Discussed is a study of human factors that was designed to measure the time to perform maintenance using two types of manuals (format) presented in two media types, for a total of four conditions. The types of manuals were the then-current Field Engineering Maintenance Manual (FEMM) and Field Engineering Theory of Operation Manual (FETOM) in both hard copy and microfiche, and a new Graphic Integrated Manual (GIM) covering the same subject matter, also in hard copy and microfiche. The objective of the study was to compare performance in solving problems on an electromechanical machine, the IBM 5424 Multi-Function Card Unit, through the use of standard and graphic integrated manuals in both hard copy and microfiche for that machine. Test results are analyzed and conclusions are presented. The general conclusion is that the new graphic integrated manuals in hard copy format lead to better performance both in education and on the job.

Effects of manual style on performance in education and machine maintenance

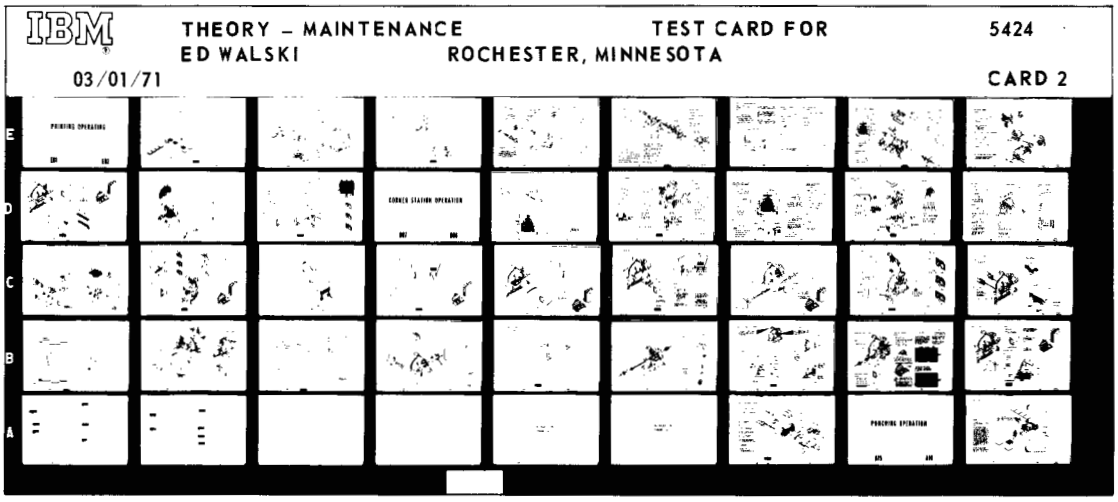
by J. M. Judisch, B. A. Rupp, and R. A. Dassinger

There are times when apparent cost reductions lead to an increase in real cost. The study reported here was conducted because divergent points of view on the effectiveness of two different machine maintenance manual formats and two media conditions required behavioral experimentation to determine the better approach.

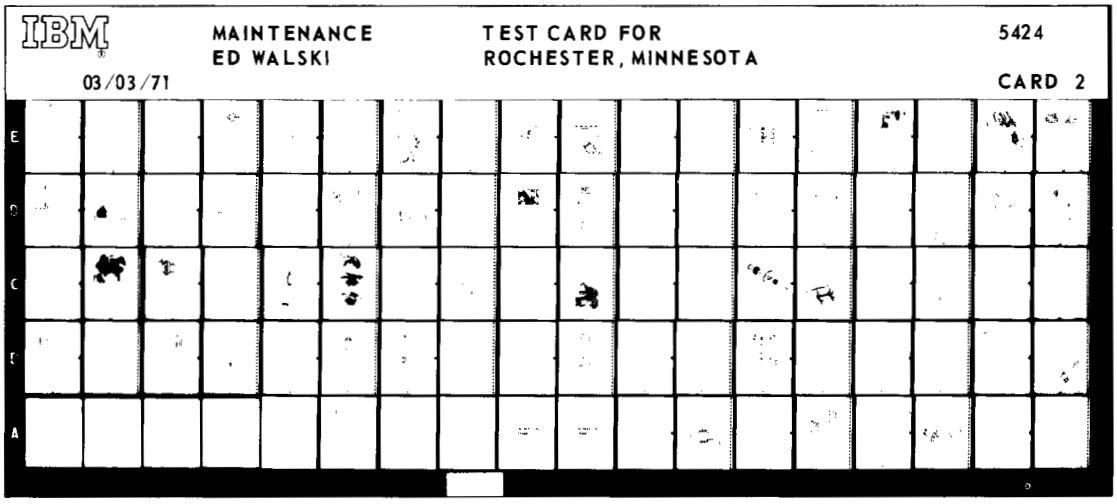
media

One point of view was that if maintenance documentation were to be placed on microfiche instead of hard copy on paper there would be significant cost savings. The reason was that a single three and a quarter by seven and a quarter inch microfiche card could contain as much information as ninety hard copy printed pages. Cost savings would result from lowered printing costs, reduced turnaround time, and lowered distribution costs, owing

Figure 1 Sample microfiche card: (A) graphic integrated manual; (B) traditional manual



(A)

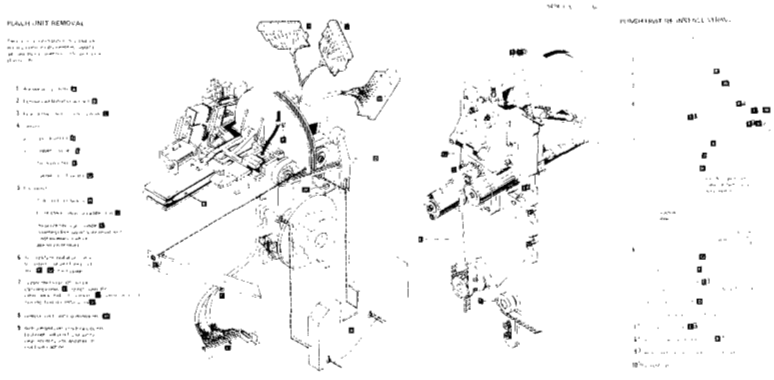


(B)

to the greatly reduced weight of microfiche cards as compared to the equivalent in printed hard copy manuals. A typical microfiche card (in the graphic integrated manual format) used for maintenance purposes in this experiment is shown in Figure 1 (A); the traditional format is shown in Figure 1 (B).

The salient question to be investigated was whether an IBM customer engineer (CE) could use the manuals provided as effectively in microfiche format as in hard copy format. Although the cost of printing and distributing hard copy manuals is significantly

Figure 2 Sample page from the Graphic Integrated Manual (GIM)



higher than that for microfiche cards, the putative savings might prove to be lost if repair time were increased by even a small amount.

format

A second question to be investigated was whether a new graphic integrated documentation process that costs more to develop and produce than manuals currently used in training and the field would be worth the greater cost. The way to determine this was to investigate whether customer engineers could demonstrate time savings by using the new graphic process. Associated with this question was concern over negative transfer of training because customer engineers would previously have been trained to use the standard or more or less traditional documentation format. Could they readily adapt to a new format, or would its differences inhibit learning? As an analogy, such a change might be compared to the experience of persons used to driving on the right side of the road who are required to drive on the left. Previous experience makes the transition difficult until the old learning has been extinguished and the new learning implemented.

To address these issues, we initiated a research project to evaluate the new Graphic Integrated Manuals (GIMs), a sample page of which is shown in Figure 2. The testing was done by the participation of customer engineers who service highly complex electromechanical devices. Chosen as the device for study was the IBM 5424 Multi-Function Card Unit, which reads, punches, interprets, sorts, and collates ninety-six-column cards used by the System/3 Model 10 computer. This experiment was designed to compare and measure any differences there might be between customer engineer performance (i.e., time to fix a problem on that card unit) using graphic integrated manuals and traditional Field Engineering Maintenance Manuals (FEMM) and Field Engineering Theory of Operations Manuals (FETOM). A sample page

Figure 3 Sample page from a traditional manual

from one of these manuals is shown in Figure 3. This study was also designed to measure the performance of customer engineers using graphic integrated manuals and traditional manuals with the contents presented in both hard copy and microfiche format. The microfiche were to be viewed on a portable viewer then in current use.

We measured and compared the performance of one group of customer engineers whom we had trained using the traditional style of manuals and another group whom we had trained on the System/3 Model 10 using the graphic integrated manuals for the multi-function card unit. Also important to our study were the customer engineers' attitudes toward the four documentation conditions.

Methodology and procedure

There were two major conditions to be tested: (1) Media, that is, the use of printed hard copy manuals and the same manuals presented in microfiche and viewed with a particular model of viewer; (2) Format, namely, the use of traditional manuals and the use of new graphic integrated manuals. Thus, there were a total of four conditions.

Subjects for this experiment volunteered from classes that ranged in size from ten to fifteen students. Since four conditions were to be tested, the volunteers were grouped in units of four. Thirty-two students were required to provide a sufficiently large sample size, that is, sixteen students trained using the two format conditions.

Because few classes had sixteen students and because not all students could stay the additional week required to participate in our experiment, we decided to select eight students from each of four classes. These four classes received training on the entire Sys-

tem/3, including the printer and the central processing unit as well as the multi-function card unit, which was the test device in our experiment.

The only difference in training was in the documentation used for the multifunction card unit. The first two classes were taught using the traditional documents, including FEMM and FETOM, except that these texts had been revised and updated both technically and in writing style. The other two classes were instructed using the experimental graphic integrated manual for the 5424 Multi-Function Card Unit that was based on the information from the 5424 FEMM and FETOM, but presented in the new graphic format. Thus, the two modes of instruction used two of the same documentation conditions in training that would later be used in the testing.

The classes chosen for this experiment had been previously scheduled and had to fit the time allotted for the experiment. Class members were asked to volunteer to remain the additional week required for the experiment, provided that so doing conflicted with neither their personal obligations nor their managers' plans. When more than eight volunteers met these requirements, the first eight to volunteer became subjects.

The eight customer engineers who volunteered from each of the four classes that participated in the experiment were first given the regular seventeen-day systems training class for System/3 Model 10 along with their classmates. The experiment discussed in this paper was conducted after the students had received that basic training. The next section discusses the design of the experiment.[1] The results of an analysis of variance with repeated measures are given in the Appendix.

experimental design

Recall that there were two groups of students who volunteered to be the subjects of the experiment to test two subconditions on the training texts. These two groups were characterized as follows:

- Group 1 consisted of sixteen subjects, on the basis of eight from each of two classes who had been trained using traditional texts.
- Group 2 consisted of sixteen subjects, on the basis of eight from each of two classes. As students, these subjects had been trained using traditional manuals for all other aspects of the System/3 Model 10 except for the 5424 Multi-Function Card Unit where they had been trained using graphic integrated manuals as texts.

To test the four types of documentation (i.e., the experimental conditions), each student in the two groups was given a set of twenty-four problems to solve, divided into four groups of six problems for each of the following four types of documentation:

Table 1 Experimental conditions

Training mode	*Graphic integrated manuals*		*Traditional manuals*	
	Hard copy	*Microfiche*	*Hard copy*	*Microfiche*
Using traditional manuals	Group 1	Group 1	Group 1	Group 1
Using graphic integrated manuals	Group 2	Group 2	Group 2	Group 2

Table 2 Design of customer engineer problem solving schedule for each group of participants

Customer engineer designation	*Problem numbers with manual type and format used for their solution*			
	1-6	*7-12*	*13-18*	*19-24*
1	G-H	T-H	G-M	T-M
2	T-H	T-M	G-H	G-M
3	G-M	G-H	T-M	T-H
4	T-M	G-M	T-H	G-H
5	G-M	T-M	T-H	G-H
6	T-M	T-H	G-H	G-M
7	T-H	G-H	G-M	T-M
8	G-H	G-M	T-M	T-H

G-H: Graphic integrated manuals in hard copy media
G-M: Graphic integrated manuals in microfiche media
T-H: Traditional manuals in hard copy media
T-M: Traditional manuals in microfiche media

- Traditional 5424 Multi-Function Card Unit manuals, i.e., technically updated Field Engineering Maintenance Manual (FEMM) and Field Engineering Theory of Operations Manual (FETOM) on hard copy media.
- Traditional 5424 Multi-Function Card Unit manual, i.e., technically updated Field Engineering Maintenance Manual and Field Engineering Theory of Operations Manual on microfiche media.
- Graphic Integrated Manual for the 5424 Multi-Function Card Unit on hard copy media.
- Graphic Integrated Manual for the 5424 Multi-Function Card Unit on microfiche media.

The experimental conditions for the two groups are displayed in Table 1.

Given twenty-four problems to be solved and the mode of training each of the eight participants in the experiment had received, Table 2 displays the distribution of the four documentation conditions used by the participants to solve the problems they were given. The twenty-four problems are displayed in groups of six for the four possible combinations of manual type and format across the top of the table. The customer engineer participants are designated by numbers one through eight along the left side of the table.

Also notice in Table 2 that manual type and format are evenly distributed with respect to customer engineers and problem groups so as to minimize any bias that might have been caused by the nature of the problems or by their positions in the sequence of tests. Thus, to give an extreme example, all eight customer engineers do not solve problems one through six using hard copy graphic integrated manuals.

experimental procedure

The order of problem presentation remained constant over all subjects. The conditions on manuals, however, were counterbalanced to minimize differences among problems. Thus each customer engineer served as his own control, thereby allowing the greatest possible economy of participants and materials.

Each group of eight participants was allowed three days for performing the tests. The morning of the fourth day was used as an interview session to record customer engineer reactions, opinions, and attitudes on videotape.

Each customer engineer was allowed a maximum of two hours for a repair action. For some problems, he was also required to diagnose a failure in an allowed time of fifteen minutes. An observer directed the customer engineer to a problem when he did not diagnose it in the time allotted. Diagnostic time was not an important part of this particular experiment, and was recorded only for the edification of the participants. (In System/3, the primary diagnostic tools are Maintenance Analysis Programs (MAPs) and not the Field Engineering Maintenance Manuals and Field Engineering Theory of Operations Manuals used in this experiment.)

There was one customer engineer and one observer—who had been trained to minimize bias—assigned to a System/3 during the experiment. The observer recorded the time the customer engineer spent using the manuals provided as well as the time spent trying to solve and pondering the problem. The observation log indicated the type of manuals, if any, the customer engineer used. At the end of each problem, whether successfully solved or not, a short questionnaire was administered to record the customer engineer's attitude and opinions regarding the type and format of the manuals, including suggestions for improvement.

Table 3 Percent differences in customer engineer problem solving performance using four types and formats of manuals

	Traditional manual format; microfiche media	*Traditional manual format; hard-copy media*	*Graphic integrated manual format; microfiche media*	*Graphic integrated manual format; hard-copy media*
Traditional manual format; microfiche media	—	5.1	9.7*	14.5*
Traditional manual format; hard-copy media		—	4.8*	9.9*
Graphic integrated manual format; microfiche media			—	5.3*
Graphic integrated manual format; hard-copy media				—

*Significant at the 0.05 level.

Experimental results

An analysis of variance with repeated measures was the statistical analysis used on the data recorded in our experiment and is summarized in the Appendix table. We have derived the following results from those data and the analysis:

- *Training*. The sixteen customer engineers who had been trained using the new graphic integrated manuals solved all their problems 19.3 percent faster than customer engineers who had been trained using the traditional manuals.
- *Manual format in problem solving*. Customer engineers took 9.8 percent less time to solve problems using the graphic integrated manuals than they did using the traditional manuals.
- *Manual media in problem solving*. In the experiment, the customer engineers performed their problem-solving tasks 5.2 percent faster when they used hard copy manuals than when they used the microfiche format.

Customer engineer performances under the four conditions of manual documentation are summarized in Table 3. The conditions are presented in decreasing order of time, with the traditional microfiche format taking the longest time and hard copy graphic integrated manuals taking the shortest time.

This study was purposely designed to control two intervening time variables that would normally be present for a customer en-

gineer using microfiche by having the microfiche viewer present and plugged in at the test machine site. Since microfiche viewers are usually kept either at the field office or in the customer engineer's car, the first controlled variable was the delay time before deciding that the viewer was needed. The other controlled variable was the time required to bring the viewer to the site and plug it in once the decision was made to use it.

To estimate the effect on performance of these two variables, three quarters of an hour was allotted to deciding to use and obtaining a microfiche viewer—close to three times the actual time required to diagnose and repair the average problem. When the decision and obtaining time was added to the microfiche repair performance, the smallest difference in performance (i.e., between hard copy graphic integrated manuals and microfiche graphic integrated manuals) increased from 5.3 percent to 305 percent.

questionnaire

At the conclusion of each problem, two statements were made, and the customer engineer was asked to indicate the degree of his agreement or disagreement on a scale of one to five, from "strongly agree" (one) to "strongly disagree" (five). The first statement was: This manual is well written and organized, and provides an excellent basis for shooting bugs (solving problems). The second statement was: Microfiche is a better medium for presenting this material than hard copy.

Results for the first statement indicate that when the customer engineers used graphic integrated manuals, they strongly agreed with the statement (with a mean score of 1.75). When the same customer engineers used the traditional manuals, they disagreed slightly (with a mean score of 3.34).

The customer engineers did not agree with the second statement. Regardless of the format, either graphic integrated manuals or standard manuals, their average response was disagreement (with a mean score of 4.24). The customer engineers were stronger in their disagreement when they used traditional microfiche (mean of 4.33) than when they used traditional hard copy (mean of 4.15).

Concluding remarks

The result of this study led to three conclusions. The group of sixteen customer engineers trained using the graphic integrated manual documentation performed the twenty-four test problems 19.3 percent faster than the group of customer engineers trained using the old documentation. This difference could be explained in one of two ways: (1) Because of the graphic integrated manual documentation used in training the two classes in Group 2, they were able to perform all their problems faster; or (2) There were

major differences in the makeup of the customer engineers who comprised the two classes in Group 2 versus the customer engineers in Group 1. To better evaluate some of the large differences apparently due to training, discussions were held with the two instructors who taught the classes and with the Field Engineering Education instructor assigned to the test session.

In their opinion, the last two classes (graphic integrated manuals) were no different at the outset from any of the many other classes they had taught. Nor did they feel that the reduction in time, which was demonstrated by the classes taught using the graphic integrated manuals, could be accounted for by superior students. They felt the largest factor that reduced overall problem-solving time was the graphic integrated manual.

The students trained with graphic integrated manuals required about one to one and a half hours of lecture time. This meant they could solve problems and become more proficient on the multifunction card unit during the laboratory period. The instructors judged that this proficiency was temporary or could be considered an artifact of intensive training, and that it would be valuable to retest these same customer engineers in six months after they had had a chance to forget some of the material. The customer engineer test subjects suggested the same thing.

If, in fact, there was a difference attributable to the ability of the customer engineers by group, their class performance on another electromechanical device, the 5203 printer, should have shown similar differences. An examination of classroom performance indicated no significant difference between the performances of the groups on the printer, but there was a slight trend showing that Group 2 performed less well on 5203 problems than Group 1, even though they had performed better on 5424 problems when trained with the graphic integrated manual.

The test results predicted that the introduction of graphic integrated manuals into the field for use by customer engineers familiar with the old manuals should have no negative effect on customer engineer problem-solving performance; this was later confirmed through field surveys. All thirty-two customer engineers in the study solved the test problems faster with the graphic integrated manuals than with the old manuals. This difference reached a maximum of 14.5 percent savings when the graphic integrated manual on hard copy was compared with the old manual on microfiche (best and worst conditions and did not include the approximately 300 percent increase due to the two intervening variables). In order to look at the graphic integrated manual versus the traditional documentation, the microfiche and hard copy data were combined for each of these conditions. The results indicate a mean time savings of 9.8 percent.

Customer engineer problem-solving performance is better with hard copy than with present microfiche.

The subjects trained using the old manuals would be expected, on the basis of transfer of training, to perform better with the traditional than with the new manuals. However, they solved the twelve problems 9.8 percent faster using the graphic integrated manual over the traditional manuals.

All subjects, irrespective of training, preferred the graphic integrated manuals over the traditional manuals. The response by the customer engineers to the statement, "This manual is well written and organized, and provides an excellent basis for shooting bugs (solving problems)" showed a high level of agreement (1.75 on a five-point Likert scale), whereas the same customer engineers responded more negatively (mean 3.34) when they were required to solve problems using the old manuals.

A difference favoring hard copy over present microfiche provided a mean problem-solving savings of 5.2 percent in favor of hard copy. The attitudinal statement regarding microfiche supports this savings.

Approximately one year after the completion of this study, an in-depth, person-to-person interview of nearly two hundred System/3 customer engineers was conducted. As part of the survey, they were asked to evaluate the graphic integrated manual that had been distributed as a result of the experiment discussed in this paper. The survey results indicating that the new graphic integrated manual was thought to be one of the best documents in the customer engineer maintenance library were an improvement over previous survey results.

Appendix: 5424 Multi-Function Card Unit adjusted repair time, analysis of variance summary table

Source	*Mean squares*	*df*	*F ratio*	*Level significance*
Between subjects				
A = training (using graphic integrated manuals versus traditional manuals)	45.162	1	10.471	0.005
Error	4.130	30		
Within subjects				
J = Manual type (graphic integrated manuals versus traditional manuals)	12.785	1	7.878	0.001
AJ interaction	0.037	1	0.023	NS

Error	1.623	30		
K = Manual format (hard copy versus microfiche)	7.011	1	5.589	0.05
AK interaction	2.286	1	1.822	NS
Error	1.255	30		
JK interaction	0.312	1	0.230	NS
AJK interaction	0.677	1	0.499	NS
Error	1.356	30		

The magnitude of the differences, in terms of percentage of time savings, is indicated here in the Appendix table. The percentages indicate time savings. The conditions are presented in decreasing order of time, with traditional manuals in microfiche format taking the longest time and hard copy graphic integrated manuals taking the shortest time.

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