Industrial Retraining Programs for Technological Change

A Study of the Performance of Older Workers

Bulletin No. 1368

UNITED STATES DEPARTMENT OF LABOR
W. Willard Wirtz, Secretary

BUREAU OF LABOR STATISTICS
Ewan Clague, Commissioner

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Preface

The introduction of automation and other technological changes is often accompanied by problems of adjustment for individual workers. Many workers are compelled to acquire new skill and knowledge to maintain their employability. The retraining of older workers is considered particularly critical.

This study was undertaken by the Bureau of Labor Statistics in an attempt to understand the types of technological changes that give rise to the need for retraining in industry and the effectiveness with which older workers already on the job adapt to such retraining. It was, however, only a pilot study of limited aspects of the broad subject of older worker adaptability.

The study was conducted by Dr. Arnold Tannenbaum and Gary Grenholm of the Survey Research Center, Institute of Social Research of the University of Michigan, for the Bureau of Labor Statistics. The final draft of the bulletin was prepared by Edgar Weinberg, Chief, Division of Technological Studies, as part of the Bureau's research on the impact of technological change under the general direction of Leon Greenberg, Assistant Commissioner for Productivity and Technological Developments.

The Bureau of Labor Statistics is grateful to the companies which made their records available for this study. The Bureau is also indebted to the Institute and to numerous individuals who assisted in the extensive preliminary canvass necessary in locating the companies studied.

Contents

	Page
Introduction	1
Highlights and summary	5
Retraining of oil refinery production workers	7
Retraining of aircraft production workers, technicians, and engineers	13
Retraining of airline maintenance mechanics	21
Retraining of telephone operators	25
Selected bibliography	33

Tables:

1.	Production workers at oil refinery: Level of performance of younger and older trainees on training courses	10
2.	Production workers at oil refinery: Level of performance of older and younger trainees when differences in education are taken into account	11
3.	Instrument mechanics at oil refinery: Percent of older and younger trainees who received grades above and below average test scores	12
4.	Training courses at an aircraft plant: Comparative performance of older and younger trainees on tests	18
5.	Training courses at an aircraft plant: Comparative performance of older and younger trainees on tests, with differences in education taken into account	19
6.	Training courses given to weldors at aircraft plant: Percent of older and younger trainees, above and below median time needed to achieve certification	20
7.	Airline: Level of courses and number of courses and trainees	23
8.	Representative course titles, by level	23
9.	Airline maintenance workers: Distribution of courses according to comparative performance of older trainees	24
10.	Telephone operator trainees: Level of performance on various measures, by age group	28
11.	Telephone operator trainees: Level of performance of trainees with 8-11 years of education, on various measures, by age group	29
12.	Telephone operator trainees: Level of performance in various measures, of trainees with 12 years or more of education, by age group	30
13.	Telephone operator trainees: Level of performance on tests interpreting tickets, by age group	31

Industrial Retraining Programs for Technological Change

Introduction

The rapid pace of technological change creates widespread interest in programs for retraining workers now employed in industry. Changes in equipment, processes, and products often involve obsolescence of skill and knowledge of workers. By retraining and reassigning workers to other jobs within a firm, management is frequently able to retain in useful employment those whose former duties have been eliminated, but who have abilities and background useful in other operations. Such steps are preventive measures against the hardships of layoff and unemployment and the waste of human talents.

Measures to improve the employability of older workers are particularly important, because older workers, once laid off, generally find it difficult to obtain new jobs and may experience long periods of unemployment. As automation and other technological changes are introduced more widely, the retraining of older workers in industry for new or different jobs becomes increasingly urgent, for management and communities as well as for the workers themselves.

This study seeks to broaden understanding of the capacity of older workers in industry to adapt to technological change. An objective investigation was made of performance in retraining programs that were undertaken by firms as part of the introduction of new technology. Specifically, the study first describes various cases of technological change at selected plants and the content of the retraining courses that were given in connection with the changes. Second, the results of tests that had been given in connection with the courses are analyzed, to determine how well older workers employed in these plants performed in retraining programs.

The report is intended only as a pilot step in exploring an important aspect of technological change rather than a comprehensive investigation of the subject of older worker adaptability. Although retraining is recognized as a key problem, comparatively little information is available about the training experience and problems of workers in a job environment. Studies of adaptability often involve comparisons of rates of learning by older and younger persons under laboratory or school conditions, where motivation and other conditions are quite different from industrial training situations. 1/ A better understanding of the trainability of older workers

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1/ See E. A. Jerome, "Age and Learning--Experimental Studies," and Ross McFarland and Brian O'Doherty, "Work and Occupational Skills," Handbook of Aging and the Individual, James E. Birren, editor (Chicago, University of Chicago Press, 1959), pp. 655-699 and 487-497.

in industry has been advocated as a step toward developing measures for improving their capacity to cope with changing industrial job demands. 2/

Scope and Method. The study presents information on four companies in different industries where technological changes were introduced, requiring the retraining of employees. About 2,200 workers in different types of occupations were covered: Production workers in an oil refinery; maintenance mechanics in an airline; engineers, technicians, and craftsmen in an aircraft factory; and operators in a telephone company.

The companies covered in the study were selected after an extensive canvass covering about 100 industrial, business, and government organizations. While many of the firms had made recent technical changes requiring the retraining of employees, few had adequate records of training performance. The four finally included in this study were the only canvassed firms which had kept objective measures of the performance of individual workers during retraining, had included workers over 40 as well as under 40 in the programs, and had personnel records showing age and educational level of the workers. The information was collected through interviews with personnel and training officials. Data on the performance of trainees were obtained from company personnel and training records.

Training was usually highly specialized and each course was given to only a small number of trainees. In analyzing the results, trainees in most cases were divided into two age groups--older and younger trainees. (See tables for the age groups used in each case.) Further subdivisions were not possible because of the small number of trainees in each course. Also, because of the diversity of courses, it was not considered feasible to aggregate the results of the different tests. Accordingly, comparisons of younger and older workers are made, wherever possible, for each course. While each test covered only a small number of trainees, the total number of tests and trainees was sufficiently large to provide a basis for drawing some tentative conclusions.

The nature of recent technological changes at each plant, their effect on job requirements, the content of retraining programs, and the comparative performance of trainees of different age groups and educational levels, as measured by tests and other objective standards, are described briefly.

2/ See Employment Security and Retirement of the Older Worker, Reports and Guidelines from the White House Conference on Aging, Series No. 3 (U.S. Department of Health, Education, and Welfare, 1961), p. 27.

Some Considerations. In assessing the findings, it is important to consider certain aspects and limitations of the scope and method of the study.

First, the performance on tests of older trainees is compared with that of younger trainees. However, the study does not deal with the question of whether the performance of retrained workers met the minimum requirements established by employers. Since no evidence was found that any trainee was laid off because of test performance, presumably, companies preferred to use performance on the job to which the trainee is assigned as the yardstick for evaluating the usefulness of training, taking into account not only productivity (as affected by training), but also attendance, attitude, and reliability.

Second, the study was limited to those aspects of retraining for which objective data on the performance of trainees could be obtained from company records. Considered outside the scope of the study are the interests and attitudes of older and younger trainees about the changes in their jobs and the retraining and the opinion of supervisors and instructors about workers' performance although they are also relevant to broad questions about general adaptability to technological change.

Third, the study compares the performance of trainees of different age groups on a given date. The results reflect the influence of the expansion of educational opportunities in recent years. Age differences should not be interpreted to mean that performance necessarily changes as a trainee grows older. Studies of the effects of aging on retraining performance, where individuals are followed over several decades, would be useful, but the data for such a study are not readily available.

Fourth, the study is limited to comparisons of the performance of older and younger trainees on tests given as part of retraining. The results are not necessarily indicative of comparative on-the-job performance of older and younger trainees after retraining. For purposes of an overall assessment, comparative records of attendance, continuity of service, and productivity of trainees after having been placed on new jobs would need to be considered. Other studies by the Bureau of Labor Statistics have revealed the difficulties of making generalizations about older workers' job performance because of the wide variability in relevant factors among workers at all ages, with some older workers doing as well or better than some younger workers. Moreover, differences in productivity between age groups were often found to be relatively small. 3/

3/ See Comparative Job Performance by Age: Large Plants in Men's Footwear and Household Furniture Industries (BLS Bulletin 1223, 1957); and Comparative Job Performance by Age: Office Workers (BLS Bulletin 1273, 1960).

Finally, the results of this study do not necessarily reflect experience in retraining programs where all trainees are carefully screened so that only those with maximum potentialities for success are selected. Having made changes in equipment and methods, the companies covered had retrained workers on the job, older as well as younger.

Highlights and Summary

Technological Change and Retraining. Because of important changes in equipment, processes, or products, at the companies studied, large groups of workers had to be retrained so that plant operations after the change could be carried on efficiently. Hiring already qualified workers in place of those on the job was not considered desirable or practicable. Thus, modernization of an oil refinery required training in new processes and instrumentation; greater use of electronic equipment and new metals by an aircraft manufacturer--training of technicians, engineers, and electricians in electronics; the introduction of jets by an airline--courses for mechanics and technicians in maintenance of turbine engines; and the application of computers by a telephone company--retraining of operators in the use of mark-sense punch cards. Retraining generally involved enlarging or upgrading the knowledge or skill of employees or a modification of methods rather than completely changing over to new occupations. Retraining, in short, constituted a major step in the introduction of technological change in the companies studied.

Content of Retraining. One noteworthy aspect of the retraining given to workers was the extensive classroom instruction, often in technical subjects, required in numerous cases. Thus, the aircraft company's electricians, technicians, and engineers were given courses in electronics; the oil company's operators, courses in basic mathematics, instrumentation, and processing; and the airline's mechanics, courses in gyro instrument overhaul. The duration of the courses varied: some took as many as 800 hours of technical instruction over a 2-year period; others, only 6 hours for familiarization. Teaching methods involve lecture, practice demonstration, laboratory work, and on-the-job instruction. Older workers whose job duties were affected by the change were enrolled in these retraining programs along with younger workers and received the same instruction. Through retraining, these companies were able to make further use of experience and knowledge gained within the plant that was still relevant to the work to be done.

Older and Younger Workers in Retraining. The experience of the four companies gives no grounds for simple generalizations about the adaptability among older workers and shows no factual basis that would justify barriers to their entrance into training programs. Comparisons of test results show the younger group often doing better than the older group. The younger trainees were likely to respond more readily and learn more quickly, particularly when training courses were short and emphasis was on rapid acquisition of perceptual-motor skills. However, in a few courses where the training continued over longer periods, older workers more often performed as well or better than the younger workers. Another important finding was that some proportion--sometimes as high as 40 percent--of older workers on most of the tests analyzed did better than some of the younger workers.

Evidence from the study contradicts the notion that older workers cannot learn or cannot be retrained. The findings imply that age, by itself, is not a reliable or useful criterion for determining the suitability of workers for training. The study confirms the findings of other studies relating age to work performance, that there is great variation among individuals. Thus, while younger workers performed better on the retraining tests, on the average, there were individual older workers who performed better than average and better than some of the younger workers. Arbitrary age barriers in training programs or in employment would therefore exclude many older workers capable of high-level performance in training. In short, the findings of this study reaffirm the importance of appraising a worker's adaptability on the basis of individual capacity and aptitudes rather than on that of chronological age.

Importance of Counseling. The test results reflect, to some extent, the prevalence of informal methods of selecting trainees, reflecting the urgent need for new skills in the face of changing technology. Only a few trainees were tested, interviewed, or counseled in advance of training. The results from these few cases suggest that such procedures might result in a better matching of the aptitudes of candidates (of all ages) with the retraining to be given and in modification of training programs to meet the needs of individual workers. Counseling helps the worker not only in assessing his ability but also in allaying his apprehensions about training which older workers especially may fear and resist because of its novelty or unfamiliarity.

Education and Retraining. Some evidence, although fragmentary, suggests that lack of education may be a serious handicap for older trainees relative to younger. Older and younger workers with the same level of education differed less in performance. The older trainees had a lower average level of educational attainment and lacked recent school experience. This would seem to bear out the contention of educators that learning ability deteriorates with disuse. Over the long run, improvement and extension of educational opportunities for adults and youth may be one of the most important factors in assuring their adaptability when they become older.

Need for Additional Research. The evidence from this limited study points up the need for further research into the potentialities and problems of retraining employed older workers within industry. Since continuing technological change will undoubtedly intensify the need for retraining within industry, it would be helpful to know more about special training methods that obtain the best results from older trainees. Future research might be concerned, not only with the older worker's ability to learn, but also, for example, with the applicability of programed learning and other techniques which permit the trainee to control the pace of learning. It might explore the influence of the older worker's attitude toward training, and the effect of the instructor's practices and attitudes on the progress of older trainees. Wider dissemination of knowledge about the ability of older persons to learn and to be retrained should contribute to an easier adjustment to technological change.

Retraining of Oil Refinery Production Workers

The first study involved the retraining of production and maintenance workers of an oil refinery which had undergone extensive modernization. The refinery is a relatively small plant, employing about 450 workers. It is one of the major installations of a petroleum company.

Nature of the Technological Change. The technical changes that occasioned the retraining involved a higher degree of process integration than existed previously. In the old refinery operations, according to a company description, "crude oil and the various intermediate products are cooled, pumped to storage, and then subjected to reheating and further processing in other units. By this old system, the one still followed by most of the petroleum industry, the oil must pass through several separate installations, each subject to its own controls, before it is possible to blend the final products." Relatively obsolete reciprocating pumps were used, rather than the newer centrifugal type. The process control system was relatively crude, with manually operated temperature controls. Only five endproducts were made.

The new plant incorporates the "straight through" process. The cooling-storage-reheating parts of the old system are eliminated. Much more processing is done. Eleven endproducts are made. The capacity has been increased. According to the company, "The unit must work as one continuous operation, or not at all. Except for the delayed coking process, no part of it can stop for more than 12 hours without the entire unit slowing down significantly or shutting down completely."

An extremely complex, highly instrumented control system is used. Some 2,300 instruments record and control the actions of 235 pumps, compressors, and blowers, and 15,800 valves. The entire system is coordinated through a 96-foot semicircular central control panel. This system makes possible a higher degree of quality control than hitherto possible.

Modernization has meant significant changes for production workers. Previously, there were six different job classifications in the production department, each with its own pay rate. After the change, the job classifications for hourly workers were reduced to two. Under the new integrated system, operating workers must have some knowledge of processes in other parts of the plant as well as their own processing unit (or zone). Finally, because of the greater extent of instrumentation, workers with responsibility for keeping instruments functioning properly were transferred from the maintenance to the production department--a change reflecting their increased importance in plant operations.

Retraining Program. The company gave extensive advance retraining to prepare employees for work in the modernized refinery. In this study, however, only the two types of retraining programs for which performance data are available are described: The series of courses covering plant processes given to 82 operating workers of the production department; and the series of courses covering instrumentation given to 18 workers in the instrumentation division of the production department.

The first series were courses designed to familiarize operating workers with the new equipment and the complicated pattern of process flow, and to prepare them to meet problem situations. Two sets of courses were given, each 8 hours a day, 5 days a week--one for 3 weeks for a total of 120 hours; another for 4 weeks or 160 hours. A third set of courses was given 4 to 8 hours a week over a 2-year period. Each set involved several separate courses covering different process units of the refinery. Workers were not required to take all of the courses in a set, but a majority took more than one course. All training was administered by management personnel.

A second series of courses were given to 18 workers in the instrumentation division. One set, given by the management staff covered introductory material: The principles of measuring pressure, temperature, liquid level, flow, and their application in the refinery; elementary mathematics; operations of control valves, and the process flow of the refinery. Another set, given by the staff of a local university, covered electricity and electronics, including vacuum tubes, rectifiers, and amplifiers. A third set, given by the manufacturers of the instruments and control devices, dealt with the construction, use, and maintenance of specific control devices, valves, and meters.

A total of 21 courses was given but information was available for only six. Not all the 18 trainees took every course. The entire program took place over a 9-month period. For the first 5 months, training was given on a classroom basis, 8 hours a day, 5 days a week. For the last 4 months, half of the training was in the classroom; half, on the job.

Performance in Retraining. Information on the performance of trainees was obtained from grades on written examinations given in the classroom. The average (i.e., median) grades received on written exams were the basis of the analysis of the 12 courses for production workers shown in table 1.

For each course, the performance of each trainee was compared with the average, and these comparisons were grouped separately for younger and older trainees. The age basis used differed slightly from course to course. In 11 of the 12 courses, half or more of the younger trainees had grades above the average. In comparison, half or more of the older trainees had above average grades in only 3 of the 12 courses. However, further analysis reveals that a significant proportion of the older trainees (40 percent or more) were above average in 7 out of the 12 courses.

Moreover, the relative performance of older and younger trainees on the 12 tests compare differently when the effects of differences in education are eliminated. Table 2 reflects the performance score for each trainee in relation to the average performance score of all trainees having the same number of years of formal schooling. In 7 of the 12 courses, 50 percent or more of older trainees had above average grades and in 10 of the courses, 40 percent or more were above average. This performance was very similar to that of the younger group. In 8 courses, 50 percent or more of the younger trainees were above average and in 10 courses, 40 percent were above average.

Since the content of the six instrumentation courses was more difficult than the first set of courses, the company observed special care in the selection of trainees, placing emphasis on formal education. A number of otherwise eligible employees were eliminated because of lack of formal education. Trainees were also interviewed and given some guidance and counseling in advance concerning the training. During these briefings, they were able to ask questions, express doubts, and weigh carefully their interest in taking the course. A number of potential trainees withdrew voluntarily after learning about the training program in this initial interview. Finally, three trainees decided to exercise their option of returning to their previous jobs during the first 4 weeks of training. No information is available on their age or education.

The results shown in table 3 are particularly noteworthy. Half or more of the older trainees performed better than average in five of the six courses. In comparison, half or more of the younger employees exceeded average in only three courses. Careful selection, counseling, and guidance in advance probably contributed to the older trainees' superior performance. The small number of trainees involved, however, limits the inferences that can be drawn.

Table 1. Production workers at oil refinery: Level of performance of younger and older trainees 1/ on training courses

Name and duration of course	Younger trainees			Older trainees		
	Number of trainees	Percent		Number of trainees	Percent	
		Above average grade	Below average grade		Above average grade	Below average grade
1. Zone A (3 weeks) 2/ ...	12	58	42	10	40	60
2. Zone B-D (3 weeks)	10	50	50	11	45	55
3. Zone C (3 weeks)	10	60	40	11	36	64
4. Zone D (3 weeks)	5	80	20	5	20	80
5. Zone A (4 weeks)	15	47	53	15	53	47
6. Zone B (4 weeks)	12	58	42	13	46	54
7. Zone C (4 weeks)	15	53	47	13	31	69
8. Zone D (4 weeks)	4	50	50	3	33	67
9. Zone A (2 years)	10	50	50	10	40	60
10. Zone B (2 years)	7	75	25	8	50	50
11. Zone C (2 years)	8	63	37	8	50	50
12. Zone D (2 years)	5	60	40	6	33	67

1/ Because of the small number of trainees in each course, it was necessary to use several different age criteria for dividing the trainees: In courses 1 and 2, older trainees included those 47 years and over; courses 3, 5, and 12, 43 years and over; course 4, 51 years and over; course 6, 52 years and over; course 7, 49 years and over; course 8, 48 years and over; courses 9 and 11, 39 years and over; course 10, 42 years and over.

2/ "Zone" refers to a processing unit within the refinery.

Table 2. Production workers at oil refinery: Level of performance of older and younger trainees 1/ when differences in education are taken into account 2/

Name and duration of course	Younger trainees			Older trainees		
	Number of trainees	Percent		Number of trainees	Percent	
		Above average grade	Below average grade		Above average grade	Below average grade
1. Zone A (3 weeks)	12	50	50	9	45	55
2. Zone B-D (3 weeks) ...	10	40	60	9	67	33
3. Zone C (3 weeks)	10	50	50	10	50	50
4. Zone D (3 weeks)	3	33	67	4	50	50
5. Zone A (4 weeks)	12	58	42	13	46	54
6. Zone B (4 weeks)	12	67	33	10	40	60
7. Zone C (4 weeks)	11	82	18	13	31	69
8. Zone D (4 weeks)	5	40	60	2	100	0
9. Zone A (2 years)	12	58	42	6	33	66
10. Zone B (2 years)	6	50	50	4	50	50
11. Zone C (2 years)	8	50	50	8	63	37
12. Zone D (2 years)	4	25	75	4	75	25

1/ See footnote 1, table 1.

2/ Based on the performance score for each trainee in relation to the average performance score of all trainees having the same number of years of formal schooling.

Table 3. Instrument mechanics at oil refinery: Percent of older and younger trainees 1/ who received grades above and below average test scores

Name of course	Younger trainees			Older trainees		
	Number of trainees	Percent		Number of trainees	Percent	
		Above average grade	Below average grade		Above average grade	Below average grade
1. Company course: Elementary mathematics ...	7	29	71	6	67	33
2. Company course: Fractions and decimals	8	47	53	7	71	29
3. Vendor course: Control valves	8	50	50	7	43	57
4. Vendor course: Controls and valves	8	50	50	6	67	33
5. Vendor course: Level indicators	8	50	50	6	50	50
6. University course: Generators and a.c. circuits	7	43	57	6	50	50

1/ Older trainees include those 40 years of age and over.

Retraining of Aircraft Production Workers, Technicians, and Engineers

The second study covered the retraining of production workers, technicians, and engineers at a division of a large west coast aircraft manufacturing company. With rapid changes in military technology in recent years, the company has had to shift its work to encompass not only aircraft production, but also research and development of advanced weapons systems, electronic components, and the metallurgy of "exotic" metals, such as titanium.

The company has undertaken extensive retraining programs to cope with changing production requirements. Over 100 persons are now employed in its training department. The company's policy is as follows:

> /The company/ does not teach skills when applicants with these skills can be hired. However, intensive in-plant training has been a necessary companion of the great forward strides made by our engineers. For the past ten years the company has been working in fields never before explored by industry. It has been impossible, in most cases, to hire people with the required experience. Teaching the skill has been the only answer . . . more than 90 percent of /the company's/ requirements for skilled technicians have been met by hiring relatively inexperienced persons and training them upward through a succession of skills.

Technological Changes and Retraining. Because of the great variety of technical changes and training courses, it is not possible to present a full description of changes and all retraining given. A few representative retraining courses therefore were selected for which performance data were available covering both older and younger workers. Six different types of training courses are briefly described. The performance results are set forth in the following sections.

Training in Optical Tooling. Because of the need for greater precision in manufacturing parts, a number of new optical devices for measuring and alining have been introduced for the use of toolmakers. Higher speeds of aircraft require greater accuracy and smaller tolerances in assembling. Optical tools, which replace the level and plumb in detecting misalinements, are more sensitive to minute misalinements due to contraction or expansion of metals. They also allow the toolmaker to aline more accurately, parts in angular relationship to each other.

The training given to 24 production workers was primarily practical instruction in the everyday use of several different devices. Classroom lectures combined with demonstrations were followed by practice by the trainees themselves in setting up and using the instruments in making alinements. Each class was limited to four or five trainees.

Successful performance in this task requires: Comprehension of the purpose and nature of the instrument; acquisition of manipulative skill in setting up the device quickly and accurately; and ability to make fine visual discrimination in using the tool.

Training in Electronics. Because of the growing use of electronic equipment both in the design of aircraft and in the production tools used, the company provided extensive training in various aspects of electronics. The available data cover courses given to engineers, technical writers, and maintenance electricians.

Training for Engineers. An introductory course in electronics was given to 53 engineers. The course was intended to provide a general competence in electronics rather than skill in specific applications.

The classes met 2½ hours after work, twice a week, for a period extending over 23 months. A total of 300 hours of classes were given. The instruction consisted of classroom lectures and discussion for about half the time, and laboratory work for the rest.

While participation in this training course was voluntary and unpaid, there was strong incentive for employees to take the training. Course credit was taken into consideration in determining pay increases. Second, since there was a limit on the number of engineers each engineering department could send, there was some distinction in being selected.

Trainees were selected from all engineering departments--hydraulics, blueprint preparation, technical specifications, etc. Although all trainees were classified as engineers, as many as one out of three lacked an engineering degree. All had at least a high school education. Half of those with degrees had the mechanical engineering degree; most of the others had degrees in electrical, chemical, metallurgical, and aeronautical engineering.

Training for Technical Writers. A course on basic electronics designed to familiarize technical writers with new terminology used in describing the electronic apparatus about which they wrote was given to 38 employees. Such knowledge was essential for adequate job performance.

Classes met 2 hours after work, twice a week for about 5 months. The courses consisted of lectures and discussions. No laboratory work was given. Mathematics was minimized. Of the 38 trainees, 19 were over 40 years of age.

Training for Electronic Technicians. The third electronics course was given to prepare maintenance electricians for new jobs in the maintenance and repair of advanced electronic apparatus. In contrast to the electronics training described above, the trainees, after completion of the course, were upgraded in pay and given the job title, "Industrial Electronics Technician."

Classes were held on company time every morning for 3½ hours, 5 days a week over a 4-month period. The course involved lectures on electronic theory and laboratory work with test equipment and components. While the course material emphasized intellectual skills, the work also called for some manual dexterity and sensori-motor coordination.

The 18 trainees in the course were selected from a group of maintenance electricians after careful screening. Fifty men in this position were given an examination, testing their knowledge of AC and DC circuits, vacuum tubes, transistors, and basic algebra. Only the 20 scoring highest were accepted for training, most of whom had some experience maintaining less complicated types of electronic equipment. Of this group, two left the course before completion--one, to accept a higher paid job; another, because of illness.

Training of Machinists. With the introduction of new weapons systems, some machinists experienced difficulty in analyzing and interpreting symbols used in blueprints. The foreman of the group, therefore, requested the training department to conduct a course in blueprint reading.

The course was given during working hours, 2 hours a day for 7 days. The material presented covered explanations of the various symbols used in blueprints and the manner of translating the symbols into the final product.

A total of 17 machinists were selected by the foreman, after a preliminary screening examination given by the training department. Of the 17 trainees, 10 were 45 years of age and over.

Training of Weldors. A variety of changes in welding technology necessitated several retraining courses. Thus, new metals such as titanium and zirconium alloys, and light gage steel are now used to which the conventional welding technology is not applicable. Moreover, requirements for weld size and assembly dimensions have become more critical. For example, two metal tubes welded together end to end must not differ from an overall specified length by more than 0.0001 inch. The angle of geometric planes of plates welded together must not exceed 2°. Since materials are now more costly, greater care must be exercised.

Changes in welding technology have increased the degree of skill and knowledge required of weldors. They must have, for example, some knowledge of metallurgy. They must know what causes metal distortions in order to prevent their occurrence. Formerly, a weldor could straighten a warped section by hammering; such a crude method is no longer tolerable.

The weldor uses more complex equipment, involving a higher degree of mental and physical ability. He must adjust a larger number of variables to achieve proper regulation of temperature, gas flow, and speed of weld. He faces a number of special "tooling problems," such as welding materials enclosed in a plastic envelope filled with inert gas, or welding an entire section which is maintained at a temperature of 600 degrees F. He must perform his duties, in some cases, with one hand holding the torch and the other feeding the welding filler; one foot governing the movement of the material being welded and the other regulating the amperage as the weld proceeds.

The courses given were primarily designed to familiarize workers with some background in welding with the new equipment, processes, and techniques. Not all had been working primarily as weldors. Only 20 percent of the time involved classroom lectures and discussions of the theory and background of new methods. In the practice sessions, comprising 80 percent of the training, trainees were assigned standardized test jobs and their performance on these jobs was carefully measured and appraised. A final performance score was given each trainee based on the number of hours he needed to meet U.S. Air Force standards.

Trainees had either applied voluntarily to take the course or were recommended by their supervisor. They were selected on the basis of their performance on a preliminary welding test.

One result of the training has been to upgrade the status of weldors. Previously, the company did not classify welding as a separate craft or skill. As a result of its greater importance in manufacturing technology, welding is now recognized as a separate craft. The title "weldor" has been created and trainees who successfully complete the training courses are certified as "weldors." The union asked for and obtained a separate classification and higher pay. Today, 200 of the 240 persons engaged in welding are classified as "weldors."

Performance in Retraining. The method used to assess the performance of trainees involved both practical and written tests. Thus, trainees in the optical tooling course were graded on the accuracy of their performance using the tool on known "targets"; the time required to obtain the readings; and a written examination on the characteristics of each instrument. Greatest weight was given to the accuracy factor in calculating the overall grade.

In the electronics course for engineers, trainees were tested in five examinations, including paper and pencil tests and evaluation of laboratory work. An average of these grades was used to derive an overall assessment.

The performance of technical writers in the electronics course was assessed in four essay tests which involved the writing of technical descriptions similar to those to be done on the job. These descriptions were scored by means of a standard checklist covering quality, style, accuracy of the information presented, appropriateness of examples and terminology. The overall performance was based on an average of the tests.

The performance of trainees in the course for the development of electronic technicians was appraised on the basis of both written examinations and graded laboratory exercises. Fifteen grades were averaged to obtain an overall measure of performance.

Scores on two examinations were used in appraising the performance of machinists in the blueprint reading course: one, the screening examination given before training began; the second, the final examination given trainees, based on the interpretation of blueprints.

Table 4 shows the comparative performance of older and younger workers in the five courses described above. Half of the older trainees obtained grades above the average in only one of the six performance measures shown. A significant proportion of the older trainees, i.e., 40 percent or more, were, however, above average in three of the courses. In the case of the younger trainees, a majority were over the average in five of the six courses.

Instructors in the course for electronic technicians, reported that older trainees tended to do less well on the mathematical aspects and had trouble with making fine adjustments. Their experience, on the other hand, helped them in troubleshooting.

The comparative performance of older and younger trainees on four courses for which information permits differences in education to be taken into account, is presented in table 5. This comparison shows little difference in the performance of the two groups. On three of the four courses, more than half of the older group was above average. In the fourth course, the proportion was very close to one-half.

The performance of older and younger trainees in the four welding courses is shown in table 6. Older trainees qualified in a shorter period of time than younger trainees on two of the four courses. In each of the four courses, at least 40 percent of the older trainees qualified in the shorter period of time. According to course instructors, previous relevant experience probably accounted for the superior performance of the older trainees in these courses.

Table 4. Training courses at an aircraft plant: Comparative performance of older and younger trainees on tests

Course	Younger trainees			Older trainees 1/		
	Number of trainees	Percent		Number of trainees	Percent	
		Above average grade	Below average grade		Above average grade	Below average grade
1. Optical tooling for assemblers 2/	24	79	21	22	36	64
2. Introduction to electronics for engineers .	36	53	47	17	47	53
3. Basic electronics for technical writers	19	53	47	19	42	58
4. Electronic technician, transition and development	9	67	33	9	33	67
5. Blueprint reading I for machinists	9	78	22	8	25	75
6. Blueprint reading II for machinists	9	44	56	8	50	50

1/ In courses 1, 2, and 3, older trainees included those over 40; in course 4, those over 35; and in courses 5 and 6, those 50 and over.

2/ Only a pass or fail grade in attaining accuracy was given in this course. Consequently, the numbers below and above do not evenly divide the entire group.

Table 5. Training courses at an aircraft plant: Comparative performance of older and younger trainees on tests, with differences in education taken into account

Course	Younger trainees			Older trainees 1/		
	Number of trainees	Percent		Number of trainees	Percent	
		Above average grade	Below average grade		Above average grade	Below average grade
1. Introduction to electronics for engineers	34	56	44	17	53	47
2. Basic electronics for technical writers ...	14	57	43	19	47	53
3. Electronic technician transition and development	6	33	67	8	62	38
4. Blueprint reading II for machinists	6	67	33	6	67	33

1/ See footnote 1, table 4.

Table 6. Training courses given to weldors at aircraft plant: Percent of older and younger trainees, above and below median time needed to achieve certification

Course and hours needed to achieve certification	Percent of group	
	Younger trainees	Older trainees 1/
1. Metallic arc:		
Number of trainees	14	10
16-70 hours	64	40
71-140 hours	36	60
2. Inert gas I:		
Number of trainees	4	5
8-37 hours	75	40
38-104 hours	25	60
3. Inert gas II:		
Number of trainees	8	9
18-50 hours	50	56
51-107 hours	50	44
4. Titanium:		
Number of trainees	7	6
8-25 hours	43	50
26-48 hours	57	50

1/ In course 1, older trainees included those 45 and over; in course 2, over 40; in course 3, over 35; and in course 4, 40 and over.

Retraining of Airline Maintenance Mechanics

The third study concerns the retraining of 1,200 workers at the central maintenance facility of one of the Nation's largest airlines. The workers covered by the data were men employed in the maintenance and overhaul operations.

Nature of the Technological Change. The introduction of turbine and jet aircraft into commercial airline operations made necessary extensive retraining of mechanics engaged in maintenance and overhaul operations. Although airline workers were accustomed to relatively frequent changes in equipment, the shift to jets constituted a major change, more far-reaching than those previously experienced.

A brief comparison of some specifications of piston and jet planes highlights the greater complexities of the new equipment that created the need for retraining. Specifications on the jet are more rigid; the various control systems, more complicated; and the permissible amount of error, smaller. Part of the electrical circuits of the jet is basically a 220-volt a.c. system; part, 110-volt a.c. system; and part uses lower d.c. voltage; the piston plane uses a 28-volt d.c. system. The jets use 3,000 psi hydraulic system; the piston, a 2,000 psi system.

These technological changes had important implications for the skill and training of maintenance workers. While the same type of physical abilities and manual skills were needed, work on the more complicated jets required greater precision in maintaining the hydraulic system and more care in overhauling the electrical system. Workers needed to know about the jet planes themselves and about the special tools and instruments used in maintaining and overhauling them. Since both the aircraft and the maintenance equipment are being constantly modified, retraining and refresher courses are needed to keep workers up to date.

Retraining Courses. The changeover to jet planes was made gradually, starting with the delivery of 2 planes and building up to a total of 30. Small groups of workers consequently were retrained as they were needed. The first group of trainees had the most difficulty in retraining because it was necessary to begin before the jets were actually delivered. About 95 percent of the maintenance employees are now qualified to work on jets.

Administration of the training program was the responsibility of the training department. The procedure generally followed was for a training staff employee to visit the aircraft manufacturer to familiarize himself with the course material. On his return, he would organize the course, submit a training proposal to the department which requested the training and finally teach the course. Training by the vendor of the equipment was used occasionally when training on a particular aspect of the aircraft was needed immediately and when no member of the training staff was qualified to provide it.

The data covered by this study relate to 228 courses dealing with various aspects of aircraft maintenance and overhaul. They ranged from relatively brief "familiarization" sessions taking 6 hours to detailed technical courses lasting 260 hours. Each class was limited to 10 persons. Where training had to be given to more than 10, the course was repeated.

Courses in equipment maintenance covered both classroom and practical instruction. First, classes and lectures were held where the equipment was described and visual aids used to illustrate the procedures used in servicing the equipment. The practical work involved servicing in-service equipment. In courses on overhaul operations, for example, the equipment used came from a plane currently being overhauled. Upon completion of the operation, the equipment was tested, using appropriate testing devices, and put into service on the plane from which it was taken.

For purposes of this study, the 228 courses were classified into 6 levels, according to the number of hours of instruction given. Table 7 shows the number of courses and the number of trainees in each level. In order to illustrate the nature of the courses given at the various levels, the titles of selected courses are shown in table 8.

Because over 200 courses were given, with an average of only six trainees in each, it was not feasible to present the findings for each course. The procedure followed, therefore, was to count each course as a single observation, and to classify it according to the performance experience of older trainees. These data on trainees in each course were analyzed to determine whether the scores of the older 50 percent of the trainees fell above the median course grade more often, equally often, or less often than the younger trainees. Courses in which the range in grades was less than 5 points and/or the range of ages was less than 5 years were not included.

The results, by course level, are summarized in table 9. Older trainees did better than younger trainees in a majority of the courses given on only one course level. At every level, however, older trainees did better on at least 20 percent of the courses. When the comparisons are made on the basis of courses where older trainees did equally as well or better than younger trainees, the overlapping becomes more pronounced: older workers did equally as well as younger in a majority of the courses on two levels; and in at least one-third, on all but one level.

Table 7. Airline: Level of courses and number of courses and trainees

Course level	Number of courses	Number of trainees
All levels	228	1,349
1	8	39
2	45	286
3	45	268
4	82	476
5	21	140
6	27	140

Table 8. Representative course titles, by level

Level	Course title	Hours
1	Equipment, Plant--Test Stand No. 7205, Stationary Hydraulic Rotating	8
2	Jet Airliner--Structures, Familiarization	24
	Jet Airliner--Engine Accessories Overhaul	24
3	Jet Airliner--Interior Overhaul Familiarization ...	40
	Jet Airliner--Alternator Constant Speed Drive Mechanical Components Overhaul	36
4	Jet Airliner--Engine Final Assembly	80
	Jet Airliner--Structure Overhaul	80
	Jet Airliner--Engine, Magnaflux, Zyglo, Rework and Part Inspection	64
5	Turbojet Airliner--Electrical General Maintenance .	112
	Jet Airliner--Miscellaneous Systems Overhaul (Powerplant)	160
6	General Aircraft--Gyro Instrument Overhaul	240

Table 9. Airline maintenance workers: Distribution of courses according to comparative performance of older trainees

Course level	Number of courses	Number of trainees	Percent of courses showing that older trainees did--1/		
			Better than younger trainees	Equally as well as younger trainees	Not as well as younger trainees
1	8	39	75.0	12.5	12.5
2	45	286	20.0	11.1	68.9
3	45	268	28.8	4.5	66.7
4	82	476	29.3	15.9	54.8
5	21	140	23.8	14.3	61.9
6	27	140	33.3	18.5	48.2

1/ Percentages were computed on the basis of counting each course as a single observation. Data on the performance of trainees in each course were analyzed to determine whether the scores of the older half of the trainees fell above the median course grade more often, equally often, or less often than the younger trainees. Excluded are 24 courses in which the total range in grades is less than 5 points and/or the total range of ages is less than 5 years.

Retraining of Telephone Operators

The fourth study concerns the retraining of several hundred long-distance telephone operators, employed by a telephone company servicing the population of one of the North Central States. The operators were employed in toll centers in different parts of the State. Although there were about 60 toll centers, data on retraining were available only for operators working in 10 specific offices. All the operators studied were women. Their ages ranged between 18 and 60.

Nature of the Technological Change. The change that required the retraining of operators resulted indirectly from the introduction of electronic data processing in the accounting operations. In order to process bills for long-distance calls on computers, the company had to modify drastically the methods used by operators to record the original data on calls.

Prior to the introduction of the new accounting procedures, long-distance operators wrote the telephone numbers involved in a call on a small paper form. Both the caller's number and the number called were recorded together with other information needed for proper billing. The paper forms served as a short-term, memory-aiding device which the operator could consult while completing the call. Also, the form was used by the accounting department in billing customers.

Under the new electronic system, an IBM card was substituted for the paper form. Operators are now required to record information on calls by marking appropriate spaces on the IBM card with a special pencil, rather than writing the figures on a piece of paper. This is known as the mark-sensing procedure. The card is then forwarded to the accounting department for processing on the electronic computer.

This procedural innovation, although superficially simple, changed greatly the routine manual duties of the operators. Instead of writing numbers on slips of paper, the operator now reads down a series of vertical columns, making a mark in 1 of 10 alternative spaces for each letter or digit of the number. The number is read horizontally. Since the marks must be placed accurately within narrow limits if the card is to be processed properly on the computer, the operator must exercise care, requiring fine sensori-motor coordination. Also, the operator must make the marking both rapidly and accurately. If it is not done rapidly, service will be delayed. If mistakes are made in marking, errors will be made in billing.

Retraining Programs. The change in duties required a 2-day period of retraining for each operator. This training was given by office personnel who had been previously instructed in the new procedure by personnel from the training department.

Two types of retraining were given, both involving "learning by doing." The first dealt with the development of manual skill in marking cards; the second, with the development of skill in interpreting the markings on IBM cards.

In training operators in marking cards, a control operator--one for every two trainees--made calls to trainees, using standard telephone apparatus and the same kind of information that would be used in an actual work situation. The calls were made at the trainee's maximum speed. The trainee was required to record the appropriate information on the IBM card and place the call in the standard manner.

The second phase of the retraining involved the use of marked IBM cards as a short-term memory device in placing calls. Each trainee was required to place calls which had been recorded on a deck of 30 IBM cards. Speed and accuracy were emphasized.

Performance in Retraining. The performance of individuals on the retraining programs for marking and interpreting cards was appraised on the basis of various quantitative measures.

In appraising the performance in marking cards, five measures were computed for each trainee: Total number of tickets marked; total number of errors (mark placed in the wrong box); total number of items omitted; the number of omissions per card; and an index of marking efficiency (i.e., the difference between the total number of tickets marked and the sum of errors and omissions).

For each measure, the proportions of trainees in different age groups whose performance was above and below average were computed. In determining whether an individual's performance score was above or below average, the score (except the total errors measure) was compared with the median for the particular office where the trainee worked. Since the distribution of scores varied somewhat from office to office, the range of above average performances also differed among offices. The age distribution of trainees, however, did not differ significantly from office to office. Neither did the quality of equipment vary.

Table 10 shows that the proportion of trainees with above average scores declined with increasing age on 4 of the 5 performance measures. In the 45 and over age group, less than half of the trainees marked more than average number of tickets; omitted fewer than average number of items; had fewer than average omissions per card; and had a higher than average index of marking efficiency. On the other hand, more than half of older trainees (45 and over) achieved above average performance scores on the measure based on errors: i.e., had less than the average number of errors. The smaller number of cards marked by older trainees may be attributable to the greater care taken. It is noteworthy that of the age group 35-44, at least 40 percent of the trainees had achieved above-average scores in all five tests.

Since differences in educational background are sometimes said to account for variability in training performance, an effort was made to take account of such marking comparisons. Table 11 shows the comparative performance, by age, of operators with 8 to 11 years of education; table 12, of operators with 12 years or more of education. Older trainees among those with 8 to 11 years of education did not do as well, as a group, as younger trainees on all five tests of performance. Among those with 12 years or more of education, however, trainees 45 and over did better than younger age groups on one test; i.e., number of errors. Moreover, while older trainees did not do as well as younger age groups on the four other tests, the differences in overall performance tended to be smaller.

Table 13 shows the comparative performance of trainees on tests involving interpretation of tickets. Information was available on speed and errors in performance using old and new methods. Trainees, 45 years and over, as a group, did not do as well as younger trainees. On the new method, older operators are slower than younger operators and make a larger number of errors. It is noteworthy, however, that the performance record of older trainees, based on errors using the old method of interpreting tickets, was about the same as the record for younger trainees. This suggests that, with further experience using the new method, older trainees would probably achieve about the same level of performance with respect to errors as younger trainees.

A particularly important finding was the variability in performance among all age groups. Some older trainees achieved higher scores than some younger trainees. This was found to be the case on every test for which data are shown.

In summary, older trainees, as a group, did not perform on tests as well as younger trainees. The training involved tasks requiring some sensorimotor coordination where ability tends to be affected by aging. Nevertheless, some older trainees did better than some younger trainees. Moreover, when differences in formal education are taken into account, differences in performance were generally not as great.

Table 10. Telephone operator trainees: Level of performance on various measures, by age group

Measure and performance level	Age group (percent)			
	18-24	25-34	35-44	45 and over
Number of tickets marked:				
Above average performance 1/	54.0	51.5	41.4	25.5
Below average performance	46.0	48.5	58.6	74.5
Total number of errors:				
Above average performance	43.7	49.5	58.6	52.7
Below average performance	56.3	50.5	41.4	47.3
Total number of omissions:				
Above average performance	62.5	59.4	58.6	40.0
Below average performance	37.5	40.6	41.4	60.0
Ratio of omissions to tickets marked:				
Above average performance	55.7	52.0	47.1	29.1
Below average performance	44.3	48.0	52.9	70.9
Marking efficiency index:				
Above average performance	59.7	53.0	42.9	27.3
Below average performance	40.3	47.0	57.1	72.7
Number of trainees	176	202	70	55

1/ "Above average performance" indicates superior performance. Thus, it indicates that the number of tickets marked was greater than the average (median), and that the index of marking efficiency was higher than the average; also, that the total number of errors, total number of omissions, and the ratio of omissions to tickets marked was less than the average.

Table 11. Telephone operator trainees: Level of performance of trainees with 8-11 years of education, on various measures, by age group

Measure and level of performance	Age group (percent)			
	18-24	25-34	35-44	45 and over
Number of tickets marked:				
Above average performance 1/	57.6	51.6	33.3	19.3
Below average performance	42.4	48.4	66.7	80.7
Total number of errors:				
Above average performance	45.4	64.5	61.9	38.7
Below average performance	54.6	35.5	38.1	61.3
Total number of omissions:				
Above average performance	63.6	77.4	61.9	45.2
Below average performance	36.4	22.6	38.1	54.8
Ratio of omissions to tickets marked:				
Above average performance	51.5	61.3	38.1	25.8
Below average performance	48.5	38.7	61.9	74.2
Marking efficiency index:				
Above average performance	60.6	67.7	47.6	22.6
Below average performance	39.4	32.3	52.4	77.4
Number of trainees	33	31	21	31

1/ See footnote 1, table 10.

Table 12. Telephone operator trainees: Level of performance in various measures, of trainees with 12 years or more of education, by age group

Measure and level of performance	Age group (percent)			
	18-24	25-34	35-44	45 and over
Number of tickets marked:				
Above average performance 1/	53.5	52.5	45.4	38.9
Below average performance	46.5	47.5	54.6	61.1
Total number of errors:				
Above average performance	43.7	48.7	63.6	77.8
Below average performance	56.3	51.3	36.4	22.2
Total number of omissions:				
Above average performance	62.7	56.3	54.6	27.8
Below average performance	37.3	43.7	45.4	72.2
Ratio of omissions to tickets marked:				
Above average performance	57.0	50.0	52.3	38.9
Below average performance	43.0	50.0	47.7	61.1
Marking efficiency index:				
Above average performance	59.9	50.0	40.9	38.9
Below average performance	40.1	50.0	59.1	61.1
Number of trainees	142	158	44	18

1/ See footnote 1, table 10.

Table 13. Telephone operator trainees: Level of performance on tests interpreting tickets, by age group

Tests and level of performance	Age group (percent)			
	18-24	25-34	35-44	45 and over
Speed using old method:				
Above average performance 1/	52.2	52.7	50.9	33.3
Below average performance	47.8	47.3	49.1	66.7
Errors using old method:				
Above average performance 2/	63.0	68.5	69.1	64.9
Below average performance	37.0	31.5	30.9	35.1
Speed using new method:				
Above average performance 1/	60.9	54.6	38.2	28.1
Below average performance	39.1	45.4	61.8	71.9
Errors using new method:				
Above average performance 2/	56.5	60.6	60.0	39.3
Below average performance	43.5	39.4	40.0	60.7
Speed difference: 3/				
Above average performance	55.4	54.6	49.1	31.8
Below average performance	44.6	45.4	50.9	68.2
Number of trainees	92	165	55	57

1/ "Above average performance" signifies that speed in interpreting cards was higher than average.

2/ "Above average performance" signifies that accuracy was better than average, i.e., fewer errors were made.

3/ "Above average performance" means that the difference between speeds on new and old method was smaller than average. "Below average performance" signifies that the difference was greater than average, i.e., more time needed for new method.

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