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This report describes a project to develop and administer job sample tests for diagnostic ability in selected maintenance MOSs and to relate the results to the following factors: (1) number of recommendations for replacement of parts, components, or major assemblies erroneously condemned; (2) type of maintenance training, amount of experience, and current job assignment; (3) use of essential procedures, test equipment, and technical manuals; and (4) content of school programs in the MOS field under review. Resulting data on test performance, vehicle components erroneously condemned, and performance deficiencies are presented.

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Consulting Report

PERFORMANCE PROFICIENCY OF AUTOMOTIVE AND TURRET MECHANICS IN MALFUNCTION DIAGNOSIS AND REPAIR

William C. Osborn

May 1966

A report of Technical Advisory Service performed at the request of the Board of Inquiry on the Army Logistics System. This report is to be included as Appendix G in the final report to the Board of Inquiry.

HumRRO Division No. 2
(Armor)

The George Washington University
HUMAN RESOURCES RESEARCH OFFICE
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Appendix G

PERFORMANCE PROFICIENCY OF AUTOMOTIVE AND TURRET MECHANICS IN MALFUNCTION DIAGNOSIS AND REPAIR

PERFORMANCE PROFICIENCY OF AUTOMOTIVE AND TURRET MECHANICS IN MALFUNCTION DIAGNOSIS AND REPAIR

INTRODUCTION

Problem

This study was, in part, a follow-up of a proficiency evaluation of track vehicle mechanics conducted by HumRRO in 1960 (Smith, 1964). Under the sponsorship of CONARC, this earlier study was designed to identify aspects of organizational maintenance in which performance was weak, and which needed to be strengthened, either by better engineering of the job situation and by improved supervision, or by possible revision in training. A large sample of automotive mechanics was tested on a series of job performance exercises which included troubleshooting, testing, and adjustment tasks. An average score of 26% was found, and performances were documented by the number of vehicle parts erroneously condemned, faulty diagnostic procedures, and failure to use technical manuals or test equipment.

Recently the Board of Inquiry on the Army Logistics System was directed by the Army Vice Chief of Staff to investigate the "impact of faulty malfunction diagnosis upon repair parts supply" (TAG Letter, 1966). The apparent relevance of the earlier HumRRO report to the subject of faulty malfunction diagnosis led to a request for up-dating the information it contained, and to extend its procedures to turret repairmen and direct support automotive and turret maintenance specialties.

Objectives

The purpose of the study was to develop and administer job sample tests of diagnostic ability in selected maintenance MOS's, and to relate the resulting performance to the following factors:

1. number of recommendation for replacement of parts, components or major assemblies erroneously condemned;
2. type of maintenance training, amount of experience, and current job assignment;
3. the use of essential procedures, test equipment and technical manuals; and,
4. the content of school programs in the MOS fields under review.

METHOD

Test Development

Five tests were developed, as follows:

Organizational Level

1. Automotive Maintenance (MOS's 63A, 63B, 63C)
2. Turret Maintenance (MOS 45G20)

Support Level

3. Fuel and Electric Repairmen (MOS 63G)
4. Automotive Repairmen (MOS 63H)
5. Turret Repairmen (MOS 45G30)

The direct support MOS's and the organizational turret repair specialty were not included in the earlier study. Also the organizational-automotive tests previously used dealt, in part, with types of vehicles which are currently being phased out of use. So it was necessary to revise these tests as well as to develop the new ones.

Test Development Criteria. The test problems were drafted by a technical representative of the appropriate service school (The Armor School at Fort Knox and The Ordnance School at Aberdeen) in each relevant MOS field. With the guidance of his school staff each representative developed a set of test problems that met specific criteria.

First, diagnostic skill was to be emphasized It was recognized that diagnosing malfunctions is but one part of a mechanic's job, yet it was assumed to be the most important--particularly in view of the objectives of the study. Second, the malfunction selected was to be so critical that if it were not properly diagnosed a costly part or subassembly of the vehicle might be condemned. Third, the malfunction was to be one which often occurs in the field. Fourth, high density types of vehicles or vehicle components were to be utilized. And, fifth, test problems were to be chosen which required a limited time to perform. While these criteria were carefully considered in preparing every test item, they could not all be maximally met in each instance. So they were weighed and traded off in an effort to produce for each MOS a representative sample of items which could be used to test as many people as possible within the allotted time.

Test Item Format. In standardizing test administration and scoring procedure, each item was composed of two parts. The first part presented the content (Figure G1); it included a statement of the symptom, to be read by the

NAME____________________ UNIT____________________

63C DATE ____________________

TEST ITEM 6

MALFUNCTION: Open starter control circuit. #74 wire--M-35A1

SYMPTOM: No starter action

SPECIAL TOOLS AND EQUIPMENT LVCT, multimeter, test lamp

DIRECTIONS TO THE TESTER

Tell the subject: "Starter will not operate when starter switch is pressed. Find the trouble and report it to me."
(Check subject's performance only as each step is completed.)
Steps 3, 4, 5 need not be in sequence.

SUBJECT'S PERFORMANCE	YES	NO
1. Turn accessory switch on and depress starter switch. Observe panel lights and gauges..............(E)	____	____
2. Connect voltmeter across batteries, depress starter to check battery condition..............(O)	____	____
3. Check for voltage to magnetic starter switch #14 wire with accessory switch ON starter depressed..............(O)	____	____
4. Check for voltage to starter switch #74 wire..............(E)	____	____
5. Check for voltage from accessory switch #74 wire..............(F)	____	____
6. All parts correctly re-installed	____	____
7. Parts erroneously condemned. (Write in.)		

TECHNICAL EXPERIENCE OF SUBJECT

Subject has worked on this problem or similar ones:

Never .... ____
Occasionally .... ____
Frequently.............................. ____
Within the past 3 months .... ____
More than 3 months ago .... ____

Figure G1. Sample Test Item.

tester to the subject: a list of essential procedures or the approved steps[1] for completing the task, a space for writing in any parts mistakenly condemned, and a block for recording the subject's experience with tasks of this sort.

The other part of the score sheet (Figure G2) was a performance checklist common to all test items. As shown, it was headed by a block of four passing categories and four failing categories. If a subject correctly reported the malfunction he was scored in the pass section, his degree of pass was then indicated by one of the four descriptive statements. The same type of scoring was used if he failed.

The following sections of the checklist were used for recording the source and type of difficulty the subject encountered. Here, for example, a check could be used to show that he was unable to locate the correct vehicle components to work on, or to hook up the test equipment, or to understand a wiring diagram, and so forth. The final section of the checklist was used for recording the source of his training on that task.

All of the test items were given this two-part form. In this way, testing and scoring were made fairly uniform. After the items were tried out, a final series of fourteen test items were selected for the organizational automotive MOS's (63A, 63B, and 63C), eight items for the organizational turret repairmen (45G20), six for the direct support turret repairmen (45G30), four for the direct support automotive repairmen (63H), and four for the fuel-and-electric repairmen (63G), as listed in Figure G3.

Testing Program

Test Sites. The tests were administered at five locations, two sites in CONARC (Fort Benning and Fort Hood), and three sites in USAREUR (one in the 8th Infantry Division and two in the 4th Armored Division). A seven-man team of two HumRRO representatives and five technical personnel from the service schools conducted the testing. One week was programmed at each test site. The first two days were utilized in setting up the test stations, in recruiting and training personnel to score the tests, and in selecting the sample of people to be tested. The rest of the week was used for testing.

Test Station Layout. The organizational and direct support phases were conducted concurrently though in separate shop areas. Eight test stations were

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[1]These were the procedures given in the technical manuals. Each step was further keyed as either essential (E) or optional (O) according to the judgment of the technical expert.

SUMMARY PERFORMANCE CHECKLIST

SUBJECT__________________ TESTER __________________ ITEM NO. ______

I. SUBJECT DETECTED MALFUNCTION OR COMPLETED OPERATION PROPERLY .... ______

CHECK ONE
0. Used good procedures; knew what he was doing .... ______
1. Had a pretty good idea, but some guesswork .... ______
2. Knew very little; probably just a good guess .... ______
3. Knew very little; but used publication accurately .... ______

II. SUBJECT FAILED .... ______

CHECK ONE
0. Didn't know enough to get started .... ______
1. Started but gave up very quickly .... ______
2. Some knowledge of what to do but much guesswork also .... ______
3. Had fairly good grasp of the problem but failed .... ______

CHECK ANY STATEMENTS BELOW THAT APPLY TO OR EXPLAIN FAILURE OR POOR PERFORMANCE OF SUBJECT

Procedures

00. Proceeding O.K. but too slow .... ______
01. Didn't know essential operation or step no. (____) .... ______
02. Didn't make essential "operational" checks such as revving up engine, turning switches, etc. .... ______
03. Incorrectly reinstalled parts .... ______

Location of Malfunction

04. Unable to pick out correct system to work on .... ______
05. Got right system but wrong components .... ______
06. Got right system and right components but couldn't test them .... ______

Use of Special Tools and Test Equipment

07. Failed to use special equipment .... ______
08. Tried to use it but didn't know how to hook it up .... ______
09. Tried to use it but didn't know where to hook it up .... ______
10. Knew how and where but didn't know procedures .... ______
11. Used it properly but couldn't read results of checks .... ______
12. Used wrong equipment for test or check .... ______
13. Put too much ( ) or too little ( ) stress or load on equipment .... ______
(Check one.) .... ______

Use of Publications

14. Didn't use publications .... ______
15. Selected wrong publication .... ______
16. Selected right publication but couldn't find right section .... ______
17. Selected right publication and section but .... ______
didn't understand instructions .... ______
18. didn't understand wiring circuit diagram .... ______
19. didn't understand troubleshooting diagram .... ______
20. didn't understand technical specifications .... ______

III. HOW WAS THE SUBJECT TRAINED FOR THIS SPECIFIC TEST PROBLEM?

0. Has never had any training--entirely self-taught .... ______
1. Has had a basic maintenance course .... ______
2. Has had one or more classes on this problem, lasting between ½ day and one .... ______
week. Ordnance ____, Tech. Rep._____, Battalion (or higher) NCO's_____ .... ______
3. Was taught on job by a supervisory NCO such as the Motor Sergeant .... ______
4. Was taught on job by another mechanic .... ______
5. Other training (write in) .... ______

(Use reverse side of this page for remarks.)

Figure G2. Performance Checklist Used With Each Test Item

ORGANIZATIONAL AUTOMOTIVE		ORGANIZATIONAL TURRET	DIRECT-SUPPORT TURRET		DIRECT-SUPPORT AUTOMOTIVE		DIRECT-SUPPORT FUEL & ELEC	
STATION	PROBLEM	PROBLEM	PROBLEM	STATION	STATION	PROBLEM	STATION	PROBLEM
M151	1. Maladjusted carburetor 2. Improper carburetor float level	1. Operating cam opening roller adjustment 2. Nitrogen pressure test	1. Defective hydraulic fuse 2. Defective hydraulic *rammer*	M108/109				
M151	3. Defective spark plug 4. Defective distributor condensor	3. Defective gun firing relay 4. Low torque on traversing mechanism clutch	3. Worn lands in howitzer tube 4. Low torque on traversing mech*nism clutch*	M108/109			(F & E Van) Distributor M38A1 or M151	3. Improper advance unit adjustment
M35A1	5. *Defective* dimmer switch	5. Defective turret power switch					(Field Table) Generator 25 AMP	2. Shorted armature
M35A1	6. Open starter control circuit	6. Computer super-elevation drive shaft installation	5. Sheared pinlock piston	M60A1				
M113	7. Defective connection at neutral switch 8. Defective battery connection	7. Superelevation actuator adjustment, installation and test 8. *Nitrogen pressure* test	6. Defective power valve solenoid	M60A1 →	M60A1	1. Defective main pressure regulator valve	(Field Table) Alternator 100 AMP	3. Open rotor (Dirty slip-ring)
M113	9. Generator regulator adjustment 10. Ground in warning light circuit				M54	2. Steering gear control valve adjustment		
M60A1	11. Inoperative starter solenoid 12. Open generator circuit				M35A1	3. Defective injector nozzel		
M108/109	13. Open master relay circuit 14. Ground in master warning light circuit				M151 →	4. Defective vacuum booster pump	M151	4. Improper carburetor float level

Figure G3. Tests and Test Station Layout set up in one maintenance shop for the organizational automotive tests, as given on the left side of Figure G3. These included two 1/4-ton trucks, two 2-1/2-ton trucks, two armored personnel carriers, a medium tank, and a self-propelled howitzer. A second maintenance shop housed the remaining test stations. Both turret MOS's were tested using two self-propelled howitzers and two medium tanks (Figure G3); one of these tanks plus a 1/4-ton, 2-1/2-ton, and 5-ton truck were the stations for direct-support automotive testing; three bench areas and the 1/4-ton truck were used as stations for the fuel-and-electric repairmen. Located at each station was a complete mechanic's tool kit. The relevant technical manuals, troubleshooting guides and test equipment were also available to the test subject.

Testing Procedure. In a normal testing day 16 subjects could be given eight organizational-automotive tests (30 min. per station), 8 could be given each of four turret-artillery problems (one hr. per station), and 8 could be given the four direct support automotive or fuel-and-electric tests (one hr. per station).

Before he was tested, the subject was asked to fill out a questionnaire which required certain personnel information, maintenance experience on various military vehicles, current job assignment, and the amount of supervision received on the job. A thorough briefing was then given as to the general nature of the tests and the test procedure. The subjects were encouraged to do their best and to attempt each problem even though one or more of the vehicles was unfamiliar; they were told that they were not being personally evaluated for record, but they were urged to view the tests as a challenge and as a potential learning experience.

A subject then reported to one of the test stations. The pretrained tester at that station read the operational symptom to the subject and told him to find the trouble and report it (or to perform a particular test or adjustment). The subject was instructed to proceed just as he would on the job using the available tools, test equipment and publications. Testers were directed to avoid helping the subject beyond simply repeating the instructions. But the tester helped the subject (if there was no driver) by cranking the engine, holding a light, turning a switch, etc. when so requested. Performance was observed and recorded by the tester on the checklist. At the end of the time period (30 min. or 1 hr.) the subject moved to another station; in this way he thus completed the prescribed number of tests.

The test vehicles were situated so that a man could not easily observe the activity at adjacent stations. Care was also taken to prevent the subjects' conversing between tests. To further maintain test security, subjects were selected from different units for morning and afternoon testing, and when the testing ran into a second day. Where two full days of testing were scheduled, as with the organizational automotive group, different test problems were used the second day.

Test Subjects

For various reasons it was not possible to test all personnel in the selected MOS's; and it did not seem desirable to request a fixed number of mechanics from the supporting units for testing, for either the most experienced or the least experienced might be chosen. Instead a sampling procedure was used to assure that amount of maintenance experience and type of training would be as uniform as possible. Subjects were selected randomly within four levels of experience and three classes of training background, by screening (at each division area visited) the personnel records of the men who had the required primary MOS. But it was possible to use this screening procedure for only the more common maintenance specialties. The 45G20, 45G30 and 63G MOS's were so few in number that every available man was tested. A breakdown of the total sample is given in Table G1.

As shown, a few 63A and 63B MOS's were included in the organizational automotive testing. Because the same basic job description applies to these as to the 63C MOS--the three differing only in degree--their inclusion seemed both reasonable and interesting. However, the data for these MOS's were treated separately in the analysis.

Test Scores and Personnel Data

A subject's total performance was scored as the per cent passed of the test items taken. Group performance was summarized as median per cent passed.

Data used in the analyses (except what was recorded on the test forms) were obtained either from personnel records or from the questionnaire forms. This supplementary data included: (a) General Technical (GT) and Motor Maintenance (MM), aptitude area scores, (b) number of years of maintenance experience, (c) type and number of maintenance schools completed, (d) number of months since last attended a maintenance school course, (e) current job assignment, (f) supervision given on the job, and (g) experience with various types of vehicles.

Table G1

Number of Subjects Tested in Each MOS by Type of Training and Amount of Experience

Type of Training	MOS	Maintenance Experience 0-1 Year	1-2 Years	2-5 Years	5 or more Years	Total
	63A	0	0	0	0	0
	63B	0	0	0	0	0
Service School	63C	24	19	13	12	68
	45G20	22	5	2	1	30
	45G30	9	4	4	1	18
	63G	9	6	5	0	20
	63H	11	12	15	2	40
	63A	1	1	1	0	3
	63B	1	2	2	3	8
Other School*	63C	3	7	5	11	26
	45G20	1	0	0	0	1
	45G30	4	0	2	0	6
	63G	1	0	2	0	3
	63H	1	1	1	4	7
	63A	3	2	0	0	5
	63B	1	2	1	3	7
On Job	63C	2	5	8	9	24
	45G20	2	0	0	0	2
	45G30	0	0	0	0	0
	63G	0	0	0	0	0
	63H	3	2	2	5	12
	63A	4	3	1	0	8
	63B	2	4	3	6	15
	63C	29	31	26	32	118
Total	45G20	25	5	2	1	33
	45G30	13	4	6	1	24
	63G	10	6	7	0	23
	63H	15	15	18	11	59
						280

*Any school directly relevant to the MOS, that is six weeks or longer, and not classed as a service school.

RESULTS

Total Test Performance

Performance scores in Table G2 include the per cent of total items passed by each MOS group and the median per cent passed by individuals in the groups.[2]

Table G2
Median Per Cent Test Performance

MOS	Number of Subjects(N)	Number of Test Items	Per Cent of Total Items Passed (Group)	Median Per Cent Passed (Individual)	Internal-Consistency Reliabilities
63A	8	8	45.0	46.4	.36
63B	15	8	57.0	62.5	.44
63C	118	8	68.0	71.4	.26
45G20	33	4	49.0	50.0	.27
45G30	24	4	42.0	50.0	.35
63G	23	4	50.0	50.0	.40
63H	59	4	30.0	25.0	.21

The 63A, 63B and 63C groups were given the same series of test items. Performance of these three groups differed as expected.

As shown in Table G2, the apprentice mechanics passed 46% of the items, the wheel-vehicle mechanics passing 62%, and the track-vehicle mechanics 71%. Both organizational and direct support turret mechanics performed at the 50% level as did the fuel-electric repairmen. The direct support automotive repairmen scored the lowest on the average with a median per cent of 25.

Inconsistency of Performance. The internal consistency reliabilities (Table G2) calculated for the groups of subjects indicate a rather low correlation between a man's performance on one test item and his performance on any other. But higher consistency coefficients would be unusual under such conditions as the following: the small number of items in each test, the range of performance sampled by these few items, and the variety of vehicle types used. Such factors would be expected to lower test reliability when it is

[2] Any differences between these two scoring indexes merely reflects the tendency of individual scores to accumulate disproportionately at an extreme from the per cent of items passed by the group.

based on average interitem correlation.[3]

This tendency toward discrete performance is of special interest. It tends to weaken the notion of some general, underlying ability factor which enables a mechanic to approach two slightly different diagnostic problems with the same chance of success. Rather, it appears that his performance is largely limited to those specific tasks--easy or difficult--which he has worked on before. This inference was supported by pretest questionnaire responses. Experience with various types of vehicles was quite limited, and many individuals reported that on the job they worked repeatedly at just one or two types of tasks.

Maintenance Experience. When test performance was viewed as a function of maintenance experience (Table G3) no consistent relationship was evident.

Table G3
Median Per Cent Test Performance for
Four Levels of Maintenance Experience

	Maintenance Experience							
	0-1 yr.		1-2 yrs.		2-5 yrs.		5 or more yrs.	
MOS	N	Mdn %	N	Mdn %	N	Mdn %	N	Mdn %
63A	4	26.0	3	57.0	1	62.0	--	----
63B	2	13.0	4	66.5	3	57.0	6	63.5
63C	29	71.4	31	62.5	26	70.0	32	75.0
45G20	25	50.0	5	50.0	2	37.5	1	50.0
45G30	13	25.0	4	50.0	6	75.0	1	100
63G	10	62.5	6	25.0	7	50.0	--	----
63H	15	25.0	15	25.0	18	25.0	11	50.0

Even in MOS groups containing a relatively large number of subjects, the expected increase in proficiency with time on the job was not apparent. The 63H MOS may be an exception, in that the men with more than five years' experience passed twice as many items on the average as the rest of the group. The apparent consistent rise in performance with experience for the 63A's and 45G30's may be due to the fact that all experience levels but one contained from one to six subjects--relatively small samples.

[3]A retesting on the same or equated forms of the test would normally be the approach used in accurately estimating the reliability of this type of test.

Training Background. Test performance by type of training background is presented in Table G4. The two automotive groups which had no service school

Table G4
Median Per Cent Test Performance
for Three Types of Training Background

	Type of Training					
	Service School		Other School		On Job	
MOS	N	Mdn %	N	Mdn %	N	Mdn %
63A	--	----	3	50.0	5	43.0
63B	--	----	8	62.0	7	57.0
63C	68	65.0	26	81.2	24	62.8
45G20	30	50.0	1	0	2	37.5
45G30	18	50.0	6	12.5	--	----
63G	20	50.0	3	25.0	--	----
63H	40	25.0	7	50.0	12	25.0

training (63A and 63B) showed slightly better performance with some formal training than with none. Turret and fuel-electric repairmen trained at a service school scored higher than the others in their MOS. But here again the N's were small. The larger automotive groups, 63C and 63H, present a somewhat different picture. 63C's who had Other-School training did better by nearly twenty percentage points than either the Service-School or the OJT groups. Similarly, the 63H's who had Other-School training scored twice as high (50% as opposed to 25%) as their Service-School and OJT trained counterparts. The basis for these differences is not entirely clear. A disproportionate number of the Other-School trained subjects had 5 or more years of experience. This would in part account for the difference in test performance among the 63H training categories, as better performance was observed for this high experience group. This explanation is not adequate for the 63C's whose performance differed negligibly over experience levels. A further breakdown of the schools for the 63C MOS is given in Table G5. The mechanics trained at Knox surpassed those trained at the Sill and Benning schools by an average of 10 percentage points. While there is a possibility that Knox students had an advantage because of the Knox school's role in developing the tests, it was presumed that the items were based on a common service school curriculum. Moreover, the subjects who had only training center or army area (USAREUR) schooling demonstrated substantially higher proficiency than those who had a service school background.

Table G5

Median Per Cent Test Performance by School for 63C MOS

Type of School	School	N	Median %
Service School	Knox	36	73.2
	Sill	13	62.5
	Benning	19	62.5
Other School	Aberdeen	3	62.5
	USAREUR	8	81.5
	Training Center	12	87.4
	Other	3	62.5
No School (OJT)		24	62.8

The number of schools that a man had completed bore little relationship to his test performance, except as reflected in the above data.

Job Assignment. The subjects were grouped by current job assignment into these categories: (a) maintenance job in primary MOS, (b) clerical job in primary MOS, (c) supervisory job in primary MOS, and (d) non-MOS assignment. The number in each category is presented in Table G6 along with average test performance. As shown, the supervisory personnel scored higher than the other assignment groups in each MOS, the mechanics outperformed the clerks in all but one instance, and the men working outside of their MOS scored the lowest except for the four 63G's.

A number of individuals are not assigned in their primary MOS. The proportion of malassignments within each MOS ranged from approximately .05 for the 63C's to .28 for the 45G20's, or one man in ten. Moreover, this does not take into account individuals who have had their primary MOS changed on the job, and thus would not have been included in the present sample.

A further look at the assignments indicated that maintenance experience and training background had little relevance, except that a larger proportion of men assigned to supervisory jobs tended to come from the high experience and on-job-trained categories.

Table G6

Number of Subjects and Median Per Cent Test Performance by Current Job Assignment

	MOS Maintenance		MOS Clerical		MOS Supervision		Non MOS	
MOS Group	N	Mdn %	N	Mdn %	N	Mdn %	N	Mdn %
63A	5	50.0	2	62.0	--	----	1	12.0
63B	9	62.0	--	----	5	71.0	1	12.0
63C	89	75.0	10	50.0	14	80.0	5	37.5
45G20	24	75.0	--	----	--	----	9	25.0
45G30	16	50.0	3	0	1	75.0	4	12.5
63G	14	50.0	4	37.5	1	75.0	4	62.5
63H	40	25.0	10	37.5	5	50.0	4	12.5
TOTAL N	197		29		26		28	

Supervision On The Job. Except for the men not assigned in their MOS, all were combined on the basis of their response to the question of whether or not they are directly supervised on the job. There was no observable difference in average test performance between the 116 subjects who reported that they were supervised and the 135 who said they were not. However, there was some indication that the more proficient test subjects received proportionately less supervision on the job than did the poorer performers.

Aptitude Area Scores. Mean GT and MM scores were tabulated for the specialty fields. Among the predominantly service school trained MOS's the means in both aptitude areas were slightly lower for the turret-repair specialties (Table G7). Such differences are of little consequence in light of the

Table G7

Mean General-Technical (GT) and Motor Maintenance (MM) Aptitude Area Scores by MOS

	63A	63B	63C	45G20	45G30	63G	63H
GT	98.0	98.5	101.8	94.9	100.6	106.7	103.6
MM	115.6	108 6	113.3	103.9	103.	112.3	113.5
N	8	14	107	27	25	23	52

moderate relationship between these aptitude variables and performance test proficiency. The biserial correlation between performance test score and GT score was .21; between test performance and MM, .29.

Vehicle Components Erroneously Condemned

A total of 231 minor parts, subassemblies and major vehicle assemblies were erroneously condemned during the course of the testing. Practically all were attributable to the automotive maintenance subjects (Table G8), largely because of the emphasis of the turret tests, particularly the 45G20 series, on adjustment, test, and repair problems. The percentages at the bottom of Table G8 are based on the total number of diagnosis items taken by the MOS groups. The direct support automotive repairmen (63G and 63H) made relatively more such diagnostic errors than the organizational automotive mechanics. The error rate averages about one per organizational mechanic, slightly more than one per man for the 63H, and nearly two per man for the 63G. The 140 minor parts condemned included such items as electrical leads, spark plugs, contact points, and switches. Among the 60 operable subassemblies judged to be defective were generators, alternators, voltage regulators, batteries, and distributors. Most of the 31 major assemblies condemned were transmissions and engines.

Table G8

Number of Vehicle Components Erroneously Condemned by MOS Test Groups

	63A	63B	63C	45G2	45G3	63G	63H	Total
Minor Part	7	19	59	0	2	29	24	140
Sub-Assembly	3	3	27	0	0	12	15	60
Major Assembly	0	0	0	0	1	0	30	31
Total		118		0	3	41	69	231
Per Cent Condemned		11%		0	4%	45%	30%	15%

Performance Deficiencies

A breakdown of the pass and fail groups by degree of proficiency is given in Table G9. A relatively high proportion of failures was described by the statement, "Didn't know enough to get started." For all groups but the 63G MOS, this

Table G9

Per Cent of Test Item Performance in the Descriptive Pass-Fail Categories for High and Low Performance Groups

MOS Group	Total Test Performance	Pass: Good Procedures	Pass: Some Guesswork	Pass: All Guesswork	Pass: Accurately Used Publication	Fail: Fairly Good Procedure	Fail: Much Guesswork	Fail: Gave Up Quickly	Fail: Didn't Get Started
63C	Upper 1/3	51	24	07	11	02	02	01	01
	Lower 1/3	18	14	04	03	11	20	08	22
45G20	Upper 1/3	53	08	0	15	05	0	0	19
	Lower 1/3	02	09	0	02	27	04	04	50
45G30	Upper 1/3	55	07	02	18	07	09	02	0
	Lower 1/3	0	0	0	0	08	04	08	79
63G	Upper 1/3	47	19	05	08	03	05	08	03
	Lower 1/3	06	06	03	0	22	31	16	16
63H	Upper 1/3	36	19	01	04	17	06	01	15
	Lower 1/3	0	0	0	0	12	23	11	53

statement was characteristic of the low performance subjects. The high performance group, on the other hand, was characteristically described as, "Used good procedures, knew what he was doing."

Use of Essential Procedures. Table G10 presents the degree to which essential steps were followed in completing a test item. As shown, the trend in use of the necessary procedures is obviously in the expected direction, but not as extreme as might be anticipated. If these are steps prescribed by the

Table G10

Per Cent of Test Items by the Number of Essential Procedures Followed for High and Low Performance Groups

MOS Group	Total Test Performance	Essential Procedures Followed: More Than Half	Less Than Half	None
63C	Upper 1/3	75	21	04
	Lower 1/3	32	45	23
45G20	Upper 1/3	81	0	19
	Lower 1/3	30	04	66
45G30	Upper 1/3	86	10	04
	Lower 1/3	05	08	87
63G	Upper 1/3	75	20	05
	Lower 1/3	34	31	35
63H	Upper 1/3	65	18	17
	Lower 1/3	20	33	47

technical manuals and taught by the schools as essential in diagnosing or repairing some malfunction, it may be assumed that successful performance is not likely without adherence to these steps. However, the data documents the frequent occurrence of subjects having passed test items with substantially less than 100% of the "essential procedures."

Use of Test Equipment. The use of test equipment is summarized in Table G11. Not all of the test items required the use of gauges or other special test equipment. These cases are combined with the occurrence of proper usage in the first column of the table. The other three columns describe categories of

Table G11

Per Cent of Test Items in Categories of Test Equipment Usage for High and Low Performance Groups

MOS	Total Test Performance	Used Properly or Not Required	Use of Test Equipment: Did Not Use	Could Not Operate	Did Not Know Procedures
63C	Upper 1/3	70	23	02	04
	Lower 1/3	39	35	18	08
45G20	Upper 1/3	92	08	0	0
	Lower 1/3	70	25	05	0
45G30	Upper 1/3	86	11	0	03
	Lower 1/3	50	50	0	0
63G	Upper 1/3	78	08	06	08
	Lower 1/3	22	25	22	31
63H	Upper 1/3	85	06	03	06
	Lower 1/3	45	42	06	06

deficiency where test equipment was necessary. For example, few of the organizational or direct support turret-repair items involved the use of test equipment, yet poor performance on those items that did was primarily due simply to a failure to use it. This failure, in turn, may be attributed to either the subjects' unfamiliarity with the equipment, or his inability to recognize the need for it. Similarly, the low scoring 63H group was marked by its failure to utilize test equipment. Failures on the fuel-electric items, on the other hand, were due to an attempt to use test equipment without the ability to operate it or make the proper readings.

Use of Publications. More common than failure to use test equipment was failure to use or to understand the technical manuals (Table G12). As shown, the range was considerable: the lower third of the 45G20 group failed to use publications on 21% of the items; the lower third of the 63G group failed to use publications on 72% of the items. On approximately 30% of the test items the low scoring individuals tried to utilize publications, but either could not find the pertinent reference or could not interpret the instructions or diagrams. The poor performance of the 63H's was typified by these deficiencies in manual usage.

Table G12
Per Cent Test Items in Categories of Publications Usage
for High and Low Performance Groups

MOS	Total Test Performance	Use of Publications: Used Properly Or Not Needed	Did Not Use	Could Not Find Reference	Could Not Understand Reference
63C	Upper 1/3	60	28	04	08
	Lower 1/3	33	26	17	24
45G20	Upper 1/3	68	12	03	17
	Lower 1/3	35	21	19	25
45G30	Upper 1/3	68	11	04	17
	Lower 1/3	04	58	25	13
63G	Upper 1/3	78	11	03	08
	Lower 1/3	16	72	0	12
63H	Upper 1/3	81	05	08	06
	Lower 1/3	19	23	30	28

The distribution of low scoring 63C and 45G20 subjects was fairly level over the categories of failure to use publications or deficiency in using them; about 65% of these groups were involved in these types of failure.

DISCUSSION

Test Performance

The general level of performance proficiency among the specialty fields tested is not easily explained. There are, however, some relevant factors which were not apparent from the data.

Foremost is the doubtful comparability of the tests. Although care was exercised in their development to base them on common criteria, there was no assurance that the tests for the various MOS's were comparable in difficulty. There were few items in each test; and the interitem correlations were low; these facts would further discourage any assumption of equivalence between the five test types.

One specific fact bears upon the performance of the organizational turret repairmen. This test included both tank and artillery items, as required to be consistent with the MOS description; yet only within the past few months has the Armor School begun to give instruction in artillery.

There is an interesting relationship between the poor showing of the direct support automotive repairmen (63H) and the information they gave in the pretest questionnaire. The predominant portion of their job time is spent in removing and replacing vehicle assemblies; they acquired little or no troubleshooting experience. Consequently any diagnostic skills they acquired in school are soon lost through a lack of on the job practice.

The superior performance of this sample of organizational automotive mechanics, compared to the performance of those tested in 1960, deserves some mention. In part, the explanation for this improvement of more than 100% in average proficiency may be stated in terms of testing conditions. The current program was conducted almost exclusively indoors; a longer time limit was allowed for each test item; and much more elaborate precautions were taken before testing, to motivate the subjects to do their very best on each problem. Another part of the explanation lies in the criteria for scoring a pass or fail. In the previous study a subject who made a correct diagnosis had to follow the prescribed, essential procedures to obtain credit for passing the test item; whereas the present study used as the criterion, a correct versus an incorrect statement of the malfunction. This difference in scoring would have a considerable effect on the average proficiency reported in the two studies, particularly since a subject might make a correct diagnosis without adhering completely to prescribed procedures.

It is not likely that an improved school curriculum contributed to the observed proficiency increase since 1960. Service school trained track-vehicle mechanics who had more than five years' experience scored as well as the more recent graduates. Regardless of the causes of the improvement, it is strongly indicated that the current performance level of about 65% more accurately represents the proficiency of organizational automotive mechanics than the 26% figure reported previously.

In other respects the results of the new testing program tended to corroborate the findings of the previous one. Lack of skill in the use of special test equipment and unfamiliarity with publications still prevails as prime correlates of low proficiency. The need for a graded program of on-job training beyond formal schooling was re-emphasized, since it was found that proficiency increased very little with time on the job. The frequent rejection of serviceable parts persists as an inefficient and costly result of faulty diagnosis.

Unlike the results of the previous study, the present data do not support the notion that service school training is superior to other training programs. Rather, there is some indication in the data for the automotive MOS's that mechanics trained in local command schools are more proficient than service school graduates This may occur as a result of (a) sending better motivated and more able men to local schools on the assumption by the parent organization that it will get them back, (b) developing local school curricula which are more validly job oriented, (c) immediately applying newly learned skills after completion of school, or (d) some complex interaction of these and other factors.

Also noteworthy is the number of men who had job assignments in which they were not utilizing their primary MOS. Such a situation if continued can eventually pyramid to a point where all the effectiveness of training is lost, not to mention the problems of personnel and training management which may be created. The companion problem of changing an established primary MOS by local authority bears close scrutiny.

School and Training Center Survey

During the conduct of the present study other pertinent questions arose about the nature and background of the formal programs of instruction in the MOS fields under review. Because of the short time available for obtaining data, it was decided that detailed examination of the POI's, lesson plans, educational practices, and training cost accounting procedures, could not be conducted by the test team. Therefore, selected schools and centers were asked to provide quantitative and qualitative answers to questions on the amount of training time given to diagnosis, test equipment and maintenance publications; the availability of refresher courses and supervisory training; the use and type of achievement examinations and the cost analysis of the program. It was recognized that the information obtained would be less than reliable if the responding training commands differed in their interpretation of the questions. Further, it was recognized that the replies might be less than valid if a respondent interpreted questions in such a way that his answers were favorable to his school or center. Such possibilities are unavaoidable products of the survey method.

Table G13 is a summary of the significant quantitative information obtained. The above reservations should be considered in making interschool comparisons of these data, for the interpretation of certain questions varied, as did the amount of detail given in response to them. Such variations are not reflected in the data. In time devoted to diagnosis, for example, there was a range of from 5% to 40%; yet the extent to which each school included general principles of diagnostic procedure versus practical troubleshooting exercises was not always clear.

Table G13

Summary of Maintenance School Survey Data

School and MOS	Time Diag-nosis	Time Test Equip.	Time Tech. Manuals	Total Hours	Passing Score Achievement Exams	Cost Per Student
The Armor School 45G20	130 hrs. 39%	79hrs. 24.8%	26 hrs. 8%	328 hrs.	70%	2100.00
63C20	49.5 hrs. 18.3%	36 hrs. 13.6%	*	264 hrs.	70%	926.00
The Artillery and Missile School 63C20	52 hrs. 17%	58 hrs. 18.8%	4 hrs. 1.3%	308 hrs.	70%	896.00
The Training Center Ft. Knox, Ky. 63B20	48 hrs. 20.6%	17.5 hrs. 7%	2 hrs. 1%	232 hrs.	70%	non-avail.
The Infantry School 63C20	67 hrs. 25.3%	15.5 hrs. 6%	*	265 hrs.	70%	4889.43
The Ordnance Center and School 45G30	45 hrs. 9.5%	101 hrs. 21.4%	10 hrs. 2%	472.5 hrs.	70%	2035.00
63B20	12.5 hrs. 5.6%	18 hrs. 7.7%	2 hrs. 1%	232 hrs.	70%	non-avail.
63G20	125 hrs. 28.2%	105 hrs. 23.6%	2 hrs. .5%	443.5 hrs.	70%	1287.00
63H20	55 hrs. 10%	48 hrs. 8.7%	3 hrs. .5%	552.5 hrs.	70%	1064.00

*Covered in conjunction with other instruction.

The same applies to test equipment and technical manuals. The reported time spent on these did not always differentiate between general techniques of usage, and practical application included in other units of instruction. Similarly, individual as opposed to group instruction is not considered in the statistics. The times reported for instruction in test equipment may reflect an accurate picture of group training and therefore a misleading picture of the individual mechanic's training. For example, two hours spent by six mechanics in practicing a specific check or test may mean that each mechanic was working with the equipment for 20 minutes or less.

Given these reservations, the sum of the percentages of time devoted to diagnosis, test equipment, and manuals varied from 14% reported for the 63B20 course at The Ordnance Center and School to a high or 72% reported for The Armor School's 45G20 course. The 63C20 programs uniformly devote just over 30% of their instruction to these topics, as does the 45G30 course; whereas the direct support automotive programs differ considerably in this respect, from 19% for the 63H20 course to 52% for the 63G20 course. It is assumed that the remainder of each program is given to such topics as general automotive and artillery principles, vehicle and subsystem operation, repair, adjustment, and achievement examination.

The estimates of cost of administering each maintenance course (Table G13) are both interesting and confusing. Each training establishment derived its estimate by summing (a) the funded costs, including the salaries of civilian instructors and funds appropriated for conducting the school program; (b) the unfunded costs, including the salaries of military instructors, the cost of training aids, and the cost of operational equipment used for training; and (c) the overhead support costs, including the expenses associated with school facility maintenance. The total cost for each course was then prorated by dividing it by the number of students enrolled. As shown in the table, there is great variation in the estimates of cost per student. At The Infantry School the 63C20 course, which provides 265 hours of instruction, has a reported cost per student more than twice as large as the 45G20 course (Armor School), which provide 328 hours of instruction.

The variation in cost estimates for the three 63C20 courses is especially noticeable. Review of The Infantry School estimate indicates that it was heavily weighted by unfunded costs, which were at least six times as large as those from The Armor School and The Artillery School. Several explanations of this difference have been suggested. One is that the cost per student decreases as the number of students increases. But the fact that The Armor School produces about twice as many 63C20's as The Infantry School or The Artillery School only partially accounts for the difference in cost estimates.

A second suggested explanation is related to the cost of support vehicles utilized in the practical phases of instruction. For example, The Armor School utilizes some 35 tanks in mechanic training, but does not have to include this expense, as the tanks are provided by USATCA. Though The Armor School has not always had this financial advantage, it is not likely that The Infantry and Artillery Schools have ever had it.

Another possible explanation of the results of the cost survey is that the schools differed in what items they included in their estimates. Here, the failure to specify student expenses (e.g., salary, subsistence and travel) was a noticeable example. The discrepancies shown in the table seem to reflect the possibility of differences between schools in cost concepts, though there was not time to make a detailed study of the matter.

A view of the performance test results in terms of the school survey data indicated no positive pattern. That is, neither the total number of instructional hours nor the relative time spent on diagnosis, test equipment, or manuals appeared to have any relationship to the proficiency of the MOS groups on the performance tests. If anything is to be noted here, it is that course length tends to be inversely related to performance proficiency. This trend includes all the groups tested, the 63H20 MOS being an extreme case. These direct-support automotive repairmen scored lower on the field test than any other group, yet their training program is reported to be significantly the longest. It is logical that because their job is more complex and difficult to learn, their training will take more time. Yet the discrepancy between the content of their training program and their on-the-job duties (mentioned earlier in this report) must not be overlooked as a possible explanation of their poor test performance.

Concluding Note

The problem of developing and sustaining a high level of maintenance proficiency in the Army is extremely complex. It can not be simply traced to the schools, or to on-job training, or to supervision--any more than it can be attributed primarily to inferior test equipment or inadequate technical manuals. Personnel selection and assignment procedures, the proficiency pay program, and the training management system also make significant contributions here. No one of these factors is alone accountable; rather, they must be viewed as aspects of an integrated enterprise which as a whole determines the ultimate quality of maintenance performance.

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