the class. The researcher explained the design of the test which the students were to take and how important it was for them to take their time and consider each test item in the same light as actually working on the various automotive components in the laboratory. The process of test construction was pointed out, but it was not actually compared with the performance test. Neither was it mentioned that the test had any relation to the performance test. Therefore, students had no way of knowing that the two tests were related. Emphasis was placed on the fact that the test they were about to take was a new approach in automotive mechanics testing. They were also told they were not expected to know the answer to all questions presented, but that, like a problem they encountered while working on the automobile, if they considered all the facts, looked at

the problem objectively in relation to all they had learned and experienced in the laboratory, they could possibly derive the answer. The researcher presented the students with a biographical sketch of his own interests and mechanical background followed by a brief question and answer period concerning careers in the automotive field.

Optical scan answer sheets (Appendix E) and number two pencils were given out to each examinee and detailed instructions were given verbally with the chalkboard serving to demonstrate proper marking of this form. It was emphasized that no stray marks be allowed to remain on the form and that the answer spaces were numbered across the page rather than vertically down the page, as in some machine scored forms.

A test booklet (Appendix C) was next given to each examinee, and it was emphasized that there was no time limit involved with this test. Further, it was pointed out that the score on this test would in no way affect their course grade. Students were told that they were providing an important service to research. Encouragement was given to use the blank sheets of paper supplied in each test booklet for any comments, good or bad, which might be thought helpful. These comment sheets would be placed in a container following the completion of the test, and no identification should be placed on them. The examinees were asked if there were any questions and were told to begin.

TEST SCORING

Scoring the performance test items was done by using a checklist for the reasons presented in Chapter II. Such scoring is highly

objective for scoring performance test items. This procedure made it simpler for the participating automotive mechanics instructors to score this phase of the study. Toops indicated that the scoring of a performance test can become complicated unless such tasks are chosen which will lend themselves to easily and objectively measurable scoring points (1921:28). For this reason, all performance items were purposefully stated in simple but highly specific language. Each instructor was provided with one 26 item checklist form for each student (Appendix B). All items on the checklist were in order and followed by two blanks. The first blank was captioned "Performed With Success" and the second was captioned "Could Not Perform."

The paper and pencil test was machine scored using the optical scanner. This was possible because each student was required to place his answers on the appropriate form (Appendix E) supplied by the researcher, following proper and detailed instructions. Utilization of this form allowed additional data concerning the particular school, class, and individual student to be obtained with relative ease and convenience.

TREATMENT OF DATA

The jury of experts agreed upon the importance of each item included in the performance test which was used in this study. Also, the performance test is currently the accepted means of assessing examinee knowledge and ability in the automotive mechanics field. Validation of the paper and pencil test was of an empirical

nature involving concurrent validity and content validity to answer the questions: Can the present knowledge and ability of the examinee be accurately determined using this instrument, and are the results of this test a fair measure of an important series of tasks? (Cronbach, 1949:103-6).

In this study, the criterion for judging the ability of the automotive mechanics student was the performance test. It was not important that the student successfully complete a given number of the 26 performance tasks, but rather that he score equally well on both the performance test and the paper and pencil test. The more nearly equal his two test scores, the better relationship between the two tests, or the higher the correlation. Therefore, the high correlation between the two test instruments showed that the paper and pencil test had concurrent validity.

Downie and Heath in discussing content validity stated:

Content validity is a nonstatistical type of validity that is usually associated with achievement tests. When a test is so constructed that it adequately covers both the content and the objectives of a course or part of a course of learning, it is said to have content validity (1965:223).

The researcher and the jury of experts agreed that the paper and pencil test instrument provided an adequate means of sampling a student's ability. Inasmuch as this test was designed item by item around the performance test, it was agreed that it had a high degree of content validity.

In order to determine whether or not the paper and pencil test would actually measure performance, a correlation between the two test

instruments was computed. According to Downie and Heath (1965:215) "One of the major uses of correlation coefficients is in the computation of reliability, validity, and item statistics." A correlation is merely a means of determining the relationship between two variables which in this case consist of the performance test and the paper and pencil test.

In order to determine this relationship, the Pearson product-moment correlation coefficient (r) was utilized. The size of this computation ranges from +1 through -1. It was hoped that a correlation of .71 (corrected for attenuation) would be attained, as indicated in the research questions. The .71 level is the correlation required in order to account for 50 percent of the variance.

A correction for attenuation was necessary as indicated by Downie and Heath:

Since in any given situation both variables are unreliable to a certain extent, any correlation coefficient computed between the two would tend to be lower than true, or theoretical, relationship between the two variables. This lowered r is referred to as attenuated (1965:226).

Thus the initial correlation values were used in the formula to correct for this attenuation.

Reliability, though possible to compute using a variety of statistical measurements, was computed for the purposes of this study by using the internal consistency method, since only a single administration of the test is required (Gronlund, 1968:112-13).

The split-half odd-even method chosen for computing the reliability coefficients is pointed out by Downie and Heath:

An advantage of this method is that only one test is needed for the computation of the reliability coefficient. The test papers are scored so that from every single paper we have two scores. This is usually done by counting the number of odd-numbered items answered correctly and the number of even-numbered items answered correctly (1965:217-18).

At this stage of the computation, each student had two scores on each test - one odd and the other even. The Pearson product-moment correlation coefficient (r) was computed using the odd-even scores for both the performance test and the paper and pencil test. The resulting values of these correlations also were necessary for substitution in the correction for attenuation formula.

Time constraints as explained earlier in the chapter limited the length of the test instrument used in this study to 26 items each for both the performance test and the paper and pencil test.

As a result of computer calculations, both the validity and reliability of the paper and pencil test instrument were computed while only the reliability of the performance test instrument was computed. Thus, having developed and validated the paper and pencil test, the purpose of the study was met.

CHAPTER IV

TEST INSTRUMENTS AND DATA ANALYSIS

The initial purpose of this study was to design and validate a test of paper and pencil nature which would correlate at least .71 when corrected for attenuation with an accepted sample of like performance items. This chapter is concerned with a discussion of the accepted performance test items, the formulated paper and pencil test items, and the analysis of all data gathered during administration of the two tests.

THE PERFORMANCE TEST INSTRUMENT

The performance test used in this study consisted of 26 items. These items were stated in a highly abbreviated form since only those instructors who assisted in formulating the test would be administering it (Appendix B).

Item 1 presents the examinee with a typical four speed synchromesh transmission. The instructor asks the examinee to remove the side-plate from the transmission and place the transmission in third gear position and indicate power-flow from the input to the output shaft. All lubricating grease had been drained from the transmission and all necessary bolts had been removed prior to administration of the performance test. The examinee is allowed 5 minutes to lift the

sideplate from the transmission, place the transmission in third gear, and totally describe the power flow through the transmission.

Item 2 involves the same or a similar type four speed synchromesh transmission and the examinee is allowed 5 minutes to place the transmission in reverse drive gear and explain the power flow through the input shaft to the output shaft.

Item 3 involves the same or similar transmission and the examinee is again given 5 minutes to place the transmission in first drive gear, explaining the power flow through the input shaft to the output shaft.

Item 4 involves a typical engine which has a known worn lobe on the camshaft. The examinee has not previously inspected the engine and does not know the condition of the shaft, since it is installed in the engine block. In order that the task can be performed within the given time period, the instructor tells the examinee that it is a problem either with the intake or the exhaust valve in a specified cylinder of the engine. He is told by the instructor to select the proper equipment, measuring instruments and tools and determine the condition of the camshaft lobe in question within a 25-minute time period.

Item 5 requires the examinee to perform a standard compression test for piston ring condition and interpret the results. In order that this task can be performed within the 25-minute time limit, the instructor requires that only four of the total number of engine cylinders be tested.

Item 6 requires the examinee to select the proper tools necessary for removal and replacement of an original equipment or welded on type muffler. He is given 5 minutes to correctly select these tools.

Item 7 presents the examinee with a General Motors type distributor with instructions to utilize the correct tool for moving the stationary breaker point to correct a too high dwell condition. This involves the use of a standard distributor machine properly set up prior to presenting the examinee with the problem. It may also involve an automobile and the use of a hand held dwell meter or an oscilloscope attached to the vehicle prior to the time the examinee is asked to correct the condition. Five minutes is allowed for this task.

Item 8 requires the examinee to detect a blown head gasket between two adjoining cylinders in a typical engine. The examinee is allowed 25 minutes to determine this problem. If a V-8 engine is utilized for this test, the examinee will be told which bank of cylinders to test.

Item 9 presents the examinee with a set of spark plugs removed from a vehicle which had been operating with an extremely rich fuel mixture. The center porcelain of the spark plugs were covered with black, sooty carbon, indicative of a condition involving poor spark plug performance. He is told that the automatic choke is functioning properly and that there is no evidence of excessive oil consumption concerning the particular engine. The examinee is then asked to determine whether the spark plugs are of a heat range which is too cold for existing engine conditions. Next he is required to select a spark plug of the proper heat range to correct this condition,

thus allowing the spark plugs to operate according to manufacturer's specifications. Five minutes is allowed for this task.

Item 10 presents the examinee with a vehicle using a ceramic primary current resistor. The engine will start as soon as the ignition switch is turned to start position; however, upon allowing the spring load to return the ignition switch to the run position the engine immediately stops. This process will continue as long as the examinee turns the ignition to the start position and then allows the spring tension to return the switch to the run position. He is given 5 minutes to isolate a defective primary current resistor in the ignition system.

Item 11 presents the examinee with a badly burned piston, obviously the result of prolonged detonation. He is allowed 5 minutes to give the instructor three factors which create such a condition in an engine.

Item 12 allows the examinee 5 minutes to perform an appropriate compression test for detecting a blown head gasket which is leaking into the water jacket. The problem cylinder is identified for the examinee.

Item 13 presents the examinee with a typical V-8 engine block from which the cylinder head, crank shaft and piston assemblies have been removed. The examinee is then told to determine the cylinder condition presupposing that this engine will be overhauled. He is requested to inform the instructor whether the cylinders in question should be bored oversize and if so, to what extent. He is asked whether the

engine can be reassembled, as is, using new standard parts if wear indications do not exceed manufacturer's allowed tolerance. Ten minutes is allowed for the examinee to perform this task.

Item 14 presents the examinee with a piston which has been knurlized. He is asked why this process has been performed and what it does as far as piston treatment is concerned. The examinee is required to give an explanation of the theory behind knurlizing pistons, stating what the process does to the piston. The examinee is allowed 5 minutes to complete this task.

Item 15 presents the examinee with a differential housing assembly properly set up in a support stand, a pinion gear, a series of shims, and the proper instruments for setting up the pinion gear depth for a given ring gear pinion set. He is then allowed 20 minutes to select the required tools and properly set the pinion depth using the required shims.

Item 16 allows the examinee 10 minutes to isolate the cause of a steady low vacuum gauge reading on a typical V-8 engine to which the vacuum gauge has been previously attached. The engine is operating with the exhaust system connected to a proper collector for safety.

Item 17 presents the examinee with a reversed coil polarity oscilloscope pattern shown on an analyzer which the instructor has connected to an idling engine. The examinee is given 5 minutes to properly state the cause of this reversed polarity pattern.

Item 18 presents the examinee with several main bearing precision insert halves which have wear on the outer edges indicating that they

have been run on an hour-glass shaped crankshaft journal. The examinee is allowed 5 minutes to carefully examine the bearings and state the probable cause of a wear pattern of this type.

Item 19 requires the examinee to state the cause of a typical dwell overlap condition shown on an oscilloscope which has been connected to a typical, idling engine in the laboratory. He is allowed 5 minutes to complete the item.

Item 20 presents the examinee with a tapered roller bearing cone from a typical automobile front wheel. Five minutes is allowed to correctly determine the condition of this bearing. The bearing has previously been very carefully cleaned of all grease and properly dried.

Item 21 requires the examinee to determine the running oil clearance of a typical main bearing assembly, using gauging plastic. The engine block has previously been set up properly on an engine stand and all parts have been cleaned. All required tools and equipment have been laid out and the examinee is allowed 10 minutes to complete the task.

Item 22 presents the examinee with a typical crankshaft assembly, a set of micrometers and access to the manufacturer's specifications. Ten minutes is allowed to correctly determine the diameter of the crankshaft, compare readings with manufacturer's specifications and determine the condition of the crankshaft.

Item 23 presents the examinee with a set of engine bearings which have failed due to a lack of oil or oil pressure. The bearings are

obviously very badly scored and the examinee is allowed 5 minutes to state several factors which will lead to a bearing failure of this nature.

Item 24 presents the examinee with an idling engine to which a vacuum gauge has been connected. The gauge indication shows a continuously floating needle. The examinee is then given 10 minutes to state the factors which will lead to such a vacuum gauge indication and explain the corrective action required.

Item 25 requires the examinee to examine a cylinder head assembly from which the valve springs have been removed. The valve guides are of the integral type or the non-removable type. Several are worn in excess of manufacturer's tolerance range. The examinee is then given 10 minutes to state two factory approved procedures for restoring the over-sized guides to serviceable condition.

Item 26 presents the examinee with a typical piston assembly for examination. This piston has been operating on a bent connecting rod, therefore causing a characteristic wear pattern to appear on the piston. Five minutes is allowed for him to examine the piston and determine what the wear pattern indicated regarding engine condition and what repair procedure should be followed to restore the engine to proper operating condition.

This test sequence required four hours and twenty-five minutes for administration per student. This time, of course, was not intended to be used in one continuous testing period, but rather occurred over the three months time allowed each participating instructor.

THE PAPER AND PENCIL TEST INSTRUMENT

Test items 1, 2, and 3 involved the Borg-Warner four speed synchromesh transmission. A detailed cut-away view with labeled parts is shown accompanied by a typical floor shift type gear range selector. The selector shown in Question 1 (Appendix C) is pictured in the third gear position. A statement directs the examinee to choose from five line drawings the one which depicts power flow through the transmission when placed in the third gear position. Test items number 2 and 3 are identical except that the drive gear selector diagram and the verbal statement indicated reverse and first drive gear position respectively, be selected from the response alternatives. It was concluded by this researcher and the jury of experts that for successful completion of these three items the examinee must have a background in transmission theory and design and have received extensive instruction in the disassembly and reassembly of various designs of manual transmissions. Thus, extensive ability in both the cognitive and psychomotor domains was required. Merely having read about or talked about transmissions was insufficient for successful completion of these three items.

Test item 4 presents the examinee with a picture of a dial indicator positioned atop a single push rod of a typical V-8 engine assembly. A verbal statement of cam lobe condition followed by four line drawings of greatly exaggerated cam-to-rocker-arm conditions are presented. The examinee is to choose the one condition which will cause the stated indicator reading on the questionable lobe. For

successful completion of this item, the examinee must possess the same cognitive and psychomotor abilities as required in the previous items except, of course, they must be in the areas of engine theory and construction.

Test item 5 presents a line drawing of a typical six cylinder engine. Two compression gauge readings are shown labeled "first check" and "second check." Oil is shown being added between the two checks. The second compression check gauge readings are approximately 15 to 20 percent higher than the first readings. The examinee must choose from four exaggerated captioned line drawings the one which represents the cause for the variation in compression readings. For successful completion of this item the examinee must possess the same abilities as required in the previous item.

Test item 6 presents the examinee with an assortment of four specialized tools in picture form. The verbal statement indicates that the examinee is to examine the tools and to determine their intended use. Four pictures are presented showing: 1) a man installing a muffler assembly; 2) a cutaway of a typical V-8 engine assembly; 3) a close-up of the left side front suspension assembly; and 4) an exploded view of a rear axle assembly. The requirement is for the examinee to determine the area for which the specialized tools are designed. In order to successfully complete this test item the examinee must have a general knowledge of overall vehicle service and must have utilized the tools pictured in this particular item. It is doubtful if having read about such tools, he would group them all together as they are

pictured here for servicing only one particular vehicle area. In utilization of the tools, however, the examinee or the mechanic would have used all four of them in performing the indicated task in the psychomotor area.

Test item 7 presents the examinee with a line drawing of a typical oscilloscope pattern as might be seen while checking cam dwell angle. Accompanying this drawing is an indication of proper dwell specification. A verbal statement asks the examinee which way the stationary breaker point must be moved in order to correct the dwell pattern shown on the oscilloscope. Four line drawings of a typical breaker point cam and breaker point assembly are shown, each with an arrow showing a direction of stationary point movement. The examinee must select the one which moves the stationary point in the proper direction to bring the dwell within the factory specification range. In order for the examinee to successfully complete this test item, he must have had extensive experience in installation and adjustment of breaker points.

Test item 8 presents the examinee with a line drawing of a typical six cylinder engine. A compression gauge is shown in each cylinder. The first four gauge indications show a reasonably normal compression reading. The two gauges in cylinders number five and six show a very low compression reading. A verbal statement indicates that the examinee is to choose from four possible answer choices the one indicating the probable cause for the two low compression readings. The response choices appear as four views of the last two cylinders, number five

and six, with the cylinder head turned over so the examinee is able to view the combustion chamber and head gasket areas. A choice must be made relative to the one which would produce the compression reading shown. In order to successfully complete this test item the examinee must have performed such a compression check and have located such a condition either in the normal service setting or had the condition demonstrated in the laboratory.

Test item 9 presents the examinee with a line drawing of a typical carbon fouled spark plug assembly shown in cutaway form. This is followed by a verbal statement indicating the condition of a set of such spark plugs as removed from a typical engine. The condition of the spark plugs and the general condition of the engine from which they were removed is given. The examinee is asked to select a spark plug which would correct this condition from the four line drawings in cutaway form. In order for the student to successfully complete this item he must be very familiar with spark plug heat ranges and manufacturer's specifications. He must also have had wide experience in the installation of spark plugs to correct varying heat range conditions which are normally found in vehicles operating in both cities and on open highways or he must have witnessed a demonstration in the laboratory.

Test item 10 presents the examinee with a line drawing or schematic drawing showing a typical 12 volt ignition circuit. Following this is a verbal statement of a malfunction which could occur in the service setting. The examinee is asked to choose from four line drawings the

one which would most likely cause the malfunction indicated. In order for the examinee to successfully complete this test item he must have either encountered this difficulty in the service setting or he must have had this particular phenomenon demonstrated in a laboratory.

Test item 11 presents the examinee with two views of typically burned piston assemblies. A verbal statement indicates that these are badly burned pistons. An additional verbal statement asks for the most probable cause of pistons appearing as those pictured. The examinee is presented with three line drawings and a verbal statement as answer choices. He is to choose the alternative which most likely caused the piston condition shown. In order for the examinee to successfully complete this item he must have encountered such piston conditions in the service setting or he must have had this condition explained and demonstrated in the laboratory.

Test item 12 presents the examinee with a typical line drawing of a six cylinder engine. In each of the six cylinders is drawn a compression gauge. All gauge readings are normally high with the exception of cylinder number three which indicates a very low compression reading. Next is shown cylinder number three sectioned out of the drawing with an air supply line properly attached to this cylinder to deliver air pressure directly into the cylinder. A third line drawing shows the mechanic looking into the radiator with the cap removed. He is observing air bubbles in the radiator coolant. The examinee is asked to choose from four additional line drawings, the one which most likely explains this observed condition. The four

line drawings or answer choices show the cylinder head removed from the engine and the combustion chamber and gasket assembly of cylinder number three turned over so the examinee is able to directly view the area in question. In order for the examinee to successfully complete this test item he must have either encountered this condition in the service setting or had it demonstrated in the laboratory.

Test item 13 presents the examinee with a line drawing of a cylinder bore gauge shown positioned in a cylinder with two decimal readings shown, using extension lines from the gauge face. A verbal statement explains these two decimal readings. The examinee must choose from three additional line drawings and one verbal statement the one which most likely satisfies the requirements for restoring this engine block assembly with cylinder conditions, as indicated, to a serviceable condition. In order for the examinee to successfully complete this test item he must have either encountered such engine block conditions in the service setting or he must have had this particular procedure performed in the laboratory and followed this with actual reconditioning of the engine in question.

Test item 14 presents the examinee with a picture of a typical piston assembly with a given skirt treatment evident on the surface. This is followed by a statement indicating that this piston has received certain skirt treatment. The question is asked: "Why is the process performed?" The student is to choose from four line drawings and one verbal statement, the one which best explains the reason for the skirt treatment shown in the picture. In order for the examinee to

successfully complete this test item he must have seen this type of skirt treatment performed in the service setting or under laboratory conditions accompanied by an explanation of exactly what this accomplishes as far as piston service is concerned.

Test item 15 presents the examinee with a picture of an exploded view of a differential assembly with all parts correctly labeled. Following this is a verbal statement indicating that the examinee is to study this exploded view carefully. The next statement asks a question concerning the equipment used to determine correct pinion gear depth. Four line drawings are presented of a typical pinion gear and various measuring instruments, each of which is followed by a verbal statement explaining that particular means of measurement. The examinee is asked to choose the one response which best explains the setting of pinion gear depth. In order for the examinee to successfully complete this item he must have either performed ring gear and pinion pattern setup in the service setting or had it explained to him in the laboratory, followed by actual practice in setting and adjusting ring gear and pinion patterns.

Test item 16 presents the examinee with a line drawing of a typical V-8 engine drawn in such a manner as to indicate that it is idling. Shown connected to the intake manifold of this engine is a typical vacuum gauge with the needle indicating a steady, very low reading. This is followed by a statement asking the examinee to determine the most likely cause of this vacuum gauge indication. Four additional line drawings appear, each showing a particular engine situation. The

examinee must choose the one which would most likely cause the gauge reading indicated. In order for the examinee to successfully complete this test item he must have had service setting experience utilizing the vacuum gauge in troubleshooting or he must have had the vacuum gauge explained in detail under actual use conditions in the laboratory and followed this by extensive practice, utilizing a variety of engines exhibiting varying problems detectable using this instrument.

Test item 17 presents the examinee with an oscilloscope pattern showing a particular primary ignition circuit difficulty. Accompanying this drawing is a verbal statement: "Observation: inverted polarity image." The question is asked, "What would cause the above scope pattern?" Four additional line drawings are presented showing possible electrical problems which might produce this type of scope pattern. The examinee must choose the one which produces an oscilloscope pattern of this nature. In order to successfully complete this item, the examinee must have had extensive experience utilizing the oscilloscope either in the service setting or in the laboratory with various patterns demonstrated and carefully explained.

Test item 18 presents the examinee with a photograph of two engine bearing insert halves which show a very definite wear toward their outside edges. The verbal statement accompanying this photograph indicates that the examinee carefully examine the picture of the two insert bearing halves and choose from the possible responses the one which would most likely produce a wear pattern such as indicated. Four line drawings are presented, each accompanied by a verbal statement, indicating engine problems. In order for the examinee to successfully

complete this test item, he must have had wide experience at the service setting or have had numerous engine bearing problems explained of various engines with high mileage or having been operated with lack of proper lubrication, resulting in crankshaft deterioration.

Test item 19 presents the examinee with an oscilloscope pattern in line drawing form showing a dwell overlap condition. A verbal statement indicates the observation: "Dwell Line Overlap," followed by a question: "What would cause the above oscilloscope pattern?" Four line drawings are presented of various components of the ignition system, each followed by a verbal statement of explanation. The examinee must choose the one which would most likely cause the pictured condition. In order to successfully complete this item the examinee must have had service setting experience or a detailed explanation in the laboratory setting followed by extensive practice involving use of the oscilloscope.

Test item 20 presents the examinee with a line drawing of a typical tapered roller bearing. The question is asked: "What is the correct procedure for checking a tapered roller bearing?" Four additional line drawings are presented showing the bearings being treated in various ways. Each is accompanied by a verbal statement of explanation. The examinee must choose the one which best indicates the proper method for checking the condition of a tapered roller bearing. In order to successfully complete this test item the examinee must have had experience in cleaning, drying, and inspecting this type of bearing

assembly either in the service setting or in a laboratory following proper instruction concerning bearing construction, care, and treatment.

Test item 21 presents the examinee with a line drawing of gauging plastic and the appropriate measuring gauge. This is followed by the question: "How is engine main bearing clearance checked?" Four additional line drawings appear, each accompanied by a verbal statement, showing a cross section through an engine crankshaft, main bearing insert half and engine block bearing support webb. The examinee must choose the one depicting proper utilization of gauging plastic. In order for the examinee to successfully complete this test item he must have had experience utilizing this measuring device either in the service setting or in the laboratory following proper instruction in the correct use and interpretation of this measuring device.

Test item 22 presents the examinee with a line drawing of a micrometer shown positioned on a sectioned view of a typical crankshaft rod journal. Also presented is a typical example of factory rod journal specifications. A verbal statement is given: "All four connecting rod journals indicate the reading shown on the micrometer. Which of the following procedures should be followed?" Four additional line drawings are presented, each accompanied by a verbal statement of explanation. In order for the examinee to successfully complete this test item he must first be able to understand the manufacturer's specifications, be capable of reading a micrometer, be able to

interpret this reading, and compare it with stated specifications. The examinee must then make a judgment as to exactly what the crankshaft condition actually is and determine what procedure should be followed in restoring this crankshaft to serviceable condition for installation into an engine block assembly during a typical overhaul job. He must have had experience in either the service setting or in the laboratory followed by extensive practice in measuring various crankshafts and interpreting their condition.

Test item 23 presents the examinee with a set of rod bearing insert halves photographed after having been removed from an engine run with low oil pressure or no oil pressure. Accompanying this photograph is the statement: "Carefully examine the picture of the connecting rod bearing halves. Which of the following conditions will produce a failure of this type?" Additional line drawings appear showing possible causes for bearings appearing as those in the photograph. The examinee must choose the answer which would best explain bearings with the appearance of those shown. In order for the examinee to successfully complete this test item he must have had wide experience in analyzing engine bearing condition either in the service setting or in the laboratory, following extensive explanation and understanding of engine bearing life expectancy as well as conditions which will lead to their ultimate failure.

Test item 24 presents the examinee with a line drawing of a typical V-8 engine shown so it appears to be idling. Connected to the

intake manifold is a typical vacuum gauge. The needle of this gauge is shown oscillating through a range of 17 to approximately 23 inches of mercury. Accompanying this line drawing is the statement:

"Observation: vacuum gauge needle exhibits a continuous floating or oscillating motion." This is followed by the question: "Which of the following is the most likely cause of this vacuum gauge indication?" Four additional line drawings appear showing engine conditions which might lead to such a vacuum gauge indication. The examinee must select the one which would most likely cause the gauge indication shown. In order for the examinee to successfully complete this test item he must have had wide experience in engine troubleshooting involving an understanding of engine performance and theory. This experience could have been gained in the service setting or in the laboratory, having observed the various vacuum gauge indications as related to varying engine problems both superficial and mechanical in nature.

Test item 25 presents the examinee with a photograph of a particular valve guide of integral design being measured with a telescoping small hole gauge and appropriate micrometer. Accompanying the photograph is the statement: "Using the telescoping small hole gauge, two exhaust valve guides show varying wear as indicated. Since these are nonreplaceable valve guides, which of the indicated corrective measures should be followed?" Line drawings appear depicting possible corrective measures or alternatives. The examinee must choose the one which would best solve the valve guide problem indicated. In order for the

examinee to successfully complete this test item he must be familiar with the small hole gauge, its use, as well as utilization of the micrometer. Further, he must be familiar with the various types of valve guides used in the manufacture of cylinder heads. Also, he must be knowledgeable in cylinder head service, involving both reaming of valve guides to accept oversize valve stems as well as the knurling process which, in effect, decreases the diameter of the valve guide so that original size valves may be reinstalled.

Test item 26 presents the examinee with a photograph of a typical used piston assembly. Accompanying this photograph is the verbal statement: "A typical piston as removed from an engine during a major overhaul." Appearing with the picture is the statement: "Examine the above piston carefully, paying particular attention to the wear pattern evident. Which of the conditions results in this type of wear?" Four line drawing answer choices appear, each accompanied by a verbal statement. The examinee must choose the one which is the most likely cause for the appearance of the piston pictured. In order for the examinee to successfully complete this test item he must have observed many different piston assemblies as they have been removed from engine blocks during examination prior to either major overhaul or junking of the assembly. This could only be observed in the service setting or in the laboratory followed by a detailed explanation by an instructor concerning the various problems which result in pistons having characteristic wear patterns evident on their surfaces.

It was stated by the jury of experts that this paper and pencil test exhibited a non-verbal approach not found in any other automotive mechanics test with which they were familiar. Further, they indicated that it approached the testing of a true performance skill because it required the examinee to recognize a problem, analyze conditions, interpret test results and make a judgment, prior to selection of answer. The automotive mechanic follows this process in the service setting if he is a successful craftsman.

ANALYSIS OF TEST DATA

The results of administering the performance test to the 124 automotive mechanics students were returned to the researcher in the form of completed checklists. These checklist items were coded on optical scan forms so that they could be automatically reproduced on punch cards along with other necessary data including student class section, assigned student number, and school number. This process resulted in a data deck with all necessary information concerning each student and his respective performance test results.

The data from the paper and pencil test were already on the optical scan forms since these served as the answer sheets when the researcher administered this test form. As each school group was tested the researcher coded the necessary additional information on each optical scan form in a manner exactly corresponding with the performance test data. This process, following the automatic card punching procedure, resulted in a data deck with all necessary student information pertaining to the paper and pencil test.

This phase completed, the Biomedical Computer Program BMD 02D was selected to compute the Pearson product-moment correlation coefficient (r). "This program computes simple correlation coefficients, averages and measures of dispersion on entering variables . . ."

(Dixon, 1974:73) The results of this computation indicated a correlation of .5277 as an attenuated r . It was possible as a result of this analysis to extract the number of students who answered a varying number of both the paper and pencil test items and performance test items correctly. These totals are shown in descending order in Table 1.

According to Downie and Heath (1965:79) ". . . a scatterplot should be set up every time one is computing a correlation coefficient, no matter what computing technique is being used." The scatterplot for the correlation between the performance test and the paper and pencil test appears in the form of a computer printout in Figure 2. While this plot was not a perfect positive relationship, as indicated by the actual correlation figure, it did indicate a high positive relationship. As indicated by Downie and Heath (1965:79), "In actual life we usually have situations in which the relationship is not perfect." The scatterplot line, while not perfect, is still apparent.

In Figure 2 a cluster of 27 scores were plotted in the range of 18.0 on the abscissa and 21.0 on the ordinate. These scores were computer checked in order to determine whether they were all from one school. Had this been the case an error could have been made in performance test instrument administration or in transferring the test results to the optical scan forms. It was found, however, that these

TABLE I
 Number of Items Answered Correctly
 Per Test on Paper and Pencil Test and Performance Test

Number of Items	Number of Students Who completed Paper and Pencil Items	Number of Students Who completed Per- formance Items
26	0	13
25	3	4
24	3	4
23	3	13
22	3	8
21	2	2
20	2	1
19	5	11
18	3	2
17	9	3
16	6	5
15	5	5
14	10	6
13	10	11
12	9	4
11	8	5
10	14	6
9	9	4
8	9	3
7	3	1
6	3	1
5	1	1
4	0	0
3	0	2
2	0	1
1	0	0
0	4	8

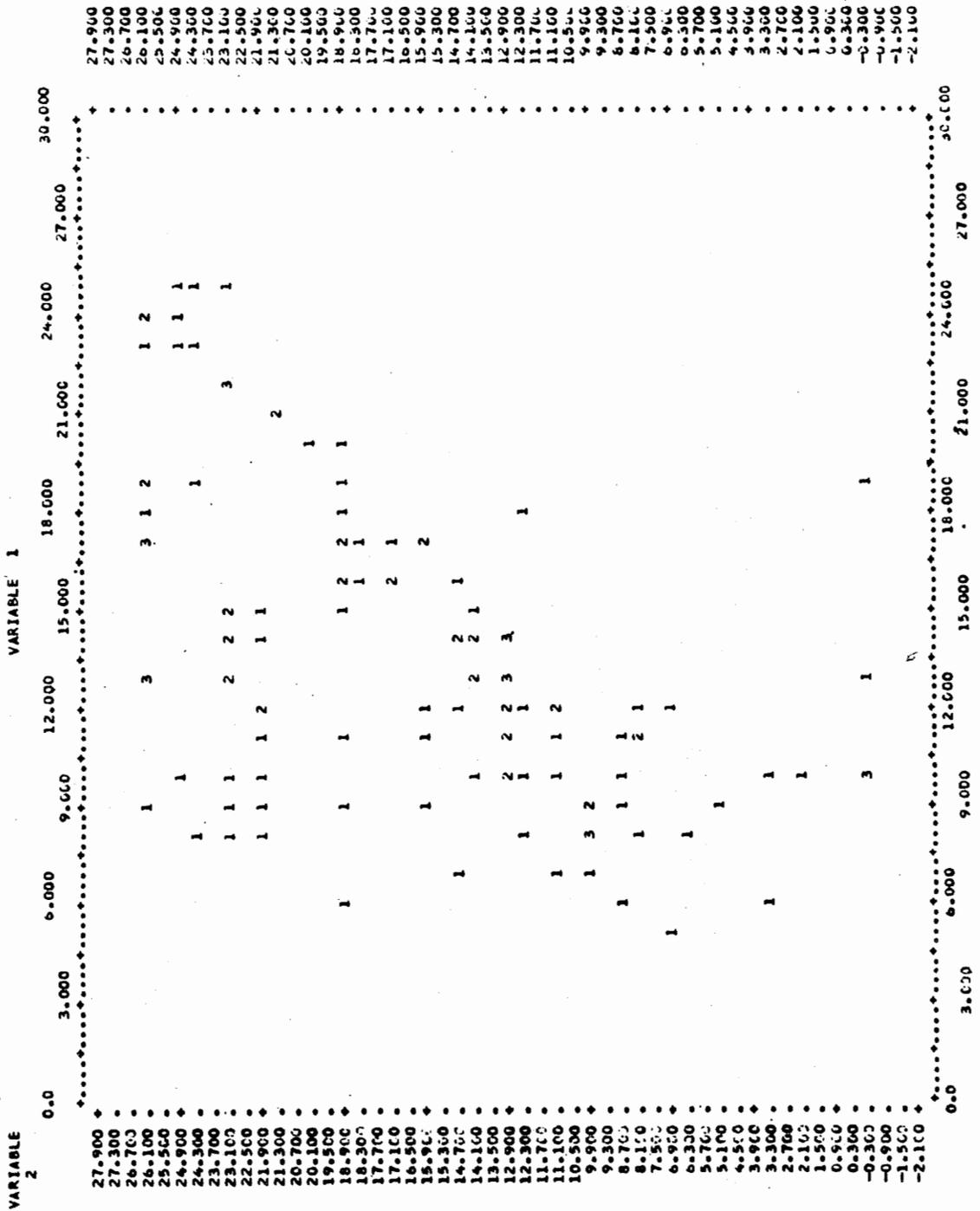


Figure 2. Scatterplot of the correlation between the paper and pencil test and the performance test.

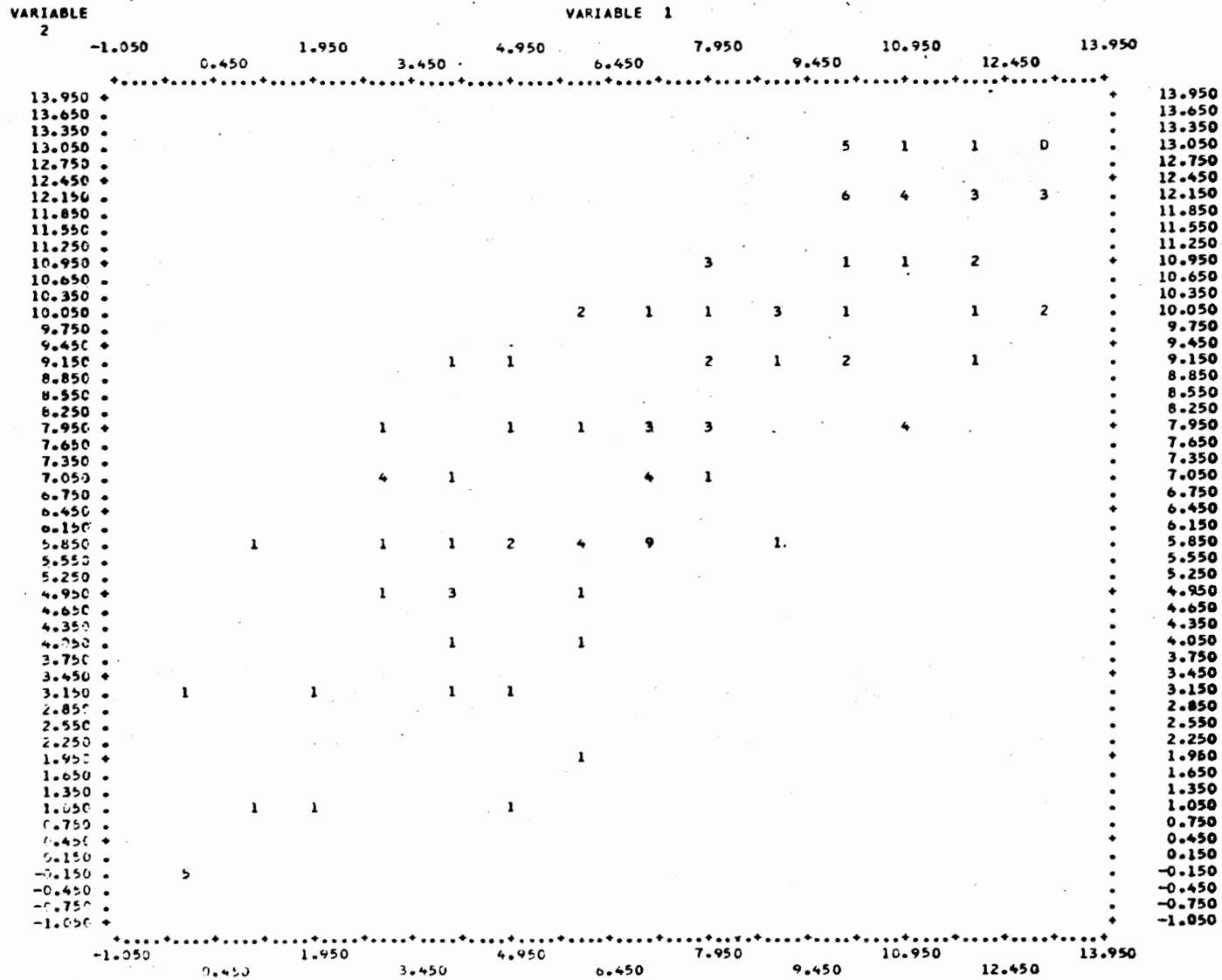
scores were from three different schools in a breakdown of 8, 9, and 10 scores respectively; no further investigation was carried out.

As indicated, the correlation coefficient of .5277 is an attenuated value. In order to correct for attenuation it was necessary to compute the reliability for both the performance test and the paper and pencil test. This was accomplished by employing the split-half odd-even method of computing reliability coefficients. The performance checklist scores had been punched on cards as a 1 for "Performed With Success" and 2 for "Could Not Perform." This same sequence was followed for the paper and pencil test thus indicating a 1 for a correct response and a 2 for each incorrect answer choice selected.

The reliability computations were completed employing a computer program, again using the Pearson product-moment correlation coefficient (r). The results of these computations indicated a reliability correlation coefficient of .8587 for the performance test and .6680 for the paper and pencil test. The scatterplot for the performance test appears as Figure 3 and indicated a high positive relationship between the two halves of the test. The scatterplot for the paper and pencil test is shown in Figure 4 and presented very definite homoscedasticity. While both scatterplots evidence this condition as well as linear regression, the paper and pencil test exhibits a wider spacing of the arrays on both the abscissa and ordinate which accounted for the lower r .

The reliability values were substituted, along with the original correlation coefficient value between the performance test and the paper and pencil test, in the formula to correct for attenuation. As a result of this computation an overall correlation coefficient resulted

Figure 3. Scatterplot of the correlation involving split-half odd-even scores of the performance test.



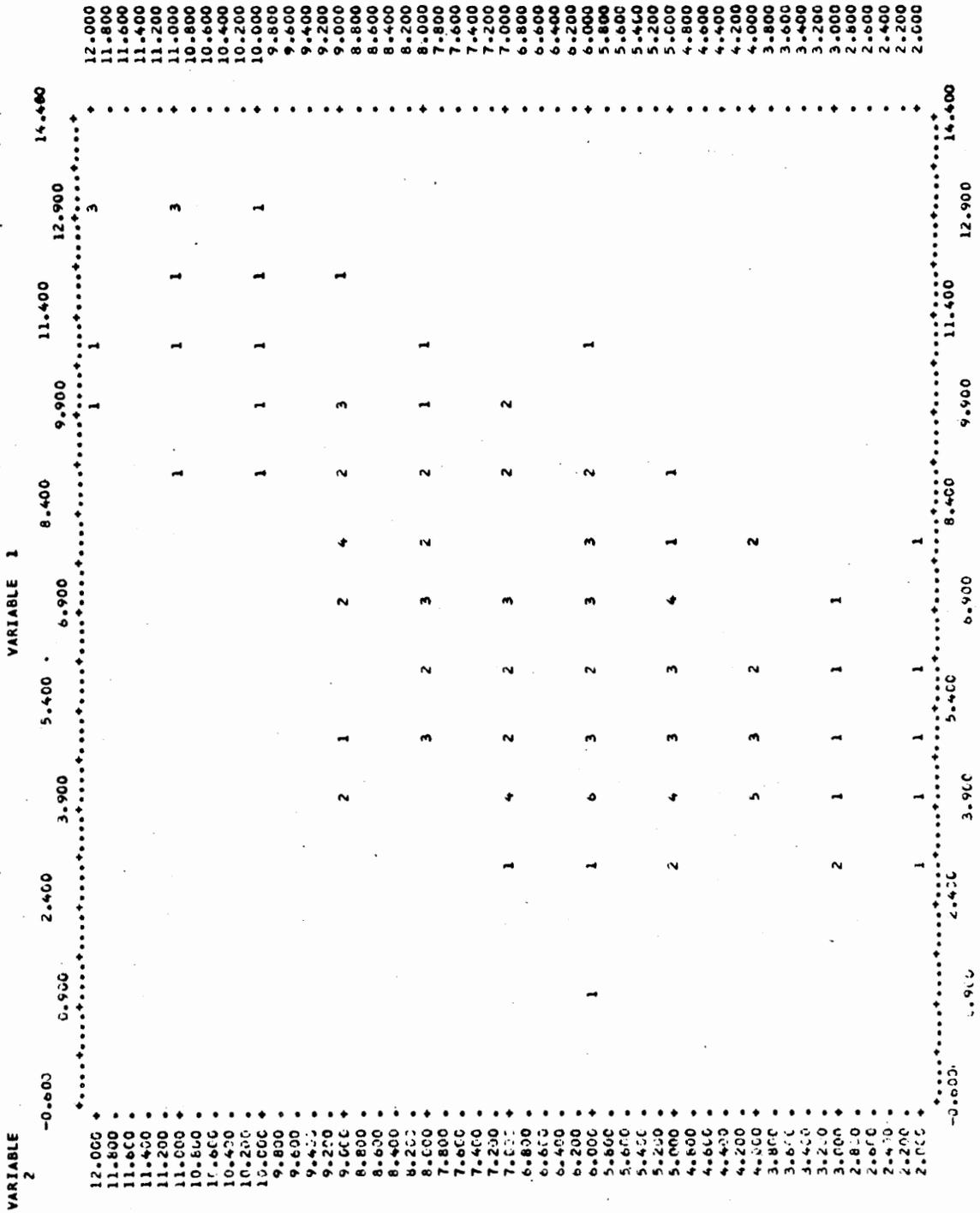


Figure 4. Scatterplot of the correlation involving split-half odd-even scores of the paper and pencil test.

in an r_c of .6967. The formula chosen to correct for attenuation is the one most generally used and is written (Downie and Heath, 1965:226):

$$r_c = \frac{r_{xy}}{\sqrt{r_{xx} r_{yy}}}$$

where r_c = the correlation between X and Y corrected for attenuation

r_{xx} , r_{yy} = the reliability coefficient of test X and test Y respectively

r_{xy} = the computed validity coefficient

thus
$$r_c = \frac{.5277}{\sqrt{(.6880) (.8587)}}$$

$$r_c = .6967$$

It was evidenced by remarks made by the student population involved in this study that this test proved to be favored over the traditional paper and pencil tests with which students were familiar. This fact is supported by the remarks of the examinees following completion of the paper and pencil test (Table 2). These remarks were transmitted to the researcher in the form of comments on a blank sheet of paper provided during the administration of this test. These comments have been changed only to that extent which allows them to read consistently but while retaining the basic concept. Many students offered several comments, some only one or none at all.

TABLE II

Listing of Comments Concerning the
Paper and Pencil Test

Number Responding	Percentage Of Total	General Comment Category
92	74	This is the best test I have taken involving mechanics.
81	65	I think this is a very fair test.
65	52	I didn't know some of the answers but with the pictures I could figure them out.
87	70	I wish all auto mechanics test were like this.
54	43	This test is like being in the shop except you don't get dirty.
72	58	This is more like the tests we have in the shop part of the class.
82	65	I had rather take this test than the regular type.
63	50	If I have to take tests, I like this one best.

CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

SUMMARY OF THE STUDY

Purpose

This study involved: 1) the selection of a number of accepted performance task items agreed upon by a jury of experts as valid for testing automotive mechanics students; 2) the formulation of each accepted performance task into a paper and pencil test item; and 3) obtaining a correlation between the two like tests of at least .71 corrected for attenuation which would account for 50 percent of the variance, thus indicating the feasibility of testing a performance or manipulative skill using a paper and pencil instrument.

The purpose created a need to state four research questions which where as follows:

1. Can a sample of accepted performance items used in testing automotive mechanics trainees be selected by a jury of experts?
2. Can a paper and pencil achievement test be developed which can measure performance skills?
3. Can the paper and pencil achievement test developed during this study be validated?
4. Can a correlation corrected for attenuation between an accepted performance test and a like paper and pencil test be achieved which would account for 50 percent of the variance?

Methodology

The early phase of this study involved the preparation of a suitable performance test. Each item of that test was then redesigned into a like problem in paper and pencil form. A jury of experts was selected to aid in designating the tasks to be included as items in the performance test. The jury of experts included ten automotive mechanics instructors and four employed mechanics.

The student population was chosen from four geographic locations in Virginia (Appendix A). The 124 students at these four locations were members of either the first or second year automotive mechanics classes.

Constraints of available shop equipment and administration time dictated a test that would not exceed thirty performance items. The final test consisted of twenty-six items covering various vehicle service areas. The test was never intended to be comprehensive since no competency measure was attempted, therefore, the jury of experts agreed that the items need not relate to each other. The construction of the performance test involved a ranking of the items selected by the jury of experts from those items considered most important to those of lesser importance.

The paper and pencil test instrument had to be designed to duplicate as nearly as possible the content of the performance test items. The successful automotive mechanic possesses a sound basic knowledge of theory, construction, and operation as they are related to his field of performance expertise. The researcher reasoned that the design of the

paper and pencil test instrument must be such that the same knowledge and skill should be prerequisite for successfully completing the paper and pencil test as for the performance test.

The researcher and the jury of experts realized that the degree of difficulty among the selected 26 performance test items and matched paper and pencil test items varied greatly. It was decided to conduct a pilot study in Montgomery County (Appendix A) and subject the results to item analysis for ranking purposes. Two Automotive Mechanics II classes totaling 25 students took the paper and pencil test. Following data analysis, all items were ranked in order from those answered most easily to those answered with most difficulty.

The initial step in data collection involved contacting each school division superintendent and director of vocational education. A copy of this letter was also sent to each school principal and automotive mechanics instructor involved (Appendix D). Having gained permission to conduct the study in four counties (Appendix A) the researcher contacted all participating instructors and gave them necessary performance checklists (Appendix B). Each instructor administered the 26 performance items to each student in both his first and second year classes over a period of three months.

The paper and pencil test (Appendix C) was administered by the researcher in May 1974 to each class involved in the study. A test booklet, optical scan answer form (Appendix E), and a number two pencil was given to each student followed by detailed instructions concerning how to take the test and correctly mark the answer form.

Test scoring involved the transfer of all performance test data to optical scan forms for automatic key punching onto data cards. Additional information concerning class section, assigned student number and school code was also included on the data cards. The paper and pencil test data were on the optical scan forms, therefore, after coding the additional student and school data these were automatically key punched, thus producing two similar data decks. The data were analyzed totally by computer.

Summary of Data

One of the initial research questions posed for this study was: Can a correlation corrected for attenuation between an accepted performance test and a like paper and pencil test be achieved which would account for 50 percent of the variance? With all scores from both the performance test and the paper and pencil test on data cards a computer program to compute the Pearson product-moment correlation coefficient (r) was written. The printout indicated an attenuated r of .5277. In order to correct for attenuation it was necessary to compute the reliability for both the performance and paper and pencil tests. Since both tests had been administered only once the split-half odd-even method for computing reliability was chosen. Both tests were so divided by computer and the necessary computation performed using the Pearson product-moment correlation coefficient (r). The results of this computation indicated an r of .8587 for the performance test and .6680 for the paper and pencil test. The performance test reliability was highly positive, however, the paper and pencil test reliability, while acceptable, was lower than had been anticipated.

The reliability figures were substituted along with the initial correlation figure into the formula to correct for attenuation. As a result of this computation a corrected correlation was obtained producing an r_c of .6967, thus accounting for 49 percent of the variance. In order to have accounted for 50 percent of the variance, an r_c of .71 was required.

CONCLUSIONS

This study involved two separate types of test instruments. The performance test instrument was administered by five different persons in four locations over a wide geographic portion of Virginia, while the paper and pencil instrument was administered in the same four locations solely by the researcher. Based on the findings of this study, however, the following conclusions may be drawn:

1. The jury of experts can be used to select acceptable performance test items.
2. Performance skills can be measured using a paper and pencil achievement test of the design developed for use in this study.
3. The paper and pencil achievement test developed for use in this study evidenced both content and concurrent validity.
4. A correlation corrected for attenuation of $r_c = .6967$ was achieved which accounted for 49 percent of the variance.
5. It is very likely that an automotive mechanics student who correctly answered certain items or all 26 items on the paper and pencil test used in this study can successfully perform these same tasks in the performance setting.

6. Successful completion of paper and pencil test items relating to other vehicle service areas cannot be generalized from successful completion of the items included on the paper and pencil test developed for this study.
7. Regardless of the degree of success achieved by the individual students on the paper and pencil test, no on-the-job success can be predicted as a result of this study.
8. As a result of the r_c obtained in this study it is highly feasible to continue investigation concerning the development of an expanded paper and pencil test for automotive mechanics.

IMPLICATIONS

The implications listed are based not only on the results of this study but upon the past experience of the researcher involving a variety of mechanical work experience in the field of both marine and automotive service. Further experience was gained as a high school automotive instructor during which time a number of paper and pencil tests were tried. None of these tests approached the problem in the manner employed in this study.

1. It is evident that many students in automotive mechanics simply do not like written tests. This produces a very definite negative attitude. If, however, the test is of a unique design and will get the students' attention, such as the type used in this study, some of the antagonism seems to disappear and they take a more genuine interest.

2. Considering the fact that the r_c between the performance test and the paper and pencil test lacked only one hundredth of a point of accounting for 50 percent of the variance, additional research appears justified.
3. It appears that not all students in the automotive mechanics classes involved in this study actually intended to work in this field. More extensive counseling and guidance would benefit many of the students.
4. It is the judgment of the researcher that while not every service area can be designed into a paper and pencil test form, the possibility exists that a large portion of tasks now tested only in the performance setting could be more economically tested through the proper paper and pencil approach.

RECOMMENDATIONS

Recommendations for Administration of Performance and Paper and Pencil Achievement Tests

When two similar instruments are to be administered and subsequently compared the following points should be considered:

1. The performance test should be administered during the first semester of the school year. This should be followed very soon by the paper and pencil test.
2. Administration of the performance test should be observed by the researcher or at least by someone not connected with the participating school. This would do two things: 1) keep the testing

- sequence moving at a predetermined rate, and 2) reduce the likelihood of subjective judgment biasing the checklist scoring.
3. All photographs used in the makeup of the paper and pencil test should be taken by the researcher to fit the specified needs as opposed to using available pictures such as those appearing in service manuals and textbooks. This would make all the pictures suit the questions rather than adapting the questions to the available pictures. Thus, an even more realistic situation could be produced in paper and pencil form.
 4. The paper and pencil instrument should be kept as nearly as possible in a non-verbal form. This was the approach attempted in this study though some items included several lengthy verbal statements. The examinees preferred those items which required the least amount of reading according to informal discussion following the test.

Recommendations for Further Study

Research should be conducted to determine if an expanded paper and pencil test instrument of the design used in this study:

1. could serve as a pretest for first year automotive mechanics students. This would be of definite benefit where the auto-tutorial instructional system was used.
2. could serve to establish a level of automotive service knowledge and ability possessed by an individual during any phase of his training.

3. could serve as a criterion to determine if an individual has attained the knowledge necessary for entry into the automotive service field.
4. would produce scores which could be compared with percentile scores of select areas of certain aptitude tests such as the Armed Services Vocational Aptitude Battery (ASVAB), for example, Mechanical Comprehension, Shop Information, Automotive Information or Electronic Information. This comparison would be useful in a determination of an individual's aptitude and likelihood of realizing success in the automotive service field.
5. could be constructed to cover the total range of automotive service areas.

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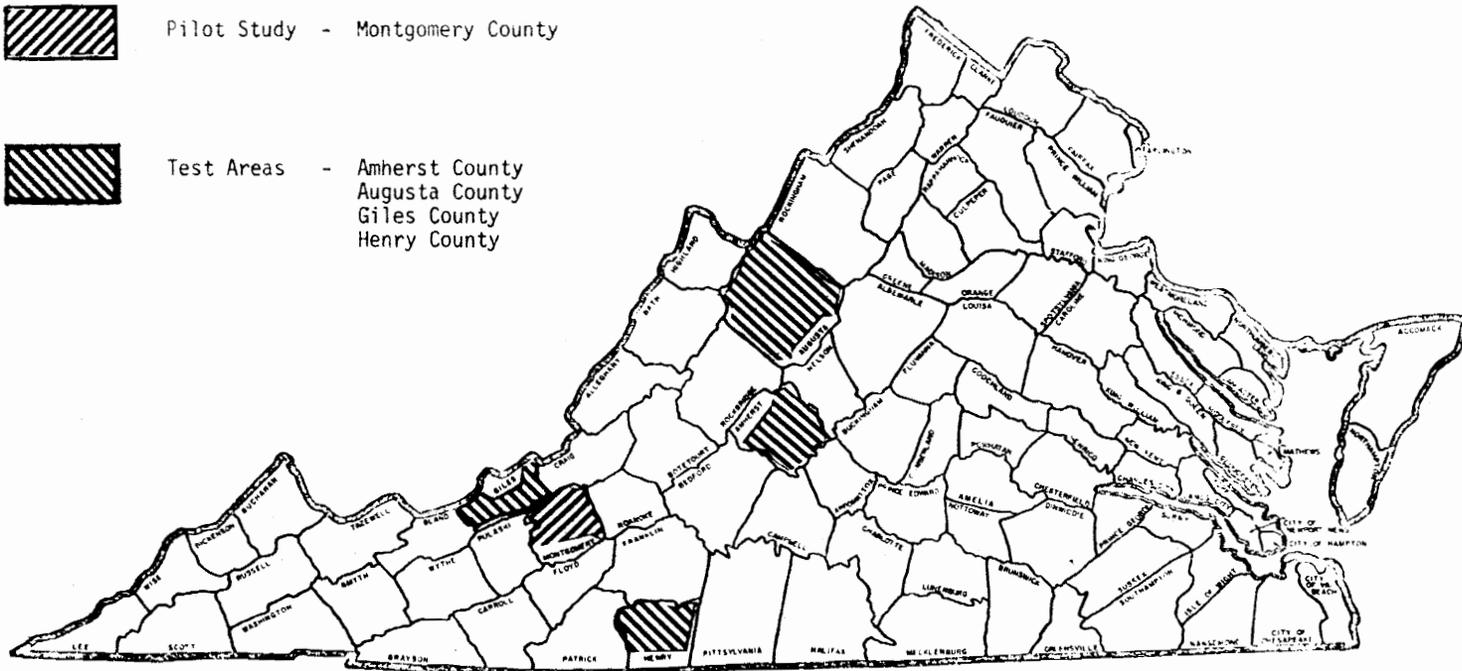
APPENDICES



Pilot Study - Montgomery County



Test Areas - Amherst County
Augusta County
Giles County
Henry County



COUNTIES OF VIRGINIA

APPENDIX A

APPENDIX B

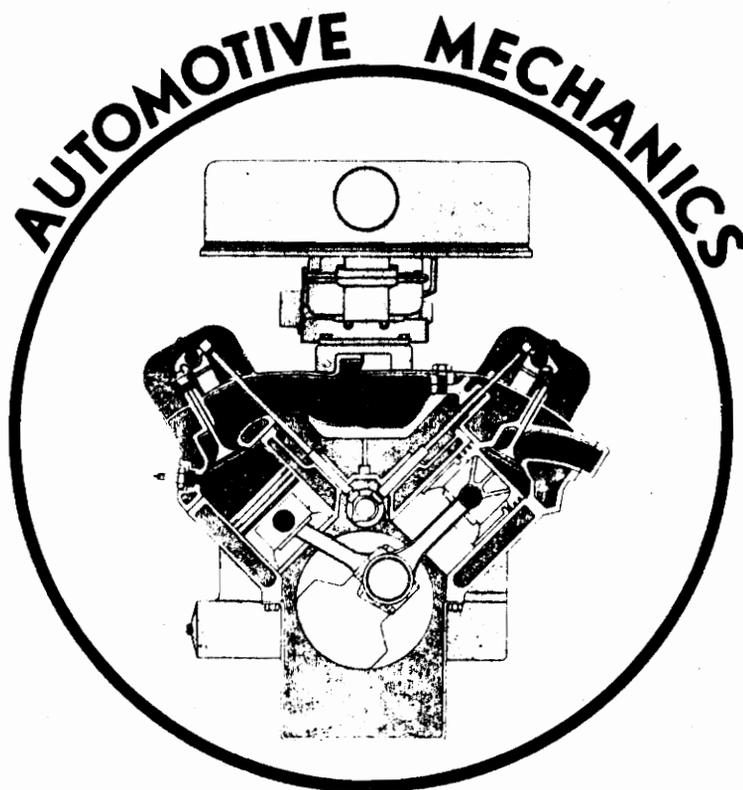
Student Name _____ Social Security Number _____ Automechanics Section _____

	Performance Task Description	Performed With Success	Could Not Perform
1	Demonstrate power flow through 4-speed transmission in third gear (5 min.)		
2	Demonstrate power flow through 4-speed transmission in reverse gear (5 min.)		
3	Demonstrate power flow through 4-speed transmission in first gear (5 min.)		
4	Perform camshaft lobe condition test (installed) (25 min.)		
5	Perform compression test for ring condition and interpret results (25 min.)		
6	Select proper tools for replacement of welded on muffler (5 min.)		
7	Move the stationary point to correct too high dwell (GM type) (5 min.)		
8	Perform test resulting in detection of a blown head gasket between two cylinders (25 min.)		
9	Choose the spark plug to correct a sooty carbon deposit on existing plugs (5 min.)		
10	Isolate a defective primary current resistor (5 min.)		
11	Examine a burned piston stating 3 factors which will result in such a condition (5 min.)		
12	Perform a compression test for detecting blown head gasket into water jacket (25 min.)		
13	Determine average cylinder condition for a typical V-8 (10 min.)		
14	Recognize and state the function of knurlizing pistons (5 min.)		
15	Select tools and set up pinion depth for a given ring gear/pinion set (20 min.)		
16	Isolate the cause of a steady low vacuum gauge reading (typical V-8) (10 min.)		
17	Isolate the cause of a reversed polarity scope pattern (5 min.)		
18	Examine and state the cause for marginal wear on insert bearings (5 min.)		
19	Isolate the cause of dwell overlap seen on the scope (5 min.)		
20	Correctly determine the condition of a front bearing cone (5 min.)		
21	Determine main bearing clearance with gauging plastic (10 min.)		
22	Determine crankshaft condition in relation to specifications (10 min.)		
23	Examine and state cause of insert bearing failure from lack of oil (5 min.)		
24	Isolate the cause of a continuously floating vacuum gauge (10 min.)		
25	Measure and state corrective action for work integral valve guides (10 min.)		
26	Examine and state the cause for a piston condition due to bent rod (5 min.)		

APPENDIX C

ACHIEVEMENT TEST

in

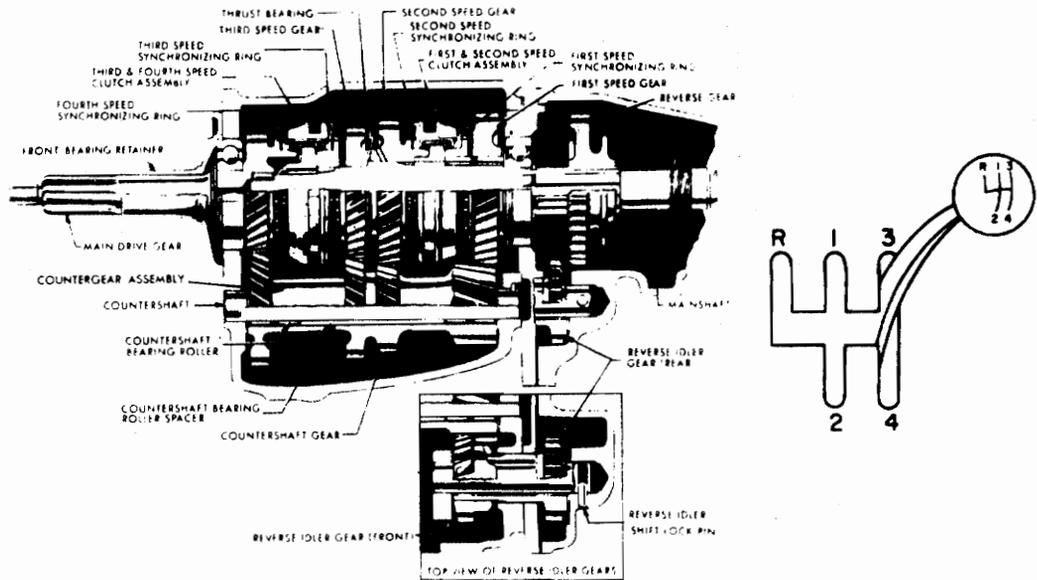


PREPARED
BY
W. R. WILLIAMS

VOCATIONAL EDUCATION EVALUATION PROJECT
DIVISION OF VOCATIONAL & TECHNICAL EDUCATION
COLLEGE OF EDUCATION

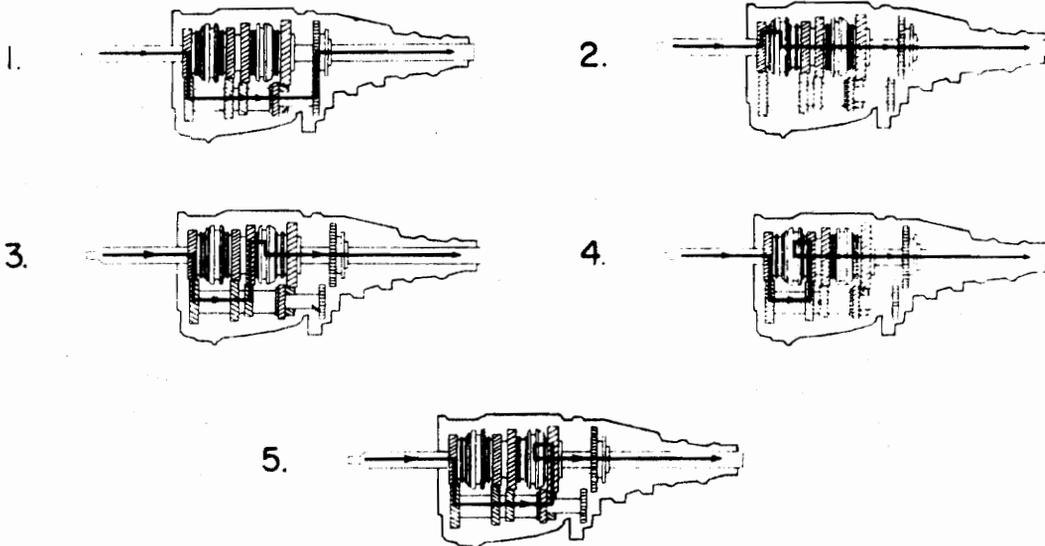
VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY
BLACKSBURG, VIRGINIA

Test Item 1

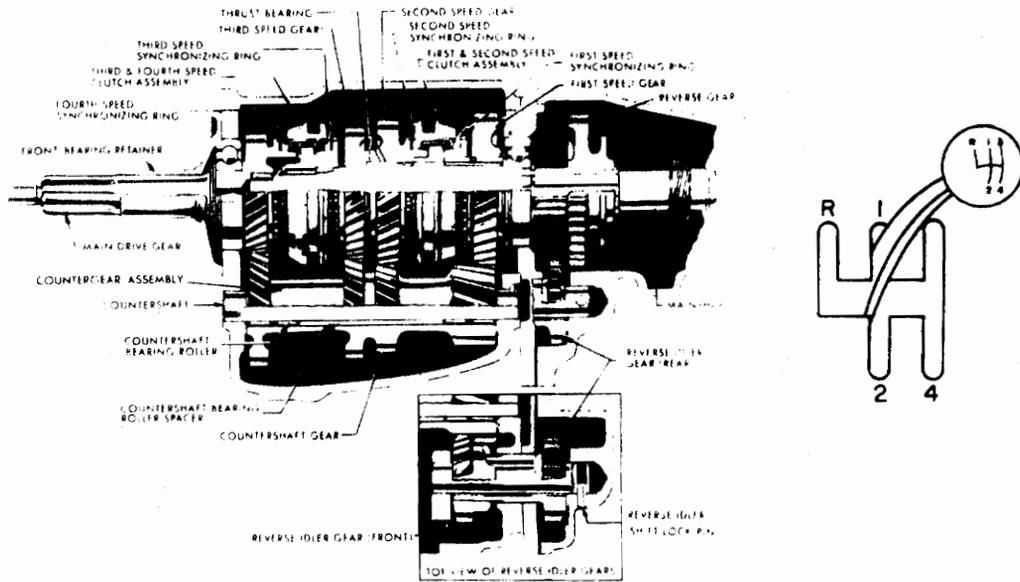


Carefully study the cutaway of the transmission noting the position of the various gears and clutch assemblies.

From the Figures 1-5 below, select the one which shows the power flow when the transmission is placed in third gear.

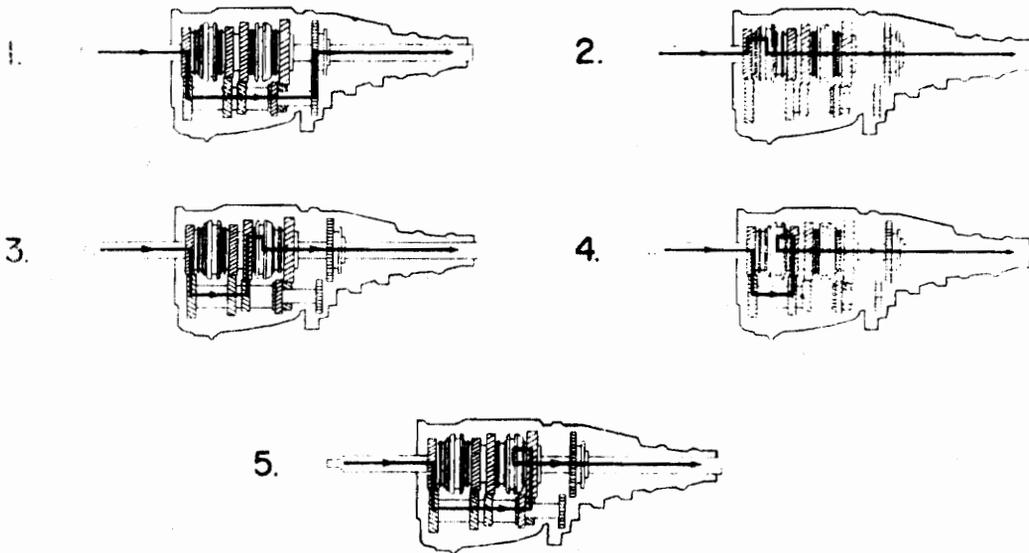


Test Item 3



Carefully study the cutaway of the transmission noting the position of the various gears and clutch assemblies.

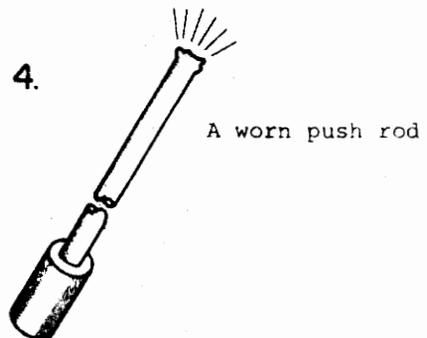
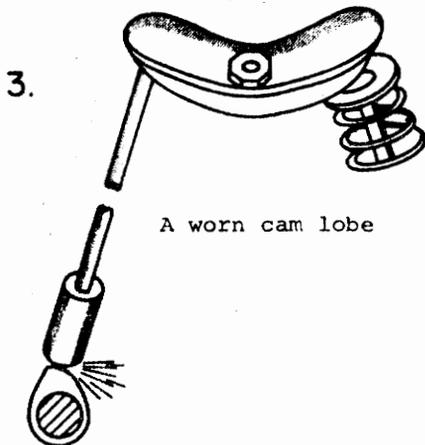
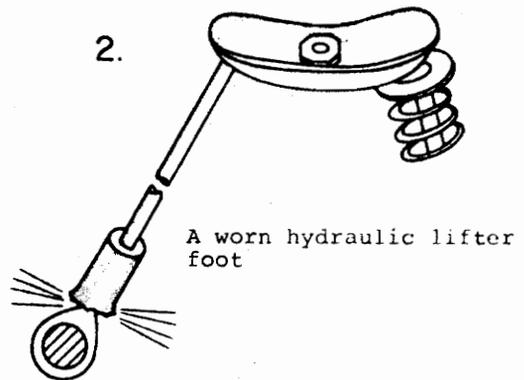
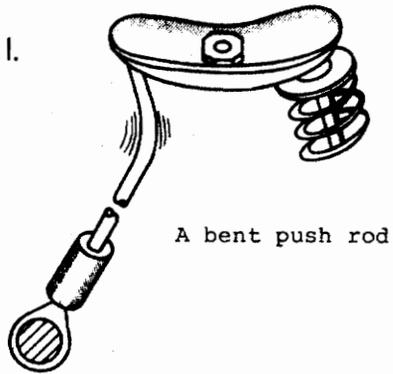
From the Figures 1-5 below, select the one which shows the power flow when the transmission is placed in first gear.



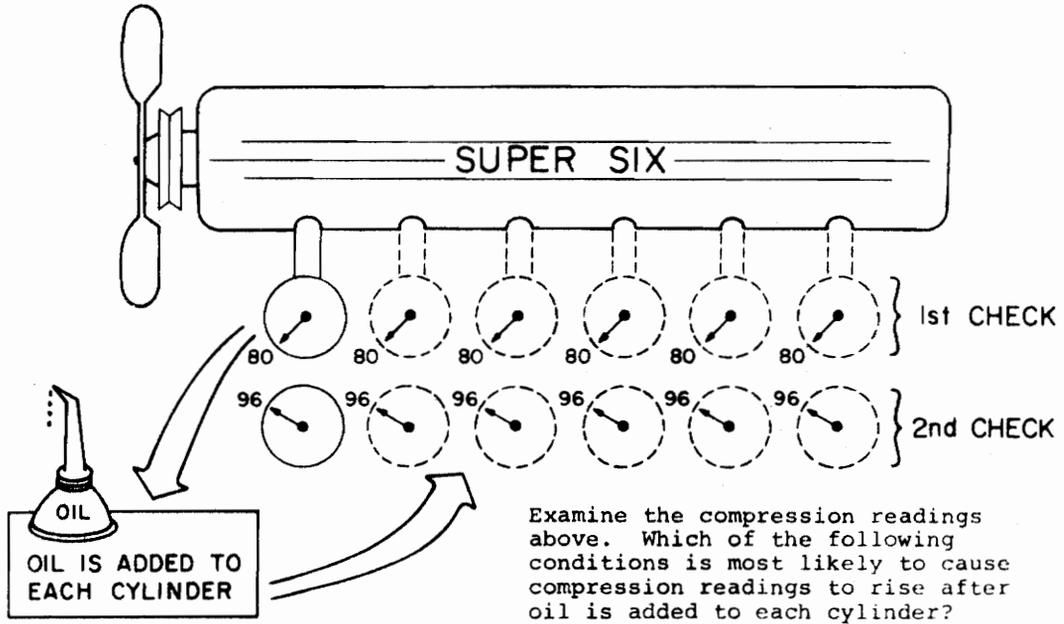
Test Item 4



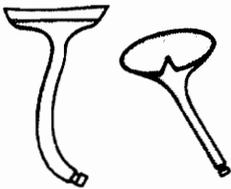
Fifteen cam lobes lift within an average of .004" of manufacturers specifications but one lobe lacks .063" of meeting specifications. Which of the following is the most likely cause of this condition?



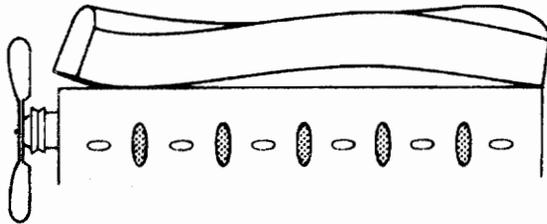
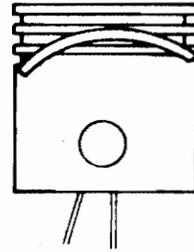
Test Item 5



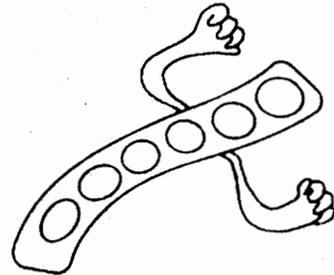
1. Bad valves



2. Worn piston rings

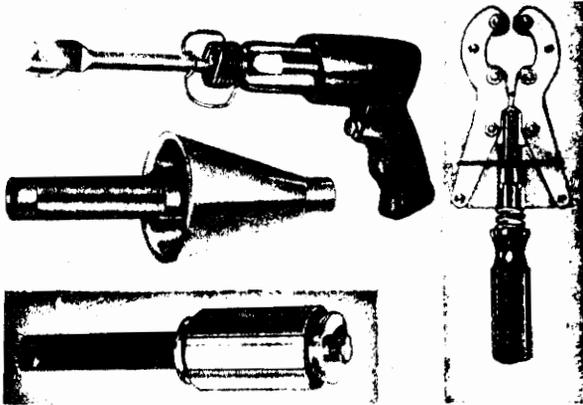


3. Warped cylinder head



4. Bad head gasket

Test Item 6

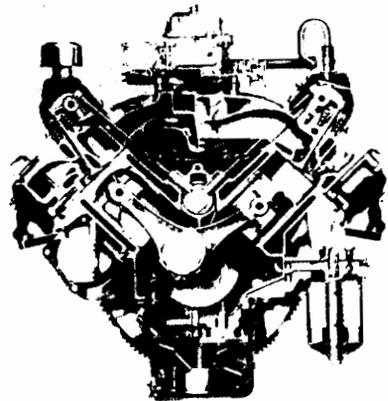


Examine the tools shown and determine their intended use.

The assortment of tools shown above are used as a set in performing service on which of the automotive areas shown below?



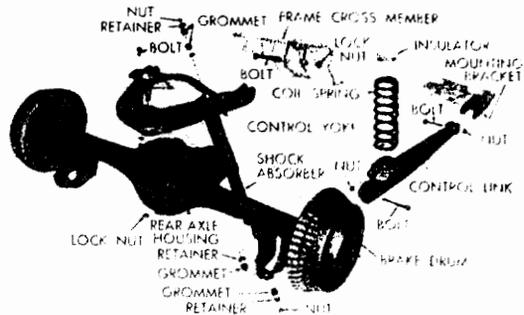
1. The exhaust system



2. The engine

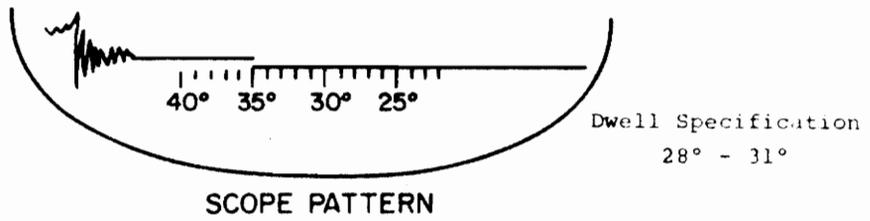


3. The suspension system

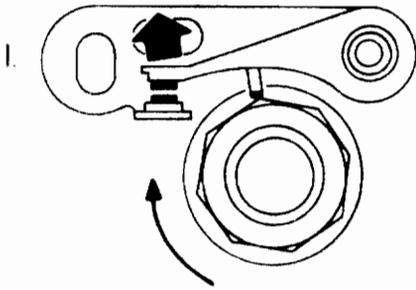


4. Rear axle service

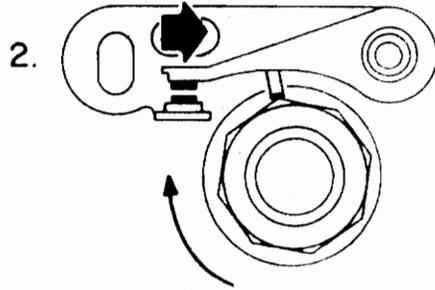
Test Item 7



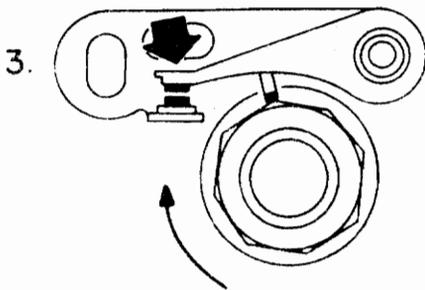
In which direction must the stationary point be moved in order to correct the condition appearing on the oscilloscope above?



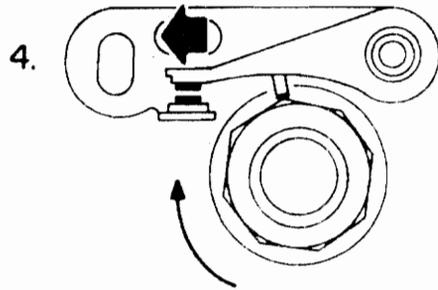
Away from the breaker cam



To the right of the breaker cam



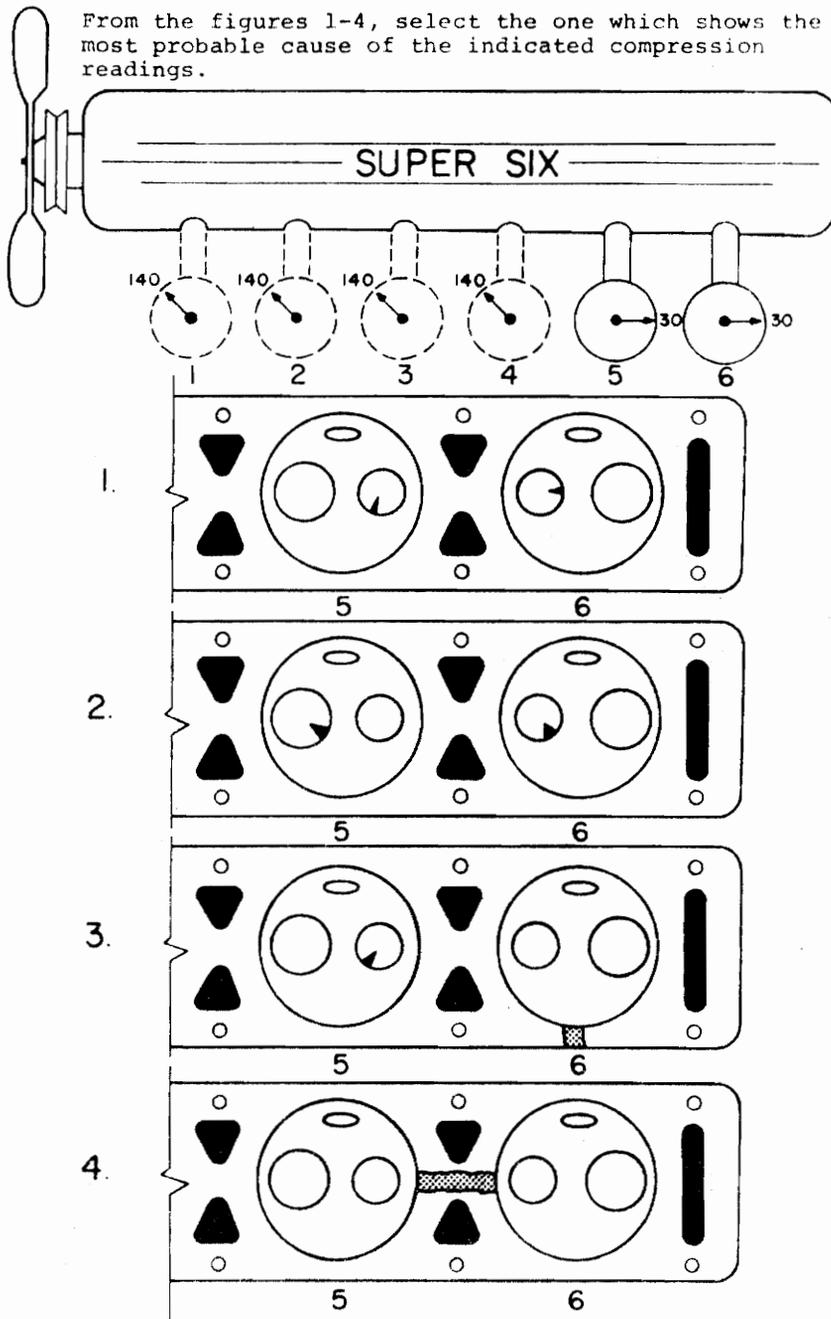
Toward the breaker cam



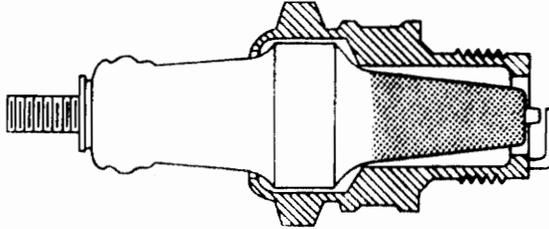
To the left of the breaker cam

Test Item 8

From the figures 1-4, select the one which shows the most probable cause of the indicated compression readings.

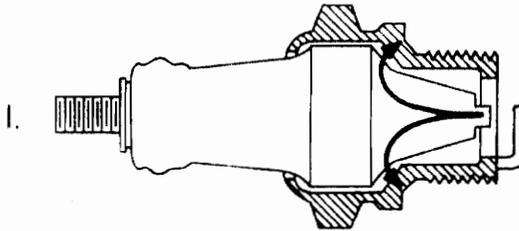


Test Item 9

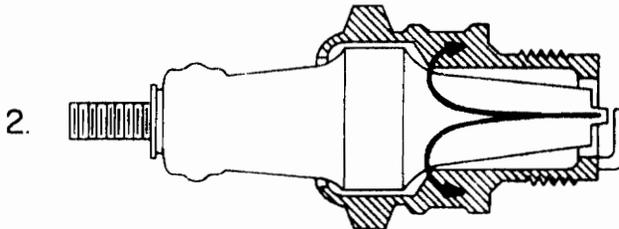


Condition:

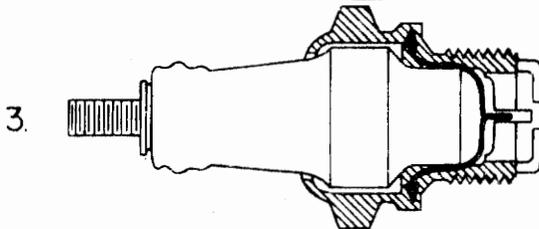
All six spark plugs have a very dark sooty carbon deposit around the center electrode. The automatic choke is working properly and there is no evidence of excessive oil consumption. Which of the following spark plug types should be installed to correct the condition?



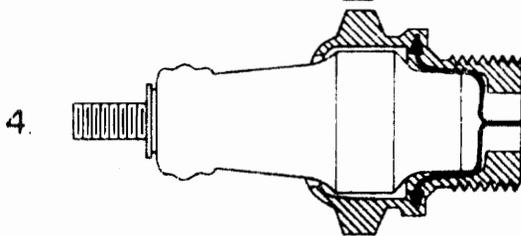
A spark plug with a shorter heat dissipation path



A spark plug with a longer heat dissipation path

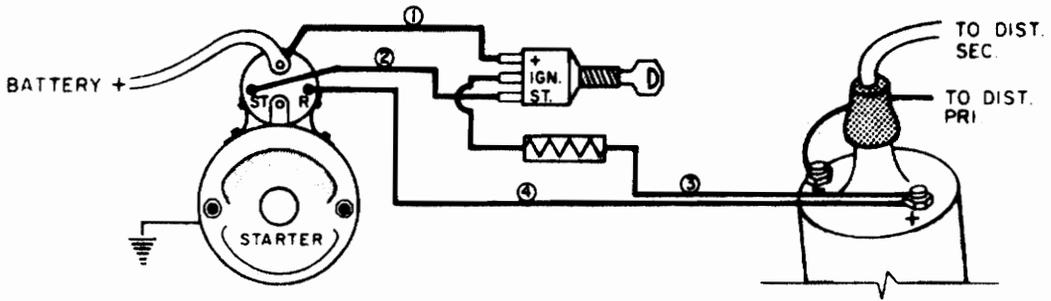


A dual electrode equipped spark plug



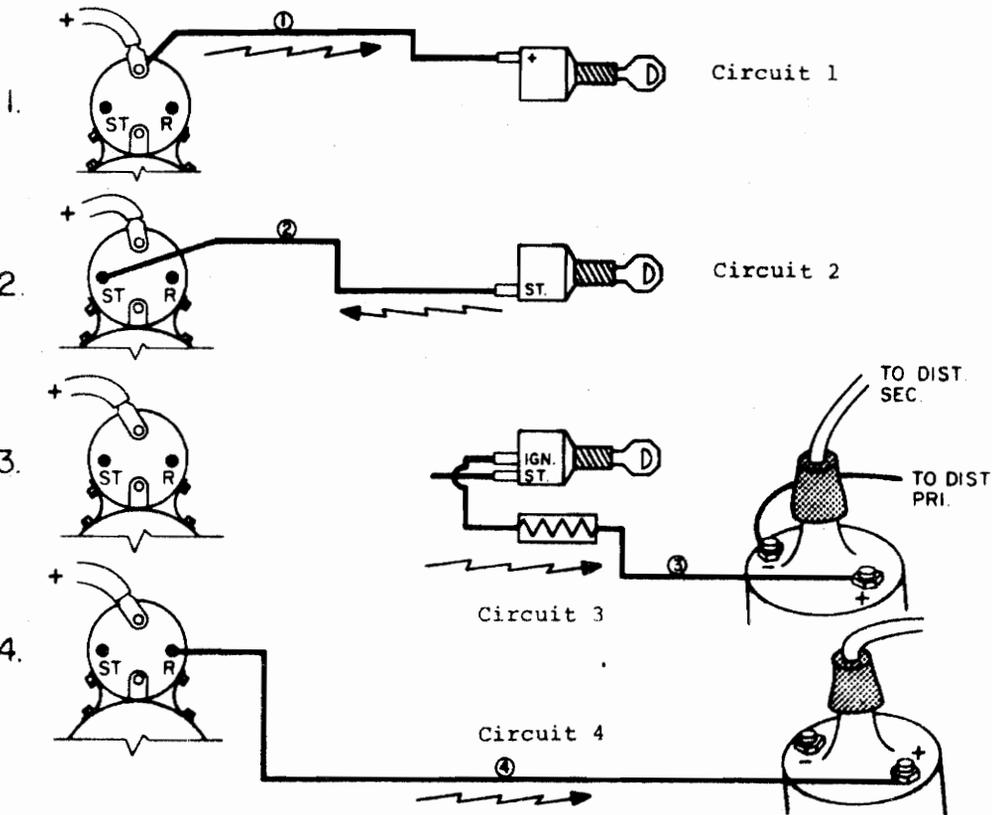
A surface gap spark plug

Test Item 10

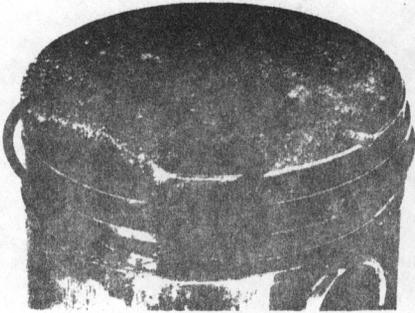


Condition:

The ignition switch is turned to the "Start" position. The starter engages the ring gear, turning the engine over. The engine starts. When the ignition switch is allowed to return to the "Ignition On", position, however, the engine immediately stops. This process continues each time starting is attempted. Which of the above circuits (numbered 1-4) must be at fault?



Test Item 11

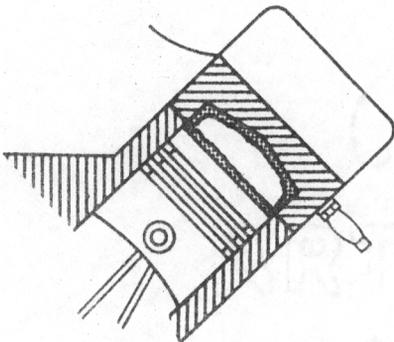
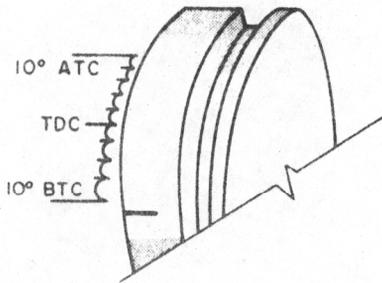


Observation:
Badly burned
pistons

What is the most likely cause for pistons looking like those pictured above?

1. Over advanced ignition timing

2. Excessively lean fuel/air mixture

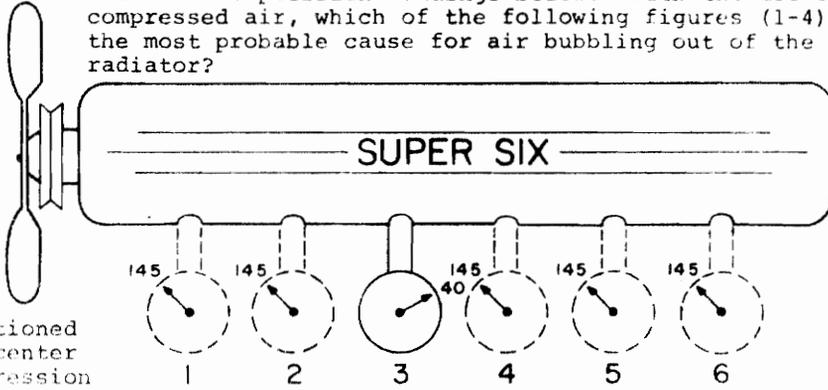


3. Heavy carbon deposits on both piston and cylinder

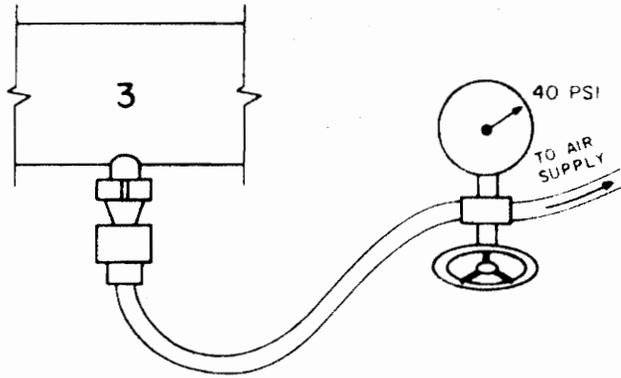
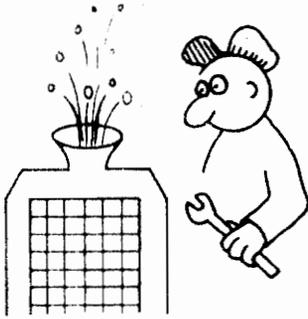
4. All of the above

Test Item 12

Note the compression readings below. With the use of compressed air, which of the following figures (1-4) shows the most probable cause for air bubbling out of the radiator?



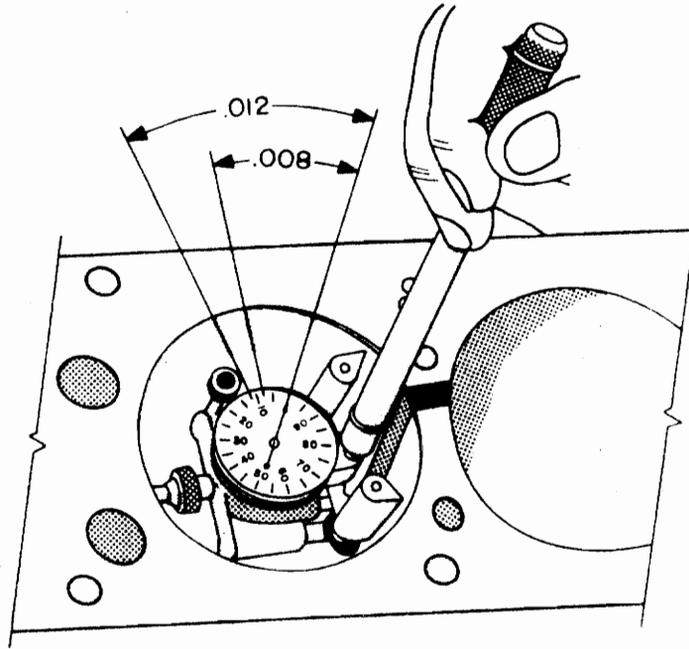
#3 positioned at top center on compression stroke



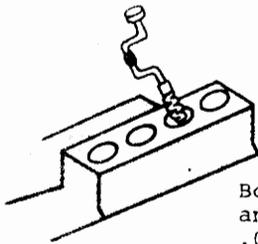
Four diagrams (1, 2, 3, 4) showing cross-sections of a cylinder with a piston at the bottom. Each diagram has a '3' below it, indicating the piston is at the top center. The diagrams illustrate different valve positions:

- 1. Both intake and exhaust valves are closed.
- 2. The intake valve is open, and the exhaust valve is closed.
- 3. Both intake and exhaust valves are open.
- 4. The intake valve is closed, and the exhaust valve is open.

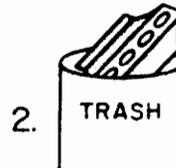
Test Item 13



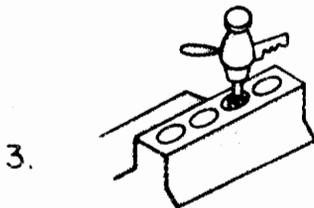
All cylinders average .008" oval wear and .012" variation in taper over the piston ring contact surface. In which of the following ways should the block be treated?



1. Bore all cylinders and hone to accommodate .020" finished pistons



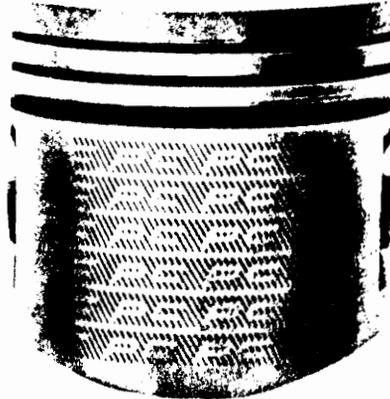
2. Discard the block



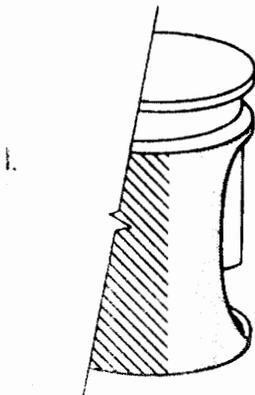
3. Hone all cylinders and install semi-finished pistons machined to fit each cylinder

4. Reassemble using all new standard parts since wear does not exceed maximum tolerances

Test Item 14



The used piston shown above has received skirt treatment. Why is this usually done?



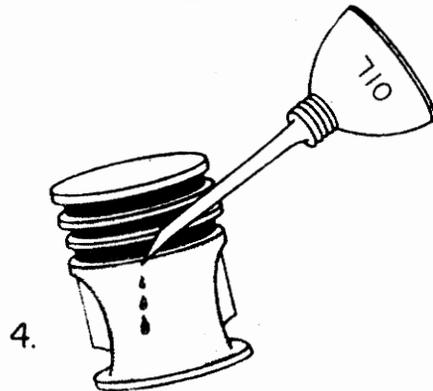
To mark the piston so that it will be discarded and not accidentally reused during overhaul



To check the piston for possible cracks

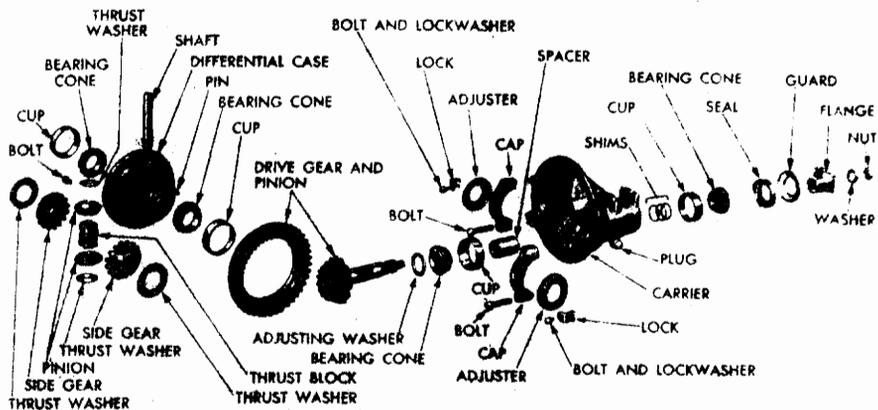


To expand the piston skirt



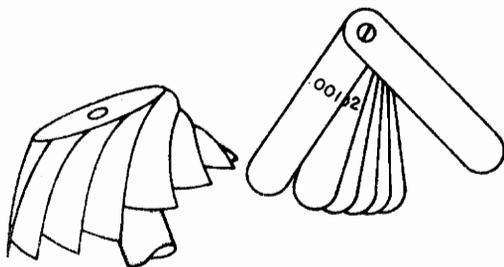
To provide a rough surface so oil will cling to the piston skirt

Test Item 15

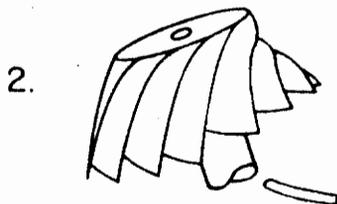


NOTE: Study the exploded view carefully.

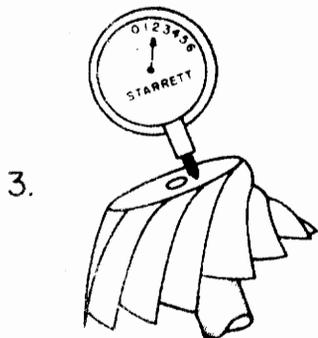
What equipment is used to determine pinion gear depth?



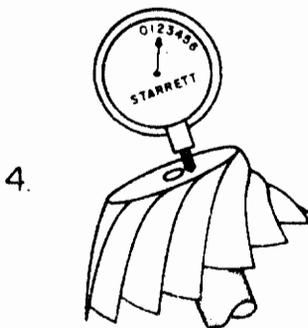
1. A flat gauge and the adjuster (shown in the above diagram)



2. Gauging plastic and the spacer (shown in the above diagram)

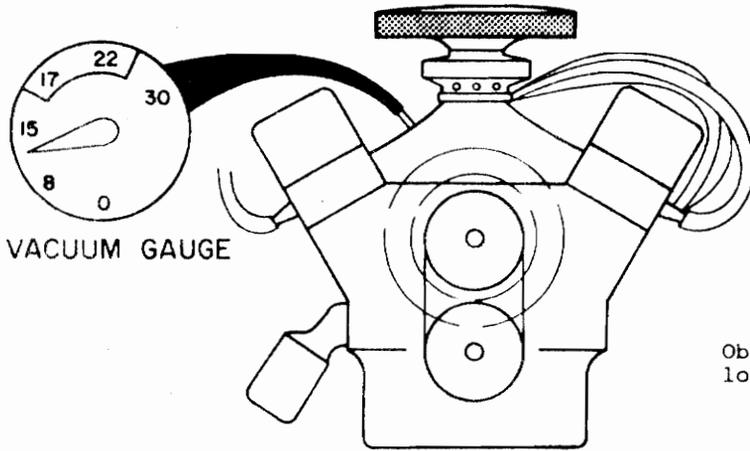


3. A dial indicator and the adjusting washer (shown in the above diagram)



4. A dial indicator and the bearing cone, cup, and shims (shown in the above diagram)

Test Item 16

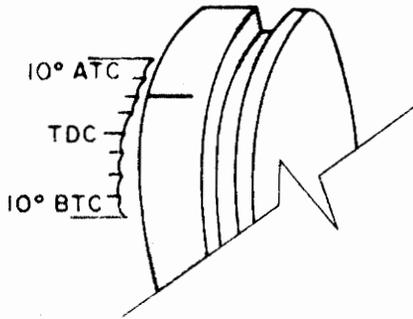


VACUUM GAUGE

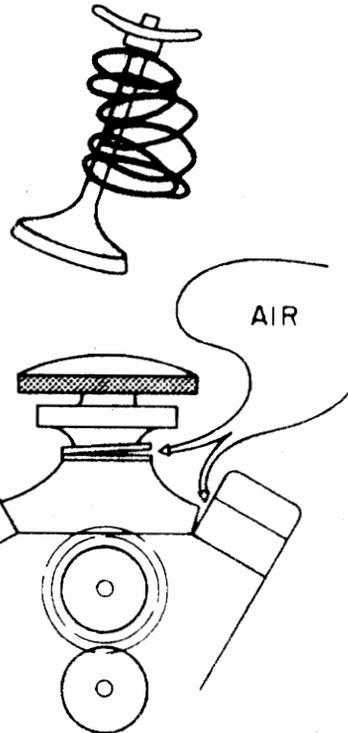
Observation: A very low gauge reading

Which of the following is the most likely cause of this vacuum gauge indication?

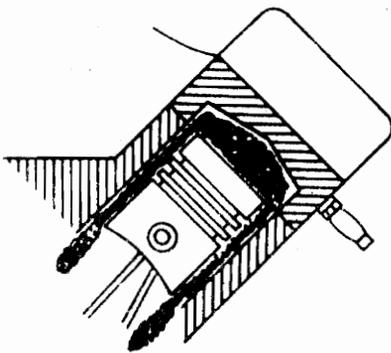
1. Late ignition timing



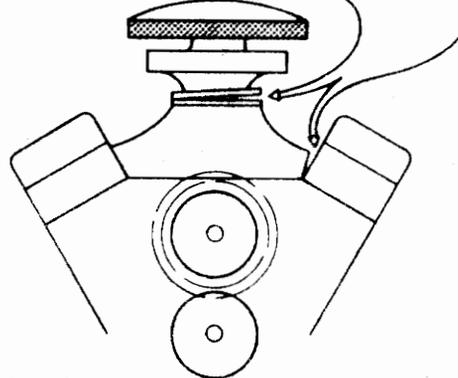
2. Weak valve springs



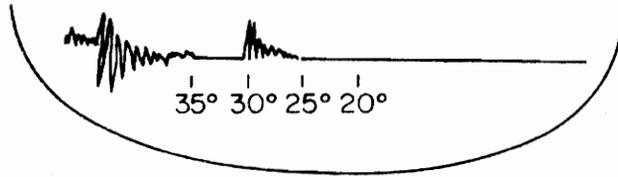
3. Leakage by pistons into crankcase



4. Induction leaks



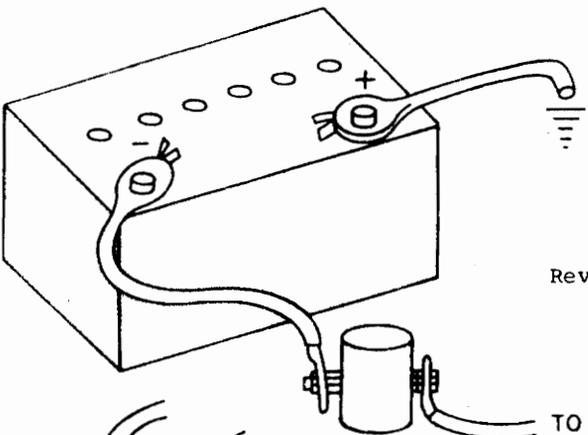
Test Item 17



SCOPE PATTERN

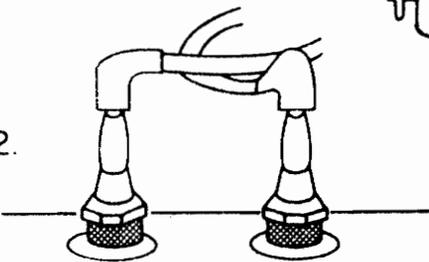
Observation: Inverted polarity image

What would cause the above scope pattern?

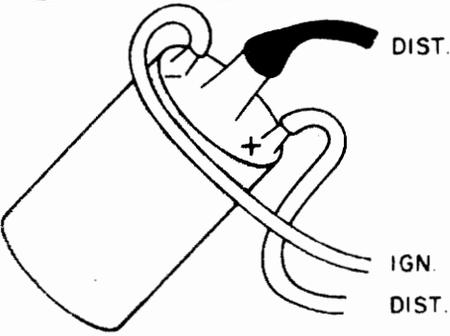
1. 

Reversed battery cables

TO STARTER

A diagram of a battery box with several terminals. The positive terminal is marked with a '+' and the negative with a '-'. Two cables are connected to the terminals, but they are swapped: the cable from the positive terminal goes to the negative terminal of the starter, and the cable from the negative terminal goes to the positive terminal of the starter.
2. 

Crossed plug secondary leads

A diagram showing two spark plug wires. The wires are plugged into two spark plug sockets, but the wires are crossed, meaning the wire from the left socket is connected to the right spark plug and vice versa.
3. 

Reversed coil primary leads

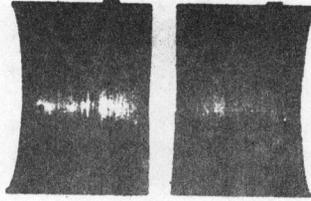
DIST.
IGN.
DIST.

A diagram of an ignition coil. The primary leads are labeled 'IGN.' and 'DIST.'. The secondary leads are labeled 'DIST.'. The primary leads are shown crossed, indicating they are reversed.
4. 

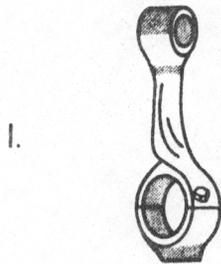
Faulty distributor rotor

A diagram of a distributor rotor. It is a circular component with a central contact and several outer contacts. One of the outer contacts is shown with a small gap or irregularity, indicating it is faulty.

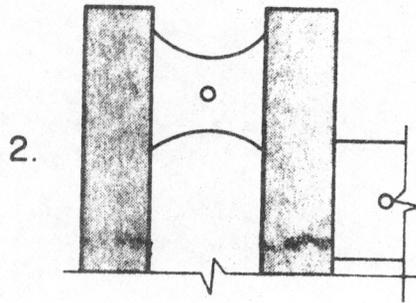
Test Item 18



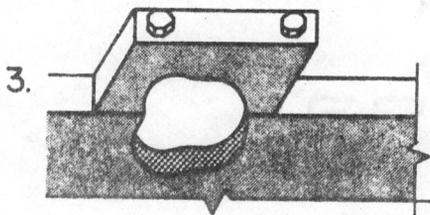
Carefully examine the picture of the two insert bearing halves. Which of the following conditions will produce a failure of this type?



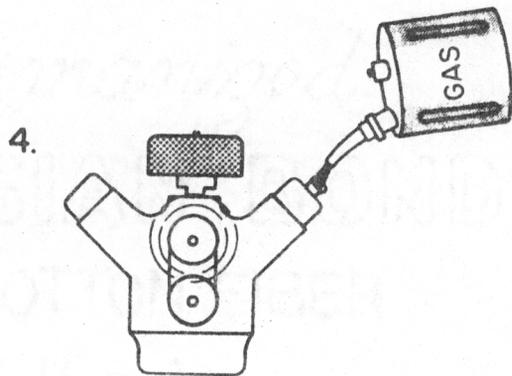
Misaligned connecting rods



"Hour glass" shaped journal on the crankshaft

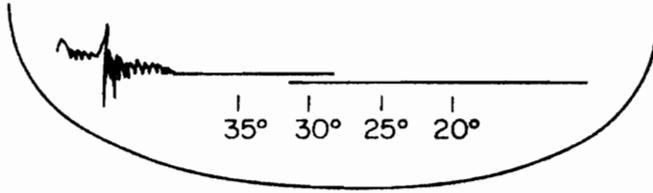


Out-of-round bearing housings



Oil dilution

Test Item 19



SCOPE PATTERN

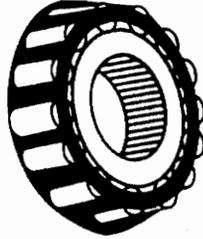
Observation: Dwell line overlap

What would cause the above scope pattern?

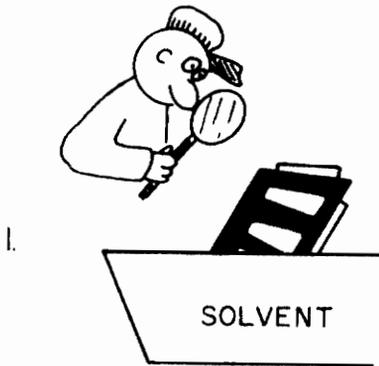
1.  A cracked distributor cap
2.  Burned contact points
3.  A worn breaker cam
4.  A burned spark plug

Test Item 20

Typical tapered
roller bearing



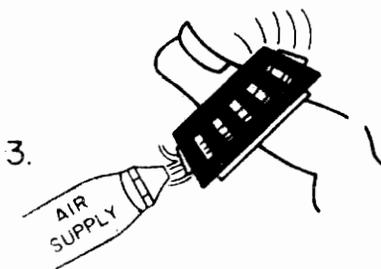
What is the correct procedure for checking a tapered-roller front wheel bearing?



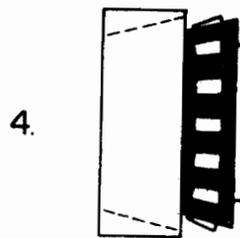
Thoroughly clean the bearing and examine the rollers.



Thoroughly clean the bearing and use backlighting to examine the race.

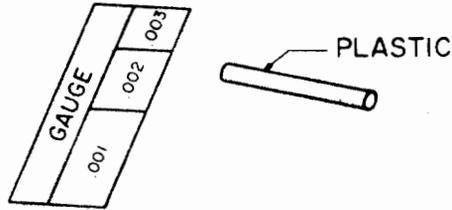


Thoroughly clean the bearing, spin it with compressed air, checking for any roughness as it rotates.

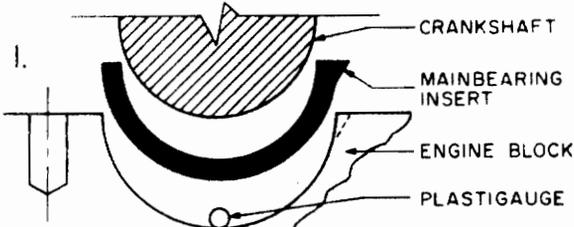


Thoroughly clean the bearing and carefully check the fit of the cup in the cone.

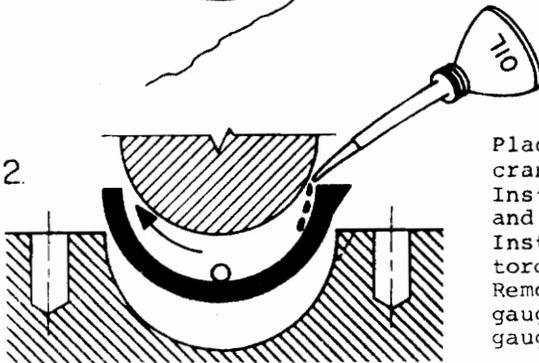
Test Item 21



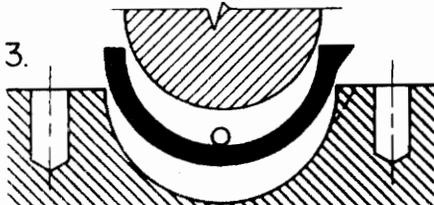
How is the engine main bearing clearance checked?



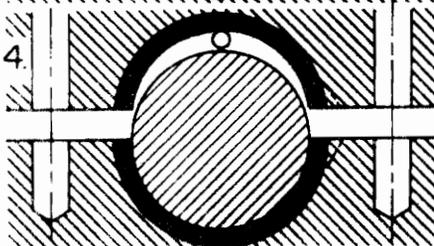
Place gauging plastic between insert bearing and engine block. Install crankshaft, bearing cap and torque to specifications. Remove all parts and measure gauging plastic spread with gauge.



Place gauging plastic between crankshaft and insert bearing. Install crankshaft using oil and a rotating motion. Install bearing cap and torque to specifications. Remove all parts and measure gauging plastic spread with gauge.

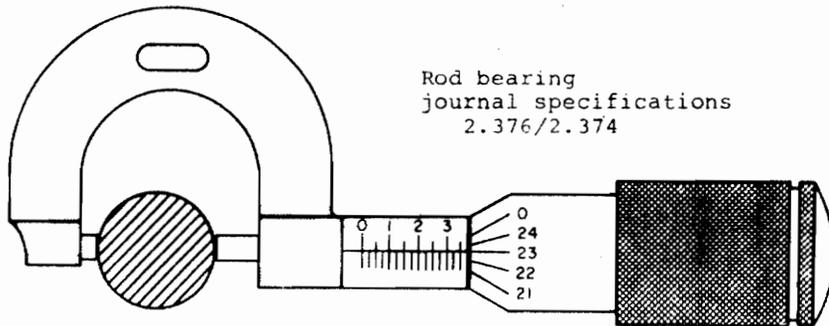


Place gauging plastic between crankshaft and insert bearing. Install crankshaft dry and do not rotate. Install bearing cap and torque to specifications. Remove all parts and measure gauging plastic spread with gauge.

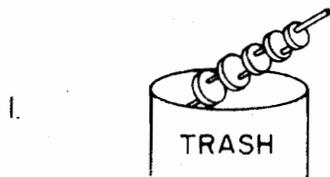


Place gauging plastic on top of the installed crankshaft. Carefully place bearing cap into position and torque to proper specifications. Remove all parts and measure gauging plastic spread with the gauge.

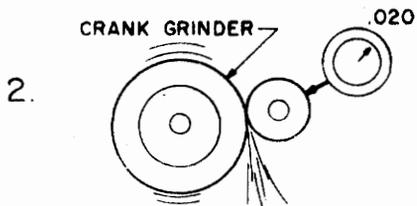
Test Item 22



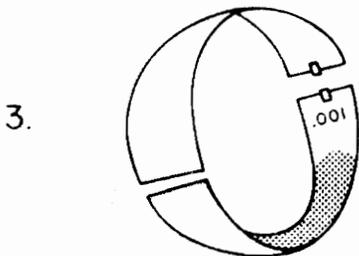
All four connecting rod journals indicate the reading shown on the micrometer. Which of the following procedures should be followed?



Discard the crankshaft



Regrind the crankshaft to .020 undersize and use the proper bearings



Thoroughly clean the crankshaft and use "as is" with a set of .001 bearings

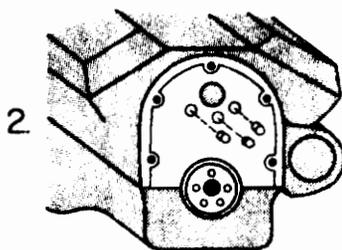
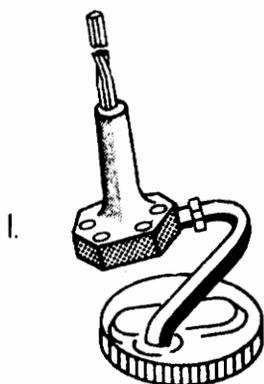


Thoroughly clean the crankshaft and use standard bearings

Test Item 23



Carefully examine the picture of the connecting rod bearing halves. Which of the following conditions will produce a failure of this type?

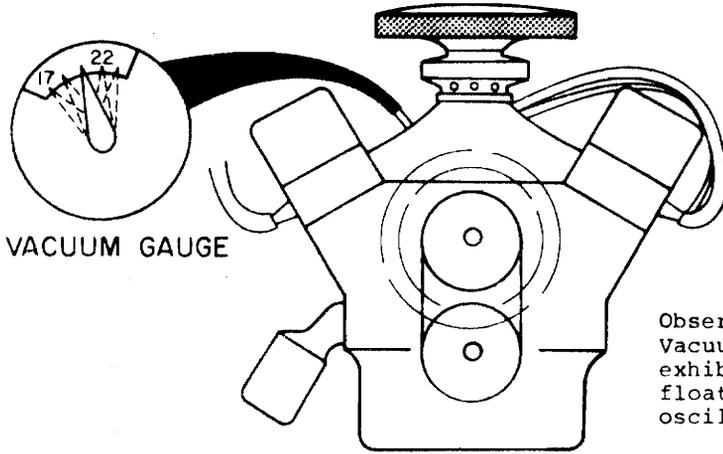


Neither (1) or (2) above

4.

Both (1) and (2) above

Test Item 24

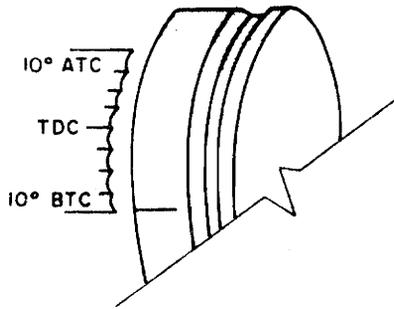


VACUUM GAUGE

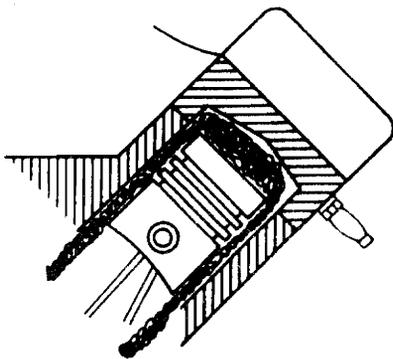
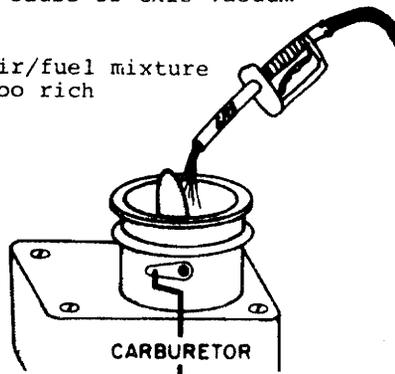
Observation:
Vacuum gauge needle
exhibits a continuous
floating or
oscillating motion

Which of the following is the most likely cause of this vacuum gauge indication?

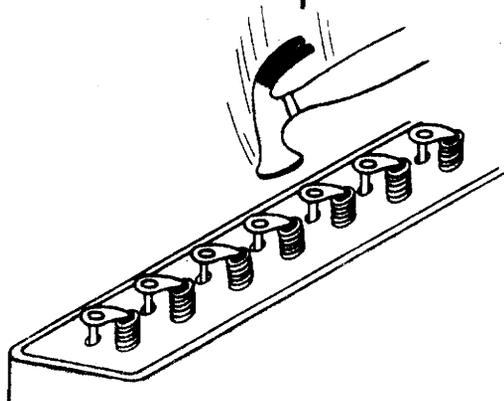
1. Ignition timing too high



2. Air/fuel mixture too rich



3. Piston rings stuck

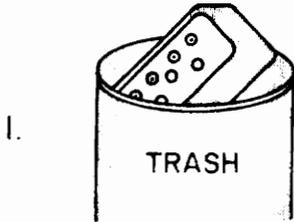


4. Valves sticking

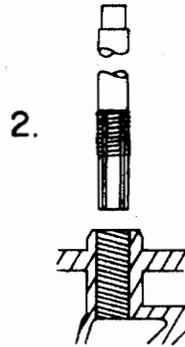
Test Item 25



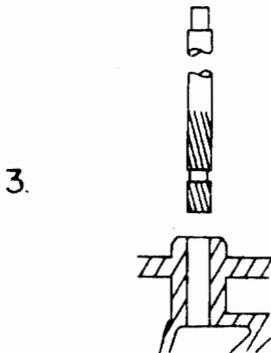
Using the telescoping small hole gauge, two exhaust valve guides show varying wear (from .006 to .008 oversize). Since these are non-replaceable (integral type) guides, which of the indicated corrective measures should be followed?



Discard the cylinder head



Knurlize the guide and ream it to accept the original sized valve stems

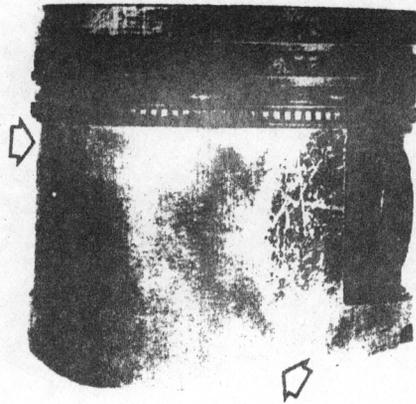


Ream the two guides and install new valves with the proper oversize stem



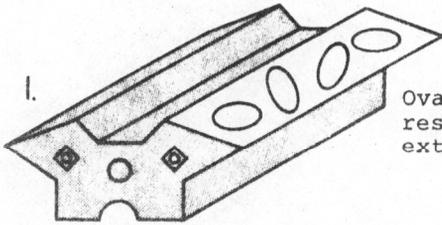
Both (2) and (3) above

Test Item 26

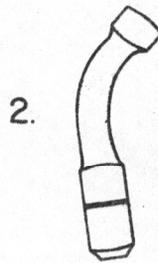


Typical piston as removed from an engine during a major overhaul

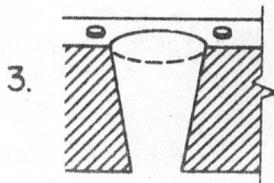
Examine the above piston carefully paying particular attention to the wear pattern evident. Which of the conditions results in this type of wear?



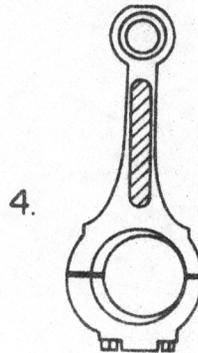
Oval cylinders resulting from extensive wear



Bent or distorted connecting rod



Tapered cylinders resulting from extensive wear



Worn connecting rod bearing housing

APPENDIX D

COLLEGE OF EDUCATION
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY*Blacksburg, Virginia 24061*

VOCATIONAL EDUCATION EVALUATION PROJECT

November 15, 1973

Dear

An attempt is being made as one facet of the Vocational Education Evaluation Project to develop a paper and pencil test which will measure performance ability in trade and industrial education to the same degree as the usual performance test. The study is presently confined to the area of automotive mechanics and the classes in _____ have been selected as one of four such groups which I would like to have participate in the study.

The study will involve the use of a performance test, and a single paper and pencil test. The performance test will be administered by the class instructor as he covers each area in question so that little, if any, additional time and inconvenience will be involved. The paper and pencil test will be brought to the school and administered during a portion of one regular class period in the latter part of April which will conclude the involvement of this school.

No data collected and reported will be identified with individual students or schools. Furthermore, no comparison between schools, instructors, or students will be made since this is not a part of the study nor is it of any interest to the project. The sole objective is to obtain a correlation between the performance and the paper and pencil test in order to determine the direction of future investigation.

Enclosed for your convenience is a response form with space provided for comments or questions and a stamped return envelope. Also included is a folder describing various aspects of the overall project which, if you have not already seen, may be of interest. Your cooperation and that of the school personnel involved will be greatly appreciated and provide valuable information that is impossible to obtain through other channels.

Sincerely,

W. R. Williams

WRW:dfw

Enclosures

APPENDIX D CONTINUED

RESPONSE FORM

Please check one of the following and feel free to make comments or raise questions concerning any phase of this study or the evaluation project.

The proposed study meets with my approval.

The proposed study does not meet with my approval because:

Comments:

School Division: _____

APPENDIX E

NAME LAST FIRST MIDDLE DATE MO DAY YR COURSE DEPT NO SEC TEST FORM SEAT NO

V
P
I
&
S
U

1 IN THE BOXES BELOW PRINT YOUR STUDENT ID NUMBER VERTICALLY, STARTING JUST UNDER THE ARROW THEN BLACKEN THE CORRESPONDING NUMBERED SPACES

↓

IDENTIFICATION NUMBER									
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9

2 NOW BLACKEN THE SPACE BELOW CORRESPONDING TO YOUR TEST FORM

TEST FORM									
A	B	C	D	E	F	G	H	I	J

3 FAILURE TO OBSERVE ANY OF THE FOLLOWING INSTRUCTIONS MAY LOWER YOUR SCORE

MAKE ALL MARKS HEAVY AND BLACK
 MAKE ALL ERASURES CLEAN (NO SMUDGES)
 MAKE NO STRAY MARKS
 USE ONLY A NO 2 PENCIL
 FILL SPACES BETWEEN DOTTED LINES COMPLETELY
 DO NOT FOLD, ROLL, DOG-EAR OR TEAR THIS SHEET
 MAKE NO MARKS TO RIGHT OF THIS LINE

4 IN BOXES BELOW PRINT SEAT NUMBER AND GROUP NUMBER IF REQUESTED BY INSTRUCTOR BLACKEN CORRESPONDING NUMBERED SPACES

SEAT NUMBER									
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9
GROUP NUMBER					SEAT NUMBER				
0	1	2	3	4	5	6	7	8	9
0	1	2	3	4	5	6	7	8	9

QUESTION NUMBERS GO ACROSS PAGE →

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110

MAKE NO MARKS TO RIGHT OF THIS LINE

VITA

William Randolph Williams was born November 10, 1937, in Lynchburg, Virginia, and moved to Snowden, Virginia. Following graduation from high school, he attended Lynchburg College, Lynchburg, Virginia, and was awarded the B.S. Degree in June, 1961.

Professional employment began as a classroom teacher with the Amherst County Virginia Public School System in the Fall of 1961 and continued for five years. During this period and concurrently while attending college he operated a marine and automotive sales and service facility. In the fall of 1966 he began instructing vocational automotive mechanics in the same school system, which was continued for an additional five years until 1971. During this period he worked weekends and summers as a commercial pilot engaged in charter flying and aerial pesticide application. In the fall of 1971 he moved to Blacksburg, Virginia, and entered Virginia Polytechnic Institute and State University as a graduate student and was awarded the M.S. Degree in Vocational and Technical Education in June, 1972. Since that time he has remained at the University working first as a Graduate Research Assistant and then as a full-time faculty member in the capacity of Teacher Educator in the Division of Vocational and Technical Education while completing the requirements for the Ed.D. Degree in Vocational and Technical Education.

He is married to the former Diane Cecelia French of Hampton, Virginia.


William Randolph Williams

THE DEVELOPMENT AND VALIDATION
OF A PAPER AND PENCIL ACHIEVEMENT
TEST IN AUTOMOTIVE MECHANICS

by

William Randolph Williams

(ABSTRACT)

The purpose of this study was to develop and validate a paper and pencil automotive mechanics achievement test and determine the feasibility of measuring the competence of mechanics using this instrument rather than the traditional performance test. It involved: 1) the selection of a number of accepted performance task items agreed upon by a jury of experts as valid for testing automotive mechanics students; 2) the formulation of each accepted performance task into a paper and pencil test item; and 3) obtaining a correlation between the two like tests of at least .71 corrected for attenuation.

Following the construction of the 26 item performance test and construction of the like 26 item paper and pencil test a pilot study was conducted with a total of 25 Automotive Mechanics II students taking the paper and pencil test. These data were collected and subjected to item analysis for the purpose of ranking the test items from those items answered most easily to those answered with most difficulty. Both tests were then arranged in this order.

successful completion of the items included on the paper and pencil test developed for this study.

7. Regardless of the degree of success achieved by the individual students on the paper and pencil test, no on-the-job success can be predicted as a result of this study.
8. As a result of the r_c obtained in this study it is highly feasible to continue investigation concerning the development of an expanded paper and pencil test for automotive mechanics.