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United States Department of Labor

THE ADAPTABILITY OF OLDER WORKERS TO TECHNOLOGICAL CHANGE

Performance of Older and Younger Workers In Industrial Retraining Courses

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Organizational Behavior
and Change Programs
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Errata

1. p. 64, l. 2: "course" should read "courses".
2. p. 99, l. 1: "Date" should read "Data".
3. p. 103, $N_{courses}$: Total of <u>204</u> should read 228.
4. Bibliographic entry: Bloomberg, W.: "Humal" should read "Human".

Introduction

Technological change is a by-word in modern industry. The invention of new machines, the creation of new techniques, the introduction of new and more effective systems of production require workers to apply new skills. The study reported here is concerned with the adaptability of older workers to technological change. We are interested, more specifically, in the relative performance of older and younger workers on jobs which have undergone technological innovation.

The data analyzed below concern 2,200 workers in four companies. These companies were chosen because they were able to provide records relevant to the performance of workers on jobs which have undergone technological change. All of the data treated in this report come from company personnel and training files.

While our sample does not comprise a random representation of workers or of technological changes in American industry, broad ranges of worker characteristics and of changes are included: women and men; highly skilled workers and workers having moderate skill; changes which involve primarily intellectual adaptation and changes which entail adaptation of a physical kind; changes which require from about 8 hours of retraining to as many as 1,120 hours.

The companies are located in three regions of the country: the Midwest, Southwest, and West Coast. They are in different industries: aircraft manufacturing, oil refining, telephone communication, and air transport. All of the companies have undergone and continue to undergo a number of technological changes. With one exception, the data reported here cover at least several changes within each company and with minor exceptions these changes have been implemented within the past two years. Together, the companies include over 127,000 employees.

Almost 100 organizations were contacted in attempting to locate companies for this study. Most of these companies are undergoing important technological change, but few were able to meet each of the following criteria:

1. Technological change has occurred within the past two years requiring the learning by workers of new skills,
2. some form of training (either vestibule or formalized, on the job) has taken place to teach workers the new job(s),
3. workers over, as well as under, the age of 45 participate in the program,
4. at least 100 workers are involved,
5. objective measures of individual performance during training or on the new job are available,
6. personnel records are available with information regarding age, education, seniority, job title before and after.

We acknowledge the invaluable help which the chosen companies have afforded us in making their records available. A number of persons were directly instrumental in helping us locate several of the companies included in this report: Samuel Hayes and Hollis Peter of the Foundation for Research on Human Behavior, S. G. Tipton of the Air Transport Association, Daniel Kruger of the Michigan State University Labor and Industrial Relations Center, and our colleagues Carol Livingstone and Floyd Mann. We thank these persons and the 100 officers of the agencies and companies around the country for the trouble they took on our behalf.

I. A Telephone Company

The change which occurred in the Telephone Company is among the least complex of those examined. A new procedure of billing long distance calls was introduced in the Accounting Department: electronic data-processing methods replaced clerical procedures in arriving at the charges billed to each subscriber. The speed, accuracy, and detail of billing performed by the Accounting Department were all expected to increase as a result of the change.

This report is concerned with one ramification of the change--that affecting the long distance operators. The job of the operator had to be modified in order to make possible the improvement in service in the Accounting Department. It should be noted that the change was not directed at improving the services rendered by the operators themselves; rather, the change was designed to help accounting procedures.

A. Background Information

The Telephone Company services one of the larger north central states. Included in the Company's service area are a number of highly industralized areas, as well as a fairly extensive rural region. The Company has some 23,000 employees, with a yearly payroll of roughly $12 million.

The Traffic Department--that Department which is concerned with long distance operations--employs some 7,400 individuals, of which about 5,300 are operators. The operators work in a number of "toll centers" located throughout the state; the toll centers may be regarded as regional long distance offices, and number about 60 all together. All operators are women between the ages of 18 and 61 years.

Although the change affected all the long distance operators of the Company, retraining data are available for only those operators working in 10 specific offices. Within each of these offices, however, information is available for all the operators employed there. The retraining itself--to be described below--was basically similar from office to office. Variations in the manner of assessing performance in the retraining program, however, necessitated using different sub-groupings of the total sample for different phases of the analysis. Chart I shows these variations, and indicates which offices were used in the analyses.

Chart I

Characteristics of the Offices used in the Analyses of the Telephone Company Data

Office	1	2	3	4	5	6	7	8	9	10
Used in the "Ticket Marking" Analysis	X	X	X	X	X	X	X	X		
Used in the "Ticket Interpretation" Analysis	X	X	X	X					X	X
Type of Training*	C	C	C	C	C	C	C	C	O	O
Number of Operators	91	20	62	70	121	86	33	20	48	78

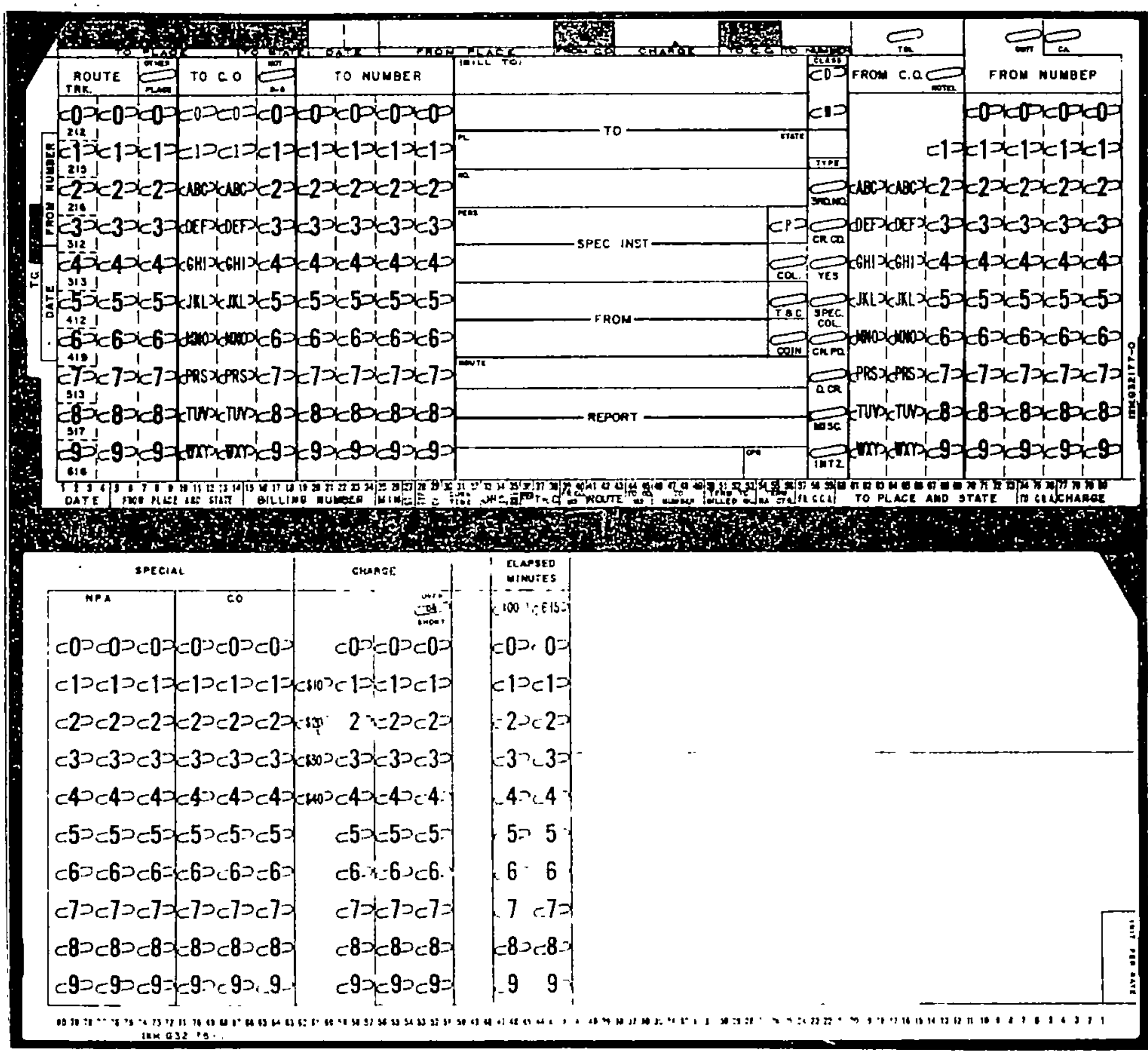
*C = "Control Operator", using artificial calls
O = "On the Job", using live calls

B. The Change

Prior to the introduction of the new accounting procedures, the operators wrote the telephone numbers involved in a call on a small paper form ("soft ticket"). Both the caller's number and the number called were recorded, together with other information needed for proper billing. The paper form served as a short-term, memory-aiding device to be referred to until the call was completed; in addition, the form provided a means by which the account department could bill customers. The new system substituted an IBM card ("hard ticket") for the paper form. The change required the operator to indicate letters and numerals by marking the appropriate "bubbles" rather than by printing the figures. A special pencil is used for this purpose. A photo-copy of the new card is shown in Chart II.

Chart II

Photo-Copies of Front and Back
of the New Mark-Sense Cards ("Tickets")



While this change is simple and straight-forward, it is by no means trivial. The task is an entirely new type of experience for most operators. For each letter or digit of a telephone number, the operator has to mark the appropriate bubble in a vertical column of ten (0-9) alternatives. Consequently, the operator has to direct her pencil over a fairly large vertical span for each letter or digit while recording the complete telephone number in a horizontal direction. In this sense, the task is not a "natural" one. In addition, the new task requires a good deal of fine sensori-motor coordination. As the photo-copy indicates, the bubbles to be marked are quite close together both vertically and horizontally. This relative "crowding" of the card complicates the task of locating the proper bubble in the first place; beyond that, it requires that the actual movement used in marking the bubble be accurately controlled.

The electronic data processing equipment used in the Accounting Department is sensitive to the marks placed on the cards by the operators. In order for this equipment to function properly, the mark must be accurately positioned. If the mark is not large enough (or not dark enough), the mark-sensing equipment will not be activated. If the mark is too long, the equipment will record digits that were not intended. Consequently, the operator must make and place her marks within fairly narrow tolerance limits.

Another problem facing the operator is that the marking has to be done rapidly and accurately; if it is not done rapidly, service will be delayed. On the accuracy side, every mistake in marking is a mistake in billing.

The operator is also faced with the problem of interpreting the marks when the card is used in the process of placing a call. Rather than reading letters and numerals directly, and then taking the appropriate action, the operator now has to interpret a position on the card as representing a letter or a numeral;

only after this extra information-processing step has been completed can the appropriate action be taken. This problem is complicated by the fact that five or six calls may be processed simultaneously.

C. Introducing the Change

Information about the change moved down the management hierarchy. Operators were informed by their supervisors about two weeks before the training began. The union had no part in planning the new procedures for operators nor in its implementation. No modifications were made in the union agreement as a result of the change.

D. The Retraining Courses

The Training Department was responsible for the overall administration of the training program. Training was administered by office personnel who were previously instructed by the Training Department. The training lasted two days for each operator, but the duration of training in an office depended on the number of operators involved.

Operator training involved two distinct aspects. The first dealt with the development of skill in marking the cards, while the second involved interpreting the marked cards. It is important to note that with the exception of the new marking system, the same circuit equipment was employed.

1. Marking Cards

Training in marking the cards was administered in the following fashion. "Control operators" fed artificial calls to trainees, providing them with the same kind of information they would have in an actual work situation. One control operator worked with two trainees, feeding calls to each trainee at the latter's maximum speed. Trainees used the standard telephone apparatus, although, of course, the circuit was connected only between the control operator and the trainee. The trainee was required to mark the card with the appropriate information, and to "place the call" in the standard manner.

Eight offices, involving 503 operators, administered this type of training. The performance of these operators is reported below. Two other offices where training of this general type occurred are not included in our analysis because the appropriate data are not available.

The performance measures provided by the retraining course in card ("ticket") marking come from a one-half hour appraisal conducted at the end of the training. Three basic measures are available: (1) total number of tickets marked, (2) number of errors (in which the wrong bubble was marked), and (3) number of omissions (in which the proper bubble was not marked, and for which no other bubble in that column was marked). Two indices are derived from these three basic measures. The first, called "ratio of omissions," is the number of omissions divided by the total number of tickets marked by each operator (i.e., her number of omissions per card). A second index is called the "index of marking efficiency." It is obtained by subtracting the sum of "total errors" and "total omissions" from the total number of tickets marked. This index provides a single overall indication of performance.

The tables presented in this section are based on groupings of the data. With the exception of the total number of errors measure, the performance categories are <u>relative to the individual office</u>. That is, "good performance" for an operator in Office X means that her performance score is above the median <u>for that office</u>. Since the distributions vary somewhat from office to office, "good performance" in one office will not always encompass the same performance scores as would "good performance" in a second office. (However, age distributions <u>are</u> similar from office to office.) Conditions peculiar to one or a few offices (e.g., differences in the quality of equipment) do not therefore prejudice the analysis of performances in that office relative to the performances in others.

Table I shows the per cent of operators in different age groups who perform relatively well and relatively poorly on the five performance measures. On four of the five measures there is a regular increase with increasing age in the per cent of operators whose performance is poor. One measure--the total number of errors--does not show a decrement in performance with increasing age. The smaller number of errors committed by the older operators may be attributable in part to the fact that they mark fewer cards.

The composite Marking Efficiency Index, which is the most valid of the measures in the sense that most aspects of the task are included in it, shows a regular decline in performance as the operators get older.

Tables II through V present the relationships between the above performance measures and seniority, education, the Wonderlic measure of general intelligence, and the "Call Detail Test." The latter test was designed by the Company as a pre-employment operator aptitude test, while the Wonderlic measure is a standard intelligence test used in industrial settings. Both tests are part of a pre-employment battery, although scores were not available for all operators.

In general, high seniority operators tend to exhibit poor performance scores more often than do the low seniority people, although the total number of errors measure does not show this relationship.

Table III shows no striking relationship between education and performance in this task.

Tables IV and V show a slight tendency for the pre-employment tests to relate negatively to performance. The abilities which these tests assess do not seem to contribute to successful performance in marking the tickets. These two tests will not be considered further in this section of the analysis.

Tables VI and VII display the relationship between age and performance separately for operators with lesser and greater amounts of formal education, respectively. It should be noted that roughly 90 per cent of the operators in Table VII have exactly 12 years of education. Both tables show that a greater percentage of operators in the older age categories fall into the poor performance classification, regardless of how much education they have had. The fewer total number of errors committed by older operators is probably explained by the fewer number of cards which they marked.

The final two tables in this section examine the relationship between age and performance for operators of similar seniority levels. In Table IX, operators with six or more years of seniority are considered. Operators with from one to five years of seniority are examined in Table X.

I. Marking of the Tickets. Percent of operators in different age groups whose performance is relatively good and relatively poor. Total N = 503.

Performance:
A. Number of Tickets Marked

Performance	Age 18-24	25-34	35-44	45+
Good	54.0	51.5	41.4	25.5
Poor	46.0	48.5	58.6	74.5
	100%	100%	100%	100%
N =	176	202	70	55

Performance:
B. Total Number of Errors

Performance	Age 18-24	25-34	35-44	45+
Good	43.7	49.5	58.6	52.7
Poor	56.3	50.5	41.4	47.3
	100%	100%	100%	100%
N =	176	202	70	55

Performance:
C. Total Number of Omissions

Performance	Age 18-24	25-34	35-44	45+
Good	62.5	59.4	58.6	40.0
Poor	37.5	40.6	41.4	60.0
	100%	100%	100%	100%
N =	176	202	70	55

Performance:
D. Ratio of Omissions

Performance	Age 18-24	25-34	35-44	45+
Good	55.7	52.0	47.1	29.1
Poor	44.3	48.0	52.9	70.9
	100%	100%	100%	100%
N =	176	202	70	55

Performance:
E. Marking Efficiency Index: Tickets Marked - (Total Omissions + Total Errors)

Performance	Age 18-24	25-34	35-44	45+
Good	59.7	53.0	42.9	27.3
Poor	40.3	47.0	57.1	72.7
	100%	100%	100%	100%
N =	176	202	70	55

II. Marking of the Tickets. Percent of operators of differing seniority whose performance is relatively good and relatively poor. Total N = 503.

Performance:
A. Number of Tickets Marked

Performance	Seniority: 1-2	3-5	6-10	11+
Good	53.6	58.6	38.3	40.0
Poor	46.4	41.4	61.7	60.0
	100%	100%	100%	100%
N =	84	169	120	130

Performance:
B. Total Number of Errors

Performance	Seniority: 1-2	3-5	6-10	11+
Good	51.2	47.9	43.3	54.6
Poor	48.8	52.1	56.7	45.4
	100%	100%	100%	100%
N =	84	169	120	130

Performance:
C. Total Number of Omissions

Performance	Seniority: 1-2	3-5	6-10	11+
Good	61.9	62.7	56.7	51.5
Poor	38.1	37.3	43.3	48.5
	100%	100%	100%	100%
N =	84	169	120	130

Performance:
D. Ratio of Omissions

Performance	Seniority: 1-2	3-5	6-10	11+
Good	58.3	55.0	45.0	43.1
Poor	41.7	45.0	55.0	56.9
	100%	100%	100%	100%
N =	84	169	120	130

Performance:
E. Marking Efficiency Index: Tickets Marked - (Total Omissions + Total Errors)

Performance	Seniority: 1-2	3-5	6-10	11+
Good	61.9	60.4	41.7	40.8
Poor	38.1	39.6	58.3	59.2
	100%	100%	100%	100%
N =	84	169	120	130

III. Marking of the Tickets. Percent of operators differing in education whose performance is relatively good or relatively poor. Total N = 478.

Performance:
A. Number of Tickets Marked

Performance		Education 8-11	12+
	Good	41.4	51.4
	Poor	58.6	48.6
		100%	100%
	N =	116	362

Performance:
B. Total Number of Errors

	Education 8-11	12+
Good	51.7	50.0
Poor	48.3	50.0
	100%	100%
N =	116	362

Performance:
C. Total Number of Omissions

Performance		Education 8-11	12+
	Good	62.1	57.2
	Poor	37.9	42.8
		100%	100%
	N =	116	362

Performance:
D. Ratio of Omissions

	Education 8-11	12+
Good	44.8	52.5
Poor	55.2	47.5
	100%	100%
N =	116	362

Performance:
E. Marking Efficiency Index: Tickets Marked - (Total Omissions + Total Errors)

Performance		Education 8-11	12+
	Good	50.0	52.2
	Poor	50.0	47.8
		100%	100%
		116	362

IV. Marking of the Tickets. Percent of operators differing on results of the Wonderlic Test whose performance is relatively good and relatively poor. Total N = 409.

Performance:
A. Number of Tickets Marked

Performance		Wonderlic Test: Low	Wonderlic Test: High
	Good	57.9	40.3
	Poor	42.1	59.7
		100%	100%
	N =	221	186

Performance:
B. Total Number of Errors

Performance		Wonderlic Test: Low	Wonderlic Test: High
	Good	47.1	40.3
	Poor	52.9	59.7
		100%	100%
	N =	221	186

Performance:
C. Total Number of Omissions

Performance		Wonderlic Test: Low	Wonderlic Test: High
	Good	62.0	58.1
	Poor	38.0	41.9
		100%	100%
	N =	221	186

Performance:
D. Ratio of Omissions

Performance		Wonderlic Test: Low	Wonderlic Test: High
	Good	55.2	45.7
	Poor	44.8	54.3
		100%	100%
	N =	221	186

Performance:
E. Marking Efficiency Index: Tickets Marked - (Total Omissions + Total Errors)

Performance		Wonderlic Test: Low	Wonderlic Test: High
	Good	59.7	45.7
	Poor	40.3	54.3
		100%	100%
	N =	221	186

V. Marking of the Tickets. Percent of operators differing on results of the Call-Detail Test whose performance is relatively good and relatively poor. Total N = 367.

Performance:
A. Number of Tickets Marked

Performance	Call-Detail Test Low	High
Good	55.5	44.3
Poor	44.5	55.7
	100%	100%
N =	191	176

Performance:
B. Total Number of Errors

Performance	Call-Detail Test Low	High
Good	49.2	44.3
Poor	50.8	55.7
	100%	100%
N =	191	176

Performance:
C. Total Number of Omissions

Performance	Call-Detail Test Low	High
Good	62.8	57.4
Poor	37.2	42.6
	100%	100%
N =	191	176

Performance:
D. Ratio of Omissions

Performance	Call-Detail Test Low	High
Good	56.5	45.4
Poor	43.5	54.6
	100%	100%
N =	191	176

Performance:
E. Marking Efficiency Index: Tickets Marked - (Total Omissions + Toal Errors)

Performance	Call-Detail Test Low	High
Good	59.7	48.9
Poor	40.3	51.1
	100%	100%
N =	191	176

VI. Marking of the Tickets. Percent of operators with education of eight to eleven years in different age groups whose performance is relatively good and relatively poor. Total N = 116.

Performance:
A. Number of Tickets Marked

Performance	Age: 18-24	25-34	35-44	45+
Good	57.6	51.6	33.3	19.3
Poor	42.4	48.4	66.7	80.7
	100%	100%	100%	100%
N =	33	31	21	31

Performance:
B. Total Number of Errors

Performance	Age: 18-24	25-34	35-44	45+
Good	45.4	64.5	61.9	38.7
Poor	54.6	35.5	38.1	61.3
	100%	100%	100%	100%
N =	33	31	21	31

Performance:
C. Total Number of Omissions

Performance	Age: 18-24	25-34	35-44	45+
Good	63.6	77.4	61.9	45.2
Poor	36.4	22.6	38.1	54.8
	100%	100%	100%	100%
N =	33	31	21	31

Performance:
D. Ratio of Omissions

Performance	Age: 18-24	25-34	35-44	45+
Good	51.5	61.3	38.1	25.8
Poor	48.5	38.7	61.9	74.2
	100%	100%	100%	100%
N =	33	31	21	31

Performance:
E. Marking Efficiency Index: Tickets Marked - (Total Omissions + Total Errors)

Performance	Age: 18-24	25-34	35-44	45+
Good	60.6	67.7	47.6	22.6
Poor	39.4	32.3	52.4	77.4
	100%	100%	100%	100%
N =	33	31	21	31

VII. Marking of the Tickets. Percent of operators with education of twelve years or more in different age groups whose performance is relatively good and relatively poor. Total N = 362.

Performance:
A. Number of Tickets Marked

Performance	Age: 18-24	25-34	35-44	45+
Good	53.5	52.5	45.4	38.9
Poor	46.5	47.5	54.6	61.1
	100%	100%	100%	100%
N =	142	158	44	18

Performance:
B. Total Number of Errors

Performance	Age: 18-24	25-34	35-44	45+
Good	43.7	48.7	63.6	77.8
Poor	56.3	51.3	36.4	22.2
	100%	100%	100%	100%
N =	142	158	44	18

Performance:
C. Total Number of Omissions

Performance	Age: 18-24	25-34	35-44	45+
Good	62.7	56.3	54.6	27.8
Poor	37.3	43.7	45.4	72.2
	100%	100%	100%	100%
N =	142	158	44	18

Performance:
D. Ratio of Omissions

Performance	Age: 18-24	25-34	35-44	45+
Good	57.0	50.0	52.3	38.9
Poor	43.0	50.0	47.7	61.1
	100%	100%	100%	100%
N =	142	158	44	18

Performance:
E. Marking Efficiency Index: Tickets Marked - (Total Omissions + Total Errors)

Performance	Age: 18-24	25-34	35-44	45+
Good	59.9	50.0	40.9	38.9
Poor	40.1	50.0	59.1	61.1
	100%	100%	100%	100%
N =	142	158	44	18

VIII. Marking of the Tickets. Percent of operators with seniority of one to five years in different age groups whose performance is relatively good and relatively poor. Total N = 253.

Performance:
A. Number of Tickets Marked

Performance	Age 18-24	25-34	35-44	45+
Good	54.3	59.7	68.4	60.0
Poor	45.7	40.3	31.6	40.0
	100%	100%	100%	100%
N =	162	67	19	5

Performance:
B. Total Number of Errors

Performance	Age 18-24	25-34	35-44	45+
Good	45.7	50.8	73.7	40.0
Poor	54.3	49.2	26.3	60.0
	100%	100%	100%	100%
N =	162	67	19	5

Performance:
C. Total Number of Omissions

Performance	Age 18-24	25-34	35-44	45+
Good	63.6	62.7	63.2	20.0
Poor	36.4	37.3	36.8	80.0
	100%	100%	100%	100%
N =	162	67	19	5

Performance:
D. Ratio of Omissions

Performance	Age 18-24	25-34	35-44	45+
Good	57.4	56.7	52.6	20.0
Poor	42.6	43.3	47.4	80.0
	100%	100%	100%	100%
N =	162	67	19	5

Performance:
E. Marking Efficiency Index: Tickets Marked - (Total Omissions + Total Errors)

Performance	Age 18-24	25-34	35-44	45+
Good	62.3	59.7	57.9	40.0
Poor	37.7	40.3	42.1	60.0
	100%	100%	100%	100%
N =	162	67	19	5

IX. Marking of the Tickets. Percent of operators with seniority of six years or more in different age groups whose performance is relatively good and relatively poor. Total N = 250/

Performance:
A. Number of Tickets Marked

	Age 18-24	25-34	35-44	45+
Good	50.0	47.4	31.4	22.0
Poor	50.0	52.6	68.6	78.0
	100%	100%	100%	100%
N =	14	135	51	50

Performance:
B. Total Number of Errors

	Age 18-24	25-34	35-44	45+
Good	27.3	48.9	52.9	54.0
Poor	72.7	51.1	47.1	46.0
	100%	100%	100%	100%
N =	14	135	51	50

Performance:
C. Total Number of Omissions

	Age 18-24	25-34	35-44	45+
Good	50.0	57.8	56.9	42.0
Poor	50.0	42.2	43.1	58.0
	100%	100%	100%	100%
N =	14	135	51	50

Performance:
D. Ratio of Omissions

	Age 18-24	25-34	35-44	45+
Good	35.7	49.6	45.1	30.0
Poor	64.3	50.4	54.9	70.0
	100%	100%	100%	100%
N =	14	135	51	50

Performance:
E. Marking Efficiency Index: Tickets Marked - (Total Omissions + Total Errors)

	Age 18-24	25-34	35-44	45+
Good	28.6	49.6	38.0	26.0
Poor	71.4	50.4	62.0	74.0
	100%	100%	100%	100%
N =	14	135	51	50

2. Interpreting the Marked Cards

The paper forms used before the cards were introduced served as a short-term memory-aiding device. One aspect of the training was concerned with the use of IBM cards, in lieu of the paper forms, in serving the same function. This aspect of the training occurred during the time operators marked cards and placed calls. Six offices with a total of 369 operators are involved in this analysis. Chart I indicates the relevant characteristics of these offices.

Measures of performance in interpreting cards were obtained by observing the speed and accuracy with which operators placed artificial calls from a deck of thirty cards. (It should be emphasized that the measurement of "interpretation skill" was the same for all six offices, although the training differed somewhat as indicated on Chart I.) Measures were also obtained before retraining on the speed and accuracy of the operators using the old paper forms.

Table X shows the relationships between age and the various performance measures in the ticket-interpretation task. Sub-tables X-A (speed) and X-B (accuracy) present the data for the old method. These tables suggest that while the older operators may be slower than their younger co-workers, they are not inclined to make more errors.

Sub-tables X-C (speed) and X-D (errors) show the results for the new method. Older operators are clearly slower than younger operators, and this relationship seems stronger for the new method than for the old. At the same time, a relatively large proportion of operators over 44 years of age make a relatively large number of errors. For the new method, the older operator appears to be at a disadvantage both with respect to the speed and accuracy of her work.

Sub-table X-E shows the relationship between age and the difference in speed of interpreting the old and the new tickets. "Good performance" here means relatively little difference in the two speeds, while "poor performance" indicates relatively more time needed for the new method. Older operators appear in general to need more time for the new tickets (relative to the old) than do the younger operators.

Table XI displays the relationship between seniority and performance in the interpretation task. With the exception of the measure of errors using the old method, higher seniority is associated with poorer performance. This finding is probably attributable in large part to the higher age of the high seniority operators.

Table XII presents the data for education versus performance. Little relationship is evident.

Tables XIII and XIV are concerned with the relationship between the two pre-employment tests and performance. It can be seen that these tests do not discriminate between high and low performance.

The remaining tables in this section are concerned with the relationships when the range of one or another of the independent variables is restricted. Tables XV and XVI show the relationship between age and performance for low and high education operators, respectively. In almost every instance, with increasing age, a larger percentage of the operators is found in the poor performance category. The most notable exception to this tendency occurs for high education operators in the relationship between age and the old method speed measure; in that instance no distinct relationship is observed, although the older operators tend to be in the good performance category more often than the younger operators.

Tables XVII and XVIII examine the relationship of age to performance for operators of differing amounts of seniority.

X: Interpreting of the Tickets. Percent of operators in different age groups whose performance is relatively good and relatively poor. Total N = 369, except Table D. where Total N = 368.

Performance:
A. Speed Using Old Method

Performance	Age 18-24	25-34	35-44	45+
Good	52.2	52.7	50.9	33.3
Poor	47.8	47.3	49.1	66.7
	100%	100%	100%	100%
N =	92	165	55	57

Performance:
B. Errors Using Old Method

Performance	Age 18-24	25-34	35-44	45+
Good	63.0	68.5	69.1	64.9
Poor	37.0	31.5	30.9	35.1
	100%	100%	100%	100%
N =	92	165	55	57

Performance:
C. Speed Using New Method

Performance	Age 18-24	25-34	35-44	45+
Good	60.9	54.6	38.2	28.1
Poor	39.1	45.4	61.8	71.9
	100%	100%	100%	100%
N =	92	165	55	57

Performance:
D. Errors Using New Method

Performance	Age 18-24	25-34	35-44	45+
Good	56.5	60.6	60.0	39.3
Poor	43.5	39.4	40.0	60.7
	100%	100%	100%	100%
N =	92	165	55	56

Performance:
E. Speed Difference (Speed "Old" - Speed "New")

Performance	Age 18-24	25-34	35-44	45+
Good	55.4	54.6	49.1	31.8
Poor	44.6	45.4	50.9	68.2
	100%	100%	100%	10C%
N =	92	165	55	57

XI. Interpreting of the Tickets. Percent of operators of differing seniority whose performance is relatively good and relatively poor. Total N = 369 except Table D. where Total N = 368.

Performance:
A. Speed Using Old Method

Performance	Seniority 1-2	3-5	6-10	11+
Good	56.8	53.7	45.5	44.2
Poor	43.2	46.3	54.5	55.8
	100%	100%	100%	100%
	37	136	101	95

Performance:
B. Errors Using Old Method

Performance	Seniority 1-2	3-5	6-10	11+
Good	64.9	69.9	64.4	65.3
Poor	35.1	30.1	35.6	34.7
	100%	100%	100%	100%
	37	136	101	95

Performance:
C. Speed Using New Method

Performance	Seniority 1-2	3-5	6-10	11+
Good	54.0	53.7	55.4	35.8
Poor	46.0	46.3	44.6	64.2
	100%	100%	100%	100%
N =	37	136	101	95

Performance:
D. Errors Using New Method

Performance	Seniority 1-2	3-5	6-10	11+
Good	59.5	42.7	60.4	48.9
Poor	40.5	57.3	39.6	51.1
	100%	100%	100%	100%
N =	37	136	101	94

Performance:
E. Speed Difference (Speed "Old" - Speed "New")

Performance	Seniority 1-2	3-5	6-10	11+
Good	51.3	56.6	52.5	39.0
Poor	48.7	43.4	47.5	61.0
	100%	100%	100%	100%
N =	37	136	101	95

XII. Interpreting of the Tickets. Percent of operators differing in education whose performance is relatively good and relatively poor. Total N = 363; except Table D., where Total N = 362.

Performance:
A. Speed Using Old Method

Performance	Education 8-11	12+
Good	48.9	50.0
Poor	51.1	50.0
	100%	100%
N =	133	230

Performance:
B. Errors Using Old Method

	Education 8-11	12+
Good	67.7	66.1
Poor	32.3	33.9
	100%	100%
N =	133	230

Performance:
C. Speed Using New Method

Performance	Education 8-11	12+
Good	45.9	51.7
Poor	54.1	48.3
	100%	100%
N =	133	230

Performance:
D. Errors Using New Method

	Education 8-11	12+
Good	50.8	60.0
Poor	49.2	40.0
	100%	100%
N =	132	230

Performance:
E. Speed Difference (Speed "Old" - Speed "New")

Performance	Education 8-11	12+
Good	48.9	50.9
Poor	51.1	49.1
	100%	100%
N =	133	230

XIII. Interpreting of the Tickets. Percent of operators differing on results of the Wonderlic Test whose performance is relatively good and relatively poor. Total N = 303.

Performance:
A. Speed Using Old Method

Performance	Wonderlic Test Low	Wonderlic Test High
Good	49.7	52.0
Poor	50.3	48.0
	100%	100%
N =	149	154

Performance:
B. Errors Using Old Method

Performance	Wonderlic Test Low	Wonderlic Test High
Good	69.1	63.6
Poor	30.9	36.4
	100%	100%
N =	149	154

Performance:
C. Speed Using New Method

Performance	Wonderlic Test Low	Wonderlic Test High
Good	53.7	52.6
Poor	46.3	37.4
	100%	100%
N =	149	154

Performance:
D. Errors Using New Method

Performance	Wonderlic Test Low	Wonderlic Test High
Good	56.4	59.1
Poor	43.6	40.9
	100%	100%
N =	149	154

Performance:
E. Speed Difference (Speed "Old" - Speed "New")

Performance	Wonderlic Test Low	Wonderlic Test High
Good	57.0	50.7
Poor	43.0	49.3
	100%	100%
N =	149	154

XIV. Interpreting of the Tickets. Percent of operators differing on results of the Call-Detail Test whose performance is relatively good and relatively poor. Total N = 308.

Performance:
A. Speed Using Old Method

Performance	Call-Detail Test Low	Call-Detail Test High
Good	49.4	52.8
Poor	50.6	47.2
	100%	100%
N =	166	142

Performance:
B. Errors Using Old Method

Performance	Call-Detail Test Low	Call-Detail Test High
Good	69.9	65.5
Poor	30.1	34.5
	100%	100%
N =	166	142

Performance:
C. Speed Using New Method

Performance	Call-Detail Test Low	Call-Detail Test High
Good	47.0	57.8
Poor	53.0	42.2
	100%	100%
N =	166	142

Performance:
D. Errors Using New Method

Performance	Call-Detail Test Low	Call-Detail Test High
Good	60.8	54.2
Poor	39.2	45.8
	100%	100%
N =	166	142

Performance:
E. Speed Difference (Speed "Old" - Speed "New")

Performance	Call-Detail Test Low	Call-Detail Test High
Good	50.0	55.6
Poor	50.0	44.4
	100%	100%
N =	166	142

XV. Interpreting of the Tickets. Percent of operators with education of eight to eleven years in different age groups whose performance is relatively good and relatively poor. Total N = 133.

Performance:
A. Speed Using Old Method

Performance	Age 18-24	25-34	35-44	45+
Good	60.7	59.1	44.0	30.6
Poor	39.3	40.9	56.0	69.4
	100%	100%	100%	100%
N =	28	44	25	36

Performance:
B. Errors Using Old Method

Performance	Age 18-24	25-34	35-44	45+
Good	53.6	75.0	68.0	69.4
Poor	46.4	25.0	32.0	30.6
	100%	100%	100%	100%
N =	28	44	25	36

Performance:
A. Speed Using New Method

Performance	Age 18-24	25-34	35-44	45+
Good	57.1	59.1	40.0	33.3
Poor	42.9	40.9	60.0	66.7
	100%	100%	100%	100%
N =	28	44	25	36

Performance:
D. Errors Using New Method

Performance	Age 18-24	25-34	35-44	45+
Good	53.6	59.1	52.0	37.1
Poor	46.4	40.9	48.0	62.9
	100%	100%	100%	100%
N =	28	44	25	36

Performance:
E. Speed Difference (Speed "Old" - Speed "New")

Performance	Age 18-24	25-34	35-44	45+
Good	53.6	56.8	56.0	30.6
Poor	46.4	43.2	44.0	69.4
	100%	100%	100%	100%
N =	28	44	25	36

XVI. Interpreting of the Tickets. Percent of operators with education of twelve years or more in different age groups whose performance is relatively good and relatively poor. Total N = 230.

Performance:
A. Speed Using Old Method

Performance	Age 18-24	25-34	35-44	45+
Good	49.2	50.8	56.7	54.6
Poor	50.8	49.2	43.3	45.4
	100%	100%	100%	100%
N =	63	120	30	17

Performance:
B. Errors Using Old Method

	Age 18-24	25-34	35-44	45+
Good	66.7	66.7	70.0	52.9
Poor	33.3	33.3	30.0	47.1
	100%	100%	100%	100%
N =	63	120	30	17

Performance:
C. Speed Using New Method

Performance	Age 18-24	25-34	35-44	45+
Good	61.9	52.5	36.7	35.3
Poor	38.1	47.5	63.3	64.7
	100%	100%	100%	100%
N =	63	120	30	17

Performance:
D. Errors Using New Method

	Age 18-24	25-34	35-44	45+
Good	58.7	60.8	66.7	47.1
Poor	41.3	39.2	33.3	52.9
	100%	100%	100%	100%
N =	63	120	30	17

Performance:
E. Speed Difference (Speed "Old" - Speed "New")

Performance	Age 18-24	25-34	35-44	45+
Good	55.6	53.3	43.3	29.4
Poor	44.4	46.7	56.7	70.6
	100%	100%	100%	100%
N =	63	120	30	17

XVII. Interpreting of the Tickets. Percent of operators with seniority of one to five years in different age groups whose performance is relatively good and relatively poor. Total N = 173.

Performance:
A. Speed Using Old Method

Performance	Age 18-24	25-34	35-44	45+
Good	52.3	59.0	52.9	42.7
Poor	47.7	41.0	47.1	57.3
	100%	100%	100%	100%
N =	88	61	17	7

Performance:
B. Errors Using Old Method

Performance	Age 18-24	25-34	35-44	45+
Good	64.8	68.9	88.2	71.4
Poor	35.2	31.1	11.8	28.6
	100%	100%	100%	100%
N =	88	61	17	7

Performance:
C. Speed Using New Method

Performance	Age 18-24	25-34	35-44	45+
Good	61.4	50.8	35.3	28.6
Poor	38.6	49.2	64.7	71.4
	100%	100%	100%	100%
N =	88	61	17	7

Performance:
D. Errors Using New Method

Performance	Age 18-24	25-34	35-44	45+
Good	56.8	60.7	64.7	28.6
Poor	43.2	39.3	35.3	71.4
	100%	100%	100%	100%
N =	88	61	17	7

Performance:
E. Speed Difference (Speed "Old" - Speed "New")

Performance	Age 18-24	25-34	35-44	45+
Good	55.7	57.4	58.8	28.6
Poor	44.3	42.6	41.2	71.4
	100%	100%	100%	100%
N =	88	61	17	7

VIII. Interpreting of the Tickets. Percent of operators with seniority of six years or more in different age groups whose performance is relatively good and relatively poor. Total N = 196.

Performance:
A. Speed Using Old Method

Performance	Age 18-24	25-34	35-44	45+
Good	50.0	49.0	50.0	32.0
Poor	50.0	51.0	50.0	68.0
	100%	100%	100%	100%
N =	4	104	38	50

Performance:
B. Errors Using Old Method

Performance	Age 18-24	25-34	35-44	45+
Good	25.0	68.3	60.5	64.0
Poor	75.0	31.7	39.5	36.0
	100%	100%	100%	100%
N =	4	104	38	50

Performance:
C. Speed Using New Method

Performance	Age 18-24	25-34	35-44	45+
Good	50.0	56.7	39.5	28.0
Poor	50.0	43.3	60.6	72.0
	100%	100%	100%	100%
N =	4	104	38	50

Performance:
D. Errors Using New Method

Performance	Age 18-24	25-34	35-44	45+
Good	50.0	60.6	57.9	40.8
Poor	50.0	39.4	42.1	59.2
	100%	100%	100%	100%
N =	4	104	38	50

Performance:
E. Speed Difference (Speed "Old" - Speed "New")

Performance	Age 18-24	25-34	35-44	45+
Good	50.0	52.9	44.7	32.0
Poor	50.0	47.1	55.3	68.0
	100%	100%	100%	100%
N =	4	104	38	50

II. An Oil Refinery

A major technological change occurred in the Oil Refinery. The change involved the complete rebuilding of the refinery and extensive redefinition of the duties of all the people working there. For the departments examined here, the new duties required significant increases in skill-level and responsibility.

A. Background Information

The Oil Refinery is one of the major installations of a petroleum Company. The Company is among the smaller of those in the industry: its major product-distribution area is essentially limited to one "middle-eastern" state. The Company as a whole employs some 10,500 people. The amount of capital per employee approaches $31,000.

The Refinery itself has roughly 450 employees, of which 150 are in the Production Department. The following Chart indicates the numbers of employees in different departments of the Refinery immediately before and just after the change was implemented. It can be seen that there is relatively little difference in the numbers of people involved. The new employees that did join the Refinery came from Company facilities located elsewhere in the state.

Chart 3

Number of Employees Before and After
The Change in the Various Departments

Department		Before	After
Production		135	152
Laboratory		16	24
Maintenance		158	135
Office		35	50
Management		69	96
	TOTAL	413	457

While the change involved all of the employees of the Refinery, retraining data are available for only 82 men of the operating staff and 18 men of the Instrumentation Division of the Production Department.

B. The Change

The oil industry as a whole has been highly "automated" for a long time; the change at this refinery is more an extension of such automation than a change from non-automated to automated operation. The Oil Refinery can perhaps best be characterized as having undergone a drastic modernization program. The most outstanding difference between the old and the new Refinery is the degree of process integration of the facilities. To quote from a Company release:

> In the older refinery operation, 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.

In the new unit, a "straight-through" process is used. The crude oil enters the Refinery, is subjected to a large variety of treatments, and emerges as finished products. In general, the new unit eliminates the cooling-storage-reheating parts of the old system. Quoting from another Company publication:

> 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.

This type of system enabled the Company to save some $10 million in construction costs, and other "millions of dollars a year in operating costs." The new installation cost roughly $45 million, an investment exceeding $130,000 per employee at the Refinery. Some sixteen months were required for the construction of the new unit.

We will now consider in more detail some of the specific characteristics of the old and the new Refineries. Before the change, the Refinery had a relatively small through-put (capacity) per day. Only five end products were made (gasoline, kerosene, heavy fuel oils, butane, and coke). The mechanical equipment used was relatively inefficient; for example, reciprocating pumps were the most common type, as contrasted to the newer centrifugal type. The control systems used in the old refinery were relatively crude; at times, temperature was controlled manually. Temperature control within fifty degrees F was considered adequate.

Before the change, there were six different job classifications in the Production Department, each with its own pay rate. The highest paying job paid roughly twice the amount of the lowest paying job. In general, the jobs did not require a great deal of knowledge about what was occurring in the Refinery. It was sufficient, for the most part, to know what valve to turn when a particular meter gave a certain reading. The workers did not need a high degree of intellectual skill in order to perform their jobs adequately.

The modernization program changed each of the above characteristics of the Refinery. The capacity of the plant was increased greatly. While the old unit involved two basic refining processes, the new unit involves six. Compared to the five end products of the old unit, some eleven distinct products are made today; among them, regular and premium gasolines, napthas, kerosene, jet fuels, diesel oil, aviation gasoline, liquified petroleum gas, furnace oil, and coke. The control system is extremely complex. Some 2,300 instruments are used for recording and controlling the action of 235 pumps, compressors, and blowers, and of 15,800 valves. Coordination of the entire system occurs through a 96 foot semicircular central control panel. Because of this advanced control system, the accuracy obtained in the various processes is much increased. Temperature control, for instance, is kept within one degree F limits in many of the operations.

Two wage-grades exist for hourly employees in the Production Department under the new system. The higher rate is roughly 50 per cent greater than the lower. The lower rate today is comparable to the highest rate before the change. This reflects the much greater knowledge and responsibility required of workers today. Because of the degree of process integration, workers in any one area (or "zone") need to be familiar with the processes in all other zones. Seventeen men operate the entire unit. Responsibility for a very large capital investment is in the hands of a relatively few workers.

C. Introducing the Change

Many of the supervisory personnel of the Refinery were involved in the initial planning for the change. Such planning began two years before construction was initiated. In addition to the resulting "first-hand" contact with the planning of the new unit, the employees at the Refinery (and throughout the Company) were exposed to formal Company publicity concerning the change.

The union contract was extensively modified as a result of the change. Among these modifications were the changes in wage-rates and job-classifications mentioned above.

The union agreement specifies that seniority is the most important factor in the selection of employees for retraining; to this extent the union had a part in implementing the change.

D. The Retraining Courses

1. The Operating Staff of the Production Department

Three sets of courses covering essentially the same material were given. One three week and one four week set was taught eight hours a day, five days a week. A third set averaged from four to eight hours per week for two years. The rest of the trainees' time was spent in regular job duties and informal on-the-job training.

Each of the above sets involve separate courses covering each of the four zones--or process units--of the Refinery. Three of these zones (A, B, and C) involve consecutive operations in the oil refining process. The fourth--zone D--involves steam production and water treatment. Since this zone uses fuel derived from the other zones, it is integrated into the total process.

The total number of individuals involved in the analysis is 82. A relatively large proportion of trainees took more than one course within a set. In the 3-week courses, for example, almost all trainees taking the zone A course also took the zone B-D (a special combined course for the 3-week set only) and the zone C courses. Of the seventy individuals who took at least one of the 4-week courses, roughly 20 took one or more additional courses in that same 4-week set. Chart 4 indicates the extent of overlap between courses and sets.

<u>Chart 4</u>

Extent of Overlap of Trainees in Courses
Within and between Sets

3-week Set:	Trainees taking one 3-week course who:		
	1. Took no other courses	5	
	2. Took other 3-week courses only	4	
	3. Took one or more 4-week courses	17	
	4. Took one or more 4-week courses and one or more 2-year courses	4	
		30	
	Total taking 3-week courses:		30
4-week Set:	Trainees taking one 4-week course who did not take any 3-week courses, and who:		
	1. Took no other courses	23	
	2. Took other 4-week courses only	9	
	3. Took one or more 2-year courses	5	
		37	
	Total taking 4-week courses:		58
2-year Set:	Trainees taking neither 3-week nor 4-week courses who took one 2-year course and who:		
	1. Took no other courses	10	
	2. Took other 2-year courses	5	
		15	
	Total taking 2-year courses:		24
	TOTAL N:		82

Training was administered by management personnel of the Refinery, as an addition to their regular duties. The courses were designed to familiarize the trainees with the new equipment, to acquaint them with the complicated pattern of process-flow through the Refinery, and to prepare the trainees for problem-situations which could arise on the job. The trainees received grades on written examinations given in the classroom situation; they also received ratings from their supervisors on their ability to apply the "classroom knowledge" out on the job. Only an average of the written-examination grades are available for the analysis.

In addition to the examination grades, scores on three tests, administered immediately before training, are available. The first of these tests is the Western Reserve test, used as a measure of general "intelligence." The second is the Minnesota Paper Form Board Test, a paper-and-pencil test of two-dimensional spatial-relations ability. In the Revised Edition used here, the test provides the subject with a picture of a figure cut into two or more parts. The subject then attempts to visualize the figure as a whole, and selects a drawing corresponding to the complete figure. The third test is the Bennett Mechanical Comprehension Test; it measures the understanding of a variety of mechanical principles through the use of illustrations and short verbal questions.

Due to the small number of individuals involved in each course, the following tables are not completely consistent with respect to the categories used for age, education, seniority, and the aptitude and intelligence tests. In all cases these variables are divided, for purposes of analyses, as close to the median as is practicable.

Tables XIX through XXXI present the relationships found between the average course grade, age, and other variables. A total of thirteen courses are involved. Since the number of trainees in each course is small, the direction of relationships cannot be evaluated easily for each course. Table XXXI is especially problematical since it is based on only five cases. Taken together, however, the results for the various courses do indicate several meaningful relationships.

In all but two of the courses, a greater percentage of the older trainees are found in the lower grade category. The relationship between grade and seniority is not as regular as that between grade and age. In eight of the courses, the more senior trainees do less well. Higher education is associated with better performance in eight of the thirteen courses.

There seems to be no general relationship between the Western Reserve test and performance in the training courses. The relationship between the Minnesota Paper Form Board Test is in decided contrast to this: in eleven instances out of thirteen, high test performance is associated with high grade. A similar relationship exists between course grade and the score on the Bennett Mechanical Comprehension Test. In nine instances the relationship is positive.

The age distribution of the individuals in this section is indicated in Chart 5.

Chart 5

Age Distribution of Individuals in the Operating Staff of the Production Department

Age	f
18-24	2
25-34	21
35-44	27
45-61	32
	82

XIX. Production Department : 3 Week Course, Zone A.
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age	
	20-42	47+
Grade High	58	40
Grade Low	42	60
	100%	100%
N =	12	10

	Seniority	
	0-16	17+
High	60	41
Low	40	49
	100%	100%
N =	10	12

	Education	
	8-11	12+
Grade High	25	80
Grade Low	75	20
	100%	100%
N =	12	10

	Western Reserve Test	
	Low	High
High	45	60
Low	55	40
	100%	100%
N =	11	10

	Minnesota Paper Form Board Test	
	Low	High
Grade High	45	67
Grade Low	55	33
	100%	100%
N =	11	9

	Bennett Mechanical Comprehension Test	
	Low	High
High	50	63
Low	50	37
	100%	100%
N =	12	8

XX. Production Department: 3 Week Course, Zone B-D.
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age 20-42	Age 47+
Grade High	50	45
Grade Low	50	55
	100%	100%
N =	10	11

	Seniority 2-17	Seniority 18+
High	45	50
Low	55	50
	100%	100%
N =	11	10

	Education 8-11	Education 12+
Grade High	31	75
Grade Low	69	25
	100%	100%
N =	13	8

	Western Reserve Test Low	Western Reserve Test High
High	50	50
Low	50	50
	100%	100%
N =	10	10

	Minnesota Paper Form Board Test Low	Minnesota Paper Form Board Test High
Grade High	50	56
Grade Low	50	44
	100%	100%
N =	10	9

	Bennett Mechanical Comprehension Test Low	Bennett Mechanical Comprehension Test High
High	40	67
Low	60	33
	100%	100%
N =	10	9

XXI. Production Department: 3 Week Course, Zone C
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age 20-42	Age 43+
Grade High	60	36
Grade Low	40	64
	100%	100%
N =	10	11

	Seniority 0-16	Seniority 17+
High	50	45
Low	50	55
	100%	100%
N =	10	11

	Education 8-11	Education 12+
Grade High	31	75
Grade Low	69	25
	100%	100%
N =	13	8

	Western Reserve Test Low	Western Reserve Test High
High	50	50
Low	50	50
	100%	100%
N =	10	10

	Minnesota Paper Form Board Test Low	Minnesota Paper Form Board Test High
Grade High	50	50
Grade Low	50	50
	100%	100%
N =	10	10

	Bennett Mechanical Comprehension Test Low	Bennett Mechanical Comprehension Test High
High	30	70
Low	70	30
	100%	100%
N =	10	10

XXII. Production Department: 3 Week Course, Zone D
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

		Age	
		27-50	51+
Grade	High	80	20
	Low	20	80
		100%	100%
	N =	5	5

	Seniority	
	0-16	17+
High	80	20
Low	20	80
	100%	100%
N =	5	5

		Education	
		6-8	10-12
Grade	High	00	100
	Low	100	00
		100%	100%
	N =	5	5

	Western Reserve Test	
	Low	High
High	20	100
Low	80	00
	100%	100%
N =	5	4

		Minnesota Paper Form Board Test	
		Low	High
Grade	High	20	100
	Low	80	00
		100%	100%
	N =	5	4

	Bennett Mechanical Comprehension Test	
	Low	High
High	40	75
Low	60	25
	100%	100%
N =	5	4

XXIII. Production Department: 4 Week Course, Zone A
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

		Age			Seniority	
		26-42	43+		0-22	23+
Grade	High	47	53	High	50	50
	Low	53	47	Low	50	50
		100%	100%		100%	100%
	N =	15	15	N =	16	14

		Education			Western Reserve Test	
		7-10	11+		Low	High
Grade	High	46	56	High	53	50
	Low	54	44	Low	47	50
		100%	100%		100%	100%
	N =	13	16	N =	15	14

		Minnesota Paper Form Board Test			Bennett Mechanical Comprehension Test	
		Low	High		Low	High
Grade	High	29	69	High	25	79
	Low	71	31	Low	75	21
		100%	100%		100%	100%
	N =	14	16	N =	16	14

XXIV. Production Department: 4 Week Course, Zone B
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age	
	20-51	52+
Grade High	58	46
Grade Low	42	54
	100%	100%
N =	12	13

	Seniority	
	0-29	30+
High	55	50
Low	45	50
	100%	100%
N =	11	14

	Education	
	5-9	10+
Grade High	50	54
Grade Low	50	46
	100%	100%
N =	12	13

	Western Reserve Test	
	Low	High
High	55	50
Low	45	50
	100%	100%
N =	11	12

	Minnesota Paper Form Board Test	
	Low	High
Grade High	36	67
Grade Low	64	33
	100%	100%
N =	11	12

	Bennett Mechanical Comprehension Test	
	Low	High
High	25	82
Low	75	18
	100%	100%
N =	12	11

XXV. Production Department: 4 Week Course, Zone C
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

Grade	Age: 34-48	Age: 49+
High	53	31
Low	47	69
	100%	100%
N =	15	13

Grade	Seniority: 0-26	Seniority: 27+
High	54	33
Low	46	67
	100%	100%
N =	13	15

Grade	Education: 7-11	Education: 12+
High	37	50
Low	63	50
	100%	100%
N =	16	12

Grade	Western Reserve Test: Low	Western Reserve Test: High
High	43	43
Low	57	57
	100%	100%
N =	14	14

Grade	Minnesota Paper Form Board Test: Low	Minnesota Paper Form Board Test: High
High	43	43
Low	57	57
	100%	100%
N =	14	14

Grade	Bennett Mechanical Comprehension Test: Low	Bennett Mechanical Comprehension Test: High
High	43	42
Low	57	58
	100%	100%
N =	14	12

XXVI. Production Department: 4 Week Course, Zone D
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

Grade	Age: 23-34	Age: 48+
High	50	33
Low	50	67
	100%	100%
N =	4	3

Grade	Seniority: 1-2	Seniority: 12+
High	33	50
Low	67	50
	100%	100%
N =	3	4

Grade	Education: 11-12	Education: 13
High	60	00
Low	40	100
	100%	100%
N =	5	2

Grade	Western Reserve Test: Low	Western Reserve Test: High
High	50	33
Low	50	67
	100%	100%
N =	4	3

Grade	Minnesota Paper Form Board Test: Low	Minnesota Paper Form Board Test: High
High	25	67
Low	75	33
	100%	100%
N =	4	3

Grade	Bennett Mechanical Comprehension Test: Low	Bennett Mechanical Comprehension Test: High
High	33	33
Low	67	67
	100%	100%
N =	3	3

XXVII. Production Department: 2 Year Course, Zone A
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age	
	26-38	39+
Grade High	50	40
Grade Low	50	60
	100%	100%
N =	10	10

	Seniority	
	0-16	17+
High	50	40
Low	50	60
	100%	100%
N =	10	10

	Education	
	0-11	12+
Grade High	56	36
Grade Low	44	64
	100%	100%
N =	9	11

	Western Reserve Test	
	Low	High
High	50	33
Low	50	67
	100%	100%
N =	10	9

	Minnesota Paper Form Board Test	
	Low	High
Grade High	40	50
Grade Low	60	50
	100%	100%
N =	10	10

	Bennett Mechanical Comprehension Test	
	Low	High
High	37	71
Low	63	29
	100%	100%
N =	8	7

XXVIII. Production Department: 2 Year Course, Zone B
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

Age

Grade	26-41	42+
High	75	50
Low	25	50
	100%	100%
N =	7	8

Seniority

Grade	0-16	17+
High	37	57
Low	63	43
	100%	100%
N =	8	7

Education

Grade	0-10	11+
High	50	56
Low	50	44
	100%	100%
N =	6	9

Western Reserve Test

Grade	Low	High
High	43	43
Low	57	57
	100%	100%
N =	7	7

Minnesota Paper Form Board Test

Grade	Low	High
High	37	57
Low	63	43
	100%	100%
N =	8	7

Bennett Mechanical Comprehension Test

Grade	Low	High
High	43	43
Low	57	57
	100%	100%
N =	7	7

XXIX. Production Department: 2 Year Course, Zone C
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age 26-35	Age 39+
Grade High	63	50
Grade Low	37	50
	100%	100%
N =	8	8

	Seniority 0-12	Seniority 15+
High	63	50
Low	37	50
	100%	100%
N =	8	8

	Education 0-11	Education 12+
Grade High	63	50
Grade Low	37	50
	100%	100%
N =	8	8

	Western Reserve Test Low	Western Reserve Test High
High	57	63
Low	43	37
	100%	100%
N =	7	8

	Minnesota Paper Form Board Test Low	Minnesota Paper Form Board Test High
Grade High	37	75
Grade Low	63	25
	100%	100%
N =	8	8

	Bennett Mechanical Comprehension Test Low	Bennett Mechanical Comprehension Test High
High	57	50
Low	43	50
	100%	100%
N =	7	6

XXX. Production Department: 2 Year Course, Zone D
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

		Age	
		27-42	43+
Grade	High	60	33
	Low	40	67
		100%	100%
	N =	5	6

	Seniority	
	4-17	18+
High	60	33
Low	40	67
	100%	100%
N =	5	6

		Education	
		0-10	11+
Grade	High	40	50
	Low	60	50
		100%	100%
	N =	5	6

	Western Reserve Test	
	Low	High
High	20	60
Low	80	40
	100%	100%
N =	5	5

		Minnesota Paper Form Board Test	
		Low	High
Grade	High	17	80
	Low	83	20
		100%	100%
	N =	6	5

	Bennett Mechanical Comprehension Test	
	Low	High
High	40	40
Low	60	60
	100%	100%
N =	5	5

XXXI. Production Department: 2 Year Course, Operators of the Overall Unit
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

		Age	
		40-43	51+
Grade	High	50	67
	Low	50	33
		100%	100%
	N =	2	3

	Seniority	
	18-20	22+
High	33	100
Low	67	00
	100%	100%
N =	3	2

		Education	
		7-8	11+
Grade	High	67	50
	Low	33	50
		100%	100%
	N =	3	2

	Western Reserve Test	
	Low	High
High	100	00
Low	00	100
	100%	100%
N =	2	2

		Minnesota Paper Form Board Test	
		Low	High
Grade	High	33	100
	Low	67	00
		100%	100%
	N =	3	2

	Bennett Mechanical Comprehension Test	
	Low	High
High	50	67
Low	50	33
	100%	100%
N =	2	3

Tables XXXII through XXXIV show the relationships between age and performance when the effects of education are eliminated. Separate tables are presented for each set of courses (i.e., 3-week, 4-week, and 2-year). The effect of education is eliminated by computing the performance scores for each individual as a deviation from the average performance score of all individuals having the same number of years of formal schooling. These deviations represent the performance of each trainee relative to that of others having the same education. The N's in several of these tables may be slightly lower than in the earlier tables, since it is not possible to compute a deviation score if only one person happens to have a particular level of education.

No relationship between age and grade appears when education is held constant. In five of the courses a greater proportion of the older workers receive high scores, in five other courses the younger workers excell, while in two courses the same proportion of older and younger workers fall into the high grade category. The earlier finding that older workers perform less well than the younger may be explained in part by the differences in formal education between the two groups.

In Tables XXXV through XXXVII scores on the Minnesota Paper Form Board Test are employed as a control in a manner similar to that described above. (This control takes the form of restricting the range of scores on the test. For any one course, individuals in the top quartile of the distribution of test scores are regarded as having the same score on that test; those in the second quartile form the second "same-score" group, etc.) No relationship is seen between age and performance when the effect of the spatial visualization ability measured by this test is restricted.

The same "restriction of range" control is used employing the Bennett Mechanical Comprehension Test. The resulting relationships are shown in Tables XXXVIII to XL. In this instance, a consistent relationship is maintained between age and performance. Older trainees more often receive lower grades than younger trainees who have similar (Bennett) mechanical comprehension ability.

The above analyses suggest that while older workers do less well than younger workers in learning how to perform new tasks in the Refinery, this difference is not attributable to age per se. Older workers are at an educational disadvantage. When older workers are compared to younger workers of similar education, no difference in performance is apparent. A rising level of education among workers should minimize in the future the disadvantage which older workers now suffer in adapting to technologically advanced jobs of the type described above.

This analysis also suggests how appropriate selection procedures may eliminate differences in performance between younger and older workers. The results of retraining workers in the Instrumentation Division seems to illustrate this possibility.

XXXII. Production Department: All Three Week Courses
Percentage of trainees in different age groups who received relatively high and low average grades, when education is held constant.

Zone A

Grade	20-42	47+
High	50	45
Low	50	55
	100%	100%
N=	12	9

Zone B-D

	20-42	47+
High	40	67
Low	60	33
	100%	100%
N=	10	9

Zone C

Grade	20-42	43+
High	50	50
Low	50	50
	100%	100%
N=	10	10

Zone D

	27-50	51+
High	33	50
Low	67	50
	100%	100%
N=	3	4

XXXIII Production Department: All Four Week Courses.
Percentage of trainees in different age groups who received relatively high and Low average grades, when education is held constant.

Zone A

Grade	26-42	43+
High	58	46
Low	42	54
	100%	100%
N=	12	13

Zone B

	20-51	52+
High	67	40
Low	33	60
	100%	100%
N=	12	10

Zone C

Grade	34-48	49+
High	82	31
Low	18	69
	100%	100%
N=	11	13

Zone D

	23-34	48+
High	40	100
Low	60	0
	100%	100%
N=	5	2

XXXIV.

Production Department: All Two Year Courses.

Percentage of trainees of different age groups who received relatively high and low average grades, when education is held constant.

Zone A

Grade		26-38	39+
	High	58	33
	Low	42	66
		100%	100%
	N=	12	6

Zone B

		26-41	42+
	High	50	50
	Low	50	50
		100%	100%
	N=	6	4

Zone C

Grade		26-35	36+
	High	50	63
	Low	50	37
		100%	100%
	N=	8	8

Zone D

		24-42	43+
	High	25	75
	Low	75	25
		100%	100%
	N=	4	4

XXXV. Production Department: All Three Week Courses.
Percentage of trainees of different age groups who received relatively high and low average grades, when the test scores in the Minnesota Paper Form Board Test are held constant.

Zone A

Grade	20-42	47+
High	55	45
Low	45	55
	100%	100%
N=	11	9

Zone B-D

	20-42	47+
High	40	60
Low	60	40
	100%	100%
N=	10	10

Zone C

Grade	20-42	47+
High	50	50
Low	50	50
	100%	100%
N=	10	10

Zone D

	27-50	51+
High	50	60
Low	50	40
	100%	100%
N=	4	5

XXXVI. Production Department: All Four Week Courses.
Percentage of trainees of different age groups who received relatively high and low average grades, when the test scores in the Minnesota Paper Form Board Test are held constant.

Zone A

Grade	26-42	43+
High	46	47
Low	54	53
	100%	100%
N=	13	15

Zone B

	20-51	52+
High	70	36
Low	30	63
	100%	100%
N=	10	11

Zone C

Grade	34-48	49+
High	58	47
Low	42	53
	100%	100%
N=	12	15

Zone D

	23-34	48+
High	40	50
Low	50	50
	100%	100%
N=	5	2

XXXVII. Production Department: All Two Year Courses.
Percentage of trainees of different age groups who received relatively high and low average grades, when the test scores in the Minnesota Paper Form Board Test are held constant.

Zone A

Grade	26-38	39+
High	50	50
Low	50	50
	100%	100%
N=	10	10

Zone B

	26-41	42+
High	50	43
Low	50	57
	100%	100%
N=	8	7

Zone C

Grade	26-35	39+
High	63	38
Low	37	62
	100%	100%
N=	8	8

Zone D

	27-42	43+
High	43	75
Low	57	25
	100%	100%
N=	7	4

XXXVIII. Production Department: All Three Week Courses.
Percentage of trainees of different age groups who received relatively high and low average grades, when test scores from the Bennett Mechanical Aptitude Test are held constant.

Zone A

	20-42	47+
Grade High	88	33
Grade Low	12	67
	100%	100%
N=	8	12

Zone B-D

	20-42	47+
High	86	33
Low	14	67
	100%	100%
N=	7	12

Zone C

	20-42	43+
Grade High	60	40
Grade Low	40	60
	100%	100%
N=	10	10

Zone D

	27-50	51+
High	57	0
Low	43	100
	100%	100%
N=	7	2

XXXIX. Production Department: All Four Week Courses.
Percentage of trainees of different age groups who received relatively high and low average grades, when test scores from the Bennett Mechanical Aptitude Test are held constant.

Zone A

Grade	26-42	43+
High	78	46
Low	32	64
	100%	100%
N=	9	14

Zone B

Grade	20-51	52+
High	70	33
Low	30	67
	100%	100%
N=	10	12

Zone C

Grade	34-48	49+
High	64	46
Low	46	64
	100%	100%
N=	14	11

Zone D

Grade	23-34	48+
High	50	50
Low	50	50
	100%	100%
N=	4	2

XL. Production Department: All Two Year Courses.
Percentage of trainees of different age groups who received relatively high and low average grades, when test scores from the Bennett Mechanical Aptitude Test are held constant.

Zone A

Grade	26-38	39+
High	71	45
Low	39	55
	100%	100%
N=	7	9

Zone B

	26-41	42+
High	60	45
Low	40	55
	100%	100%
N=	5	9

Zone C

Grade	26-35	39+
High	80	25
Low	20	75
	100%	100%
N=	5	8

Zone D

	27-42	43+
High	60	50
Low	40	50
	100%	100%
N=	5	6

2. The Instrumentation Division

The Instrumentation Division has the responsibility of maintaining the highly technical "hardware" of the Refinery. The Division sees to it that all the numerous pieces of sensing, recording, and controlling equipment are functioning properly.

Before the change, the Instrumentation Division was part of the Maintenance Department. Today it is included within the Production Department, reflecting the increased importance of the Division's role in the operation of the unit.

The importance of this role is hard to overestimate. All of the operations of the integrated unit are carried out on the basis of the readings given by the various instruments; in addition, the actual operation of the unit is dependent upon the complex of valves and pumps, all of which are manipulated through control instruments. The instruments also control product quality. Under the old system the laboratory staff obtained the information necessary for quality control. Today, however, instruments serve this function. The purpose of the laboratory at present is to check the accuracy of the instruments, which in turn continuously check the quality of the products.

The men who took the instrumentation courses were highly selected. A number of otherwise eligible employees were eliminated because of a lack of formal education. Thirteen of the 18 men for whom training data is available have at least 12 years of education.

In addition to selection on the basis of education, "self-selection" operated in that a number of potential trainees withdrew voluntarily after an initial interview in which they became aware of the magnitude of the training program. Finally, all of the trainees had the option of returning to their previous jobs during the first four weeks of training. Three of the trainees elected to do this. Unfortunately, data are not available describing the men who withdrew voluntarily.

A total of 18 men underwent the training. Their ages run from 33 to 50 years; median age is about 40.

The training lasted 9 months. For approximately the first 5 months, training was given on a classroom basis, 8 hours a day, and 5 days a week. For the last 4 months half of the training was of the classroom variety, while the remainder took place on the job.

The courses fall into three general groups: company, university, and vendor courses. The first group includes introductory courses given by Instrument management personnel. These company courses cover principles involved in the measurement of pressure, temperature, liquid level, and flow, and the application of these principles to the Refinery situation. The courses also deal with mathematics, from simple arithmetic through fractions, decimals, exponents, logs, and some algebra. Some courses cover information necessary to understand the various types of control valves. Finally, one course deals with the process flow of the Refinery.

A second set of courses was given by staff men from a local university. These courses concern electricity and electronics, from an elementary level through vacuum tubes, rectifiers, and amplifiers.

The final set of courses was given by manufacturers of the instruments and control devices. These courses deal with the construction, use, and maintenance of specific control devices, valves, meters, etc.

A total of 21 courses was given; for each course an average grade is available. Not all the trainees took every course, however; consequently the N's vary somewhat from course to course.

Tables XLI to XLVI present the relationship between average course grade and a variety of independent variables. Since the results are essentially the same from course to course, the following tables are selected from a larger number on the following bases: (1) course with the largest number of trainees, and (2) courses which represent the variety of subject matters taught.

The small number of trainees in these courses seriously limits the inferences which can be drawn from the data. Older workers, however, do not seem to do less well in these courses than younger workers. It would seem reasonable to explain this finding in terms of the careful selection of workers, on bases other than age. Workers were chosen only if they had a sufficient degree of formal education. In addition, the self-selection described above probably eliminated some unqualified workers.

The age distribution of the trainees taking the Instrumentation Division courses is shown in Chart 6.

Chart 6

Age Distribution of Individuals
In the Instrumentation Division

Age	f
18-24	0
25-34	6
35-44	8
45-50	4
	18

XLI. Instrumentation. Division. Company Course 1: Arithmetic
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age	
	33-39	40+
Grade Good	29	67
Grade Poor	71	33
	100%	100%
N =	7	6

	Seniority	
	12-17	18-29
Good	29	60
Poor	71	40
	100%	100%
N =	7	5

	Bennett Mechanical Comprehension Test	
	Low	High
Grade Good	67	50
Grade Poor	33	50
	100%	100%
N =	3	6

	Minnesota Paper Form Board Test	
	Low	High
Good	60	50
Poor	40	50
	100%	100%
N =	5	4

	Western Reserve Test	
	Low	High
Grade Good	50	50
Grade Poor	50	50
	100%	100%
N =	6	4

XLII. Instrumentation Division. Company Course 2: *Fractions and Decimals*
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

Grade	Age: 33-39	Age: 40+
Good	47	71
Poor	53	29
	100%	100%
N =	8	7

Grade	Seniority: 12-17	Seniority: 18-29
Good	47	67
Poor	53	33
	100%	100%
N =	8	6

Grade	Bennett Mechanical Comprehension Test: Low	High
Good	25	88
Poor	75	12
	100%	100%
N =	4	6

Grade	Minnesota Paper Form Board Test: Low	High
Good	60	60
Poor	40	40
	100%	100%
N =	5	5

Grade	Western Reserve Test: Low	High
Good	50	75
Poor	50	25
	100%	100%
N =	6	4

XLIII. Instrumentation Division. Vendor Course 1: Control Valves
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age: 33-39	Age: 40+
Grade Good	50	43
Grade Poor	50	57
	100%	100%
N =	8	7

	Seniority: 12-17	Seniority: 18-29
Good	50	33
Poor	50	67
	100%	100%
N =	8	6

	Bennett Mechanical Comprehension Test: Low	High
Grade Good	50	50
Grade Poor	50	50
	100%	100%
N =	4	6

	Minnesota Paper Form Board Test: Low	High
Good	40	60
Poor	60	40
	100%	100%
N =	5	5

	Western Reserve Test: Low	High
Grade Good	80	40
Grade Poor	20	60
	100%	100%
N =	5	5

XLIV. Instrumentation Division. Vendor Course 2: Controls and Valves
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age	
	33-39	40+
Grade Good	50	67
Grade Poor	50	33
	100%	100%
N =	8	6

	Seniority	
	12-17	18-29
Good	50	60
Poor	50	40
	100%	100%
N =	8	5

	Bennett Mechanical Comprehension Test	
	Low	High
Grade Good	75	60
Grade Poor	25	40
	100%	100%
N =	4	5

	Minnesota Paper Form Board Test	
	Low	High
Good	20	100%
Poor	80	00
	100%	100%
N =	5	4

	Western Reserve Test	
	Low	High
Grade Good	20	100
Grade Poor	80	00
	100%	100%
N =	5	4

XLV. Instrumentation Division. Vendor Course 3: Level Indicators
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

	Age: 33-39	Age: 40+
Grade: Good	50	50
Grade: Poor	50	50
	100%	100%
N =	8	6

	Seniority: 12-17	Seniority: 18-29
Good	50	40
Poor	50	60
	100%	100%
N =	8	5

	Bennett Mechanical Comprehension Test: Low	High
Grade: Good	50	50
Grade: Poor	50	50
	100%	100%
N =	4	6

	Minnesota Paper Form Board Test: Low	High
Good	20	80
Poor	80	20
	100%	100%
N =	5	5

	Western Reserve Test: Low	High
Grade: Good	20	100
Grade: Poor	80	00
	100%	100%
N =	5	5

XLVI. Instrumentation Division. University Course 1: Generators and AC Circuits

Percent of trainees who received relatively high and low average grades as a function of various independent variables.

Grade	Age: 33-39	Age: 40+
Good	43	50
Poor	57	50
	100%	100%
N =	7	6

Grade	Seniority: 12-17	Seniority: 18-29
Good	57	40
Poor	43	60
	100%	100%
N =	7	5

Grade	Bennett Mechanical Comprehension Test: Low	High
Good	75	40
Poor	25	60
	100%	100%
N =	4	5

Grade	Minnesota Paper Form Board Test: Low	High
Good	40	75
Poor	60	25
	100%	100%
N =	5	4

Grade	Western Reserve Test: Low	High
Good	50	75
Poor	50	25
	100%	100%
N =	4	6

III. An Aircraft Manufacturing Company

A decade ago it would have been fairly accurate to say that an aircraft manufacturing company produced airplanes; today this statement would be a gross oversimplification. While airplanes are still a more or less important part of the output of the industry, depending upon the particular company involved, production now goes far beyond the manufacture of aircraft.

In this Company, expansion has been in the direction of advanced military systems and system-components. These are not only "air-borne" systems; they extend into several physical environments. This change in total product, together with radical changes in the nature of airplane manufacturing itself, has been accompanied by a large number of highly significant technological changes and by an increasing demand for training.

The technological changes made necessary by this expansion have been so great and so unique that there is no trained labor force upon which to draw. One Company executive expresses the problem as follows:

> [The Company] does not teach skills when applicants with those 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.

The training program resulting from the above situation is one of the most extensive in American industry. In the last ten years, over six million trainee-hours have been expended in formal training programs.

A. Background Information

The Company employs some 70,000 people in six divisions. The present data come from one division with 18,000 employees. The division is located near a large city on the west coast.

Each division has its own training department with a total of about 100 instructors in the Company as a whole.

According to a Company publication, "more than 90% of [the Company's] requirements for skilled technicians has been met by hiring relatively inexperienced persons and training them upward through a succession of skills." None of the trainees included in our analysis are new employees, however. Many have undergone Company training prior to that discussed below.

B. The Change

Because of the magnitude and variety of changes occurring in the division, it is impossible to consolidate a description of "the change" in one section. Each course for which data are available will be discussed separately. The courses were selected by the Company as being representative of the types of courses given. They were also chosen because of the availability of performance measures, and the inclusion of older, as well as younger, trainees.

Course One: Optical Tooling

The first course, "Optical Tooling," was designed to teach the use of optical measuring and aligning devices (e.g., the transit) in setting up equipment required in various manufacturing processes. The trainees held the job classification of "tool-maker." Chart 7 shows the age distribution of trainees in this course.

Chart 7

Age Distribution of Trainees
In the "Optical Tooling" Course

Age	f
18-24	0
25-34	14
35-44	18
45-56	14
	46

Optical tooling makes possible some of the precision necessary in the manufacture of present day air and space craft. The forces to which such vehicles are subjected demand that they have the highest degree of aerodynamic cleanliness; only a very minimum amount of error in assembly operations can be tolerated. Specifications frequently call for near zero tolerances; the vehicles cannot function properly (if at all) with the increased drag and/or increased weight resulting from imperfect construction of components or from imperfect assembly.

Prior to the introduction of optical tooling, the level and plumb bob provided sufficient accuracy. These devices, however, are not sufficiently sensitive for the newer and more critical manufacturing activities. For example, the old method could not detect misalignments resulting from very slight expansions or contractions in metals due to temperature variations. Today, the occurrence of such minute misalignments cannot be tolerated. Another short-coming of the old method is its limitation to line-of-sight alignments. The new method allows the alignment of parts which may be in angular relationship to each other.

Each class in the course was limited to four or five individuals. The order in which they received training depended upon the judgment of the supervisors in the departments concerned.

No changes were made in job-title, pay, or in the union contract as a result of the change.

The use of a number of different optical devices was taught in the course. Trainees were shown charts illustrating each device, and given lectures explaining the devices. The instructor then demonstrated the manner in which each tool is used. Following this, trainees set up and used the instruments for practice alignments.

Successful performance in this task requires:

A. comprehension of the purpose and nature of the instrument;

B. acquisition of manipulative skill in setting up the device quickly and accurately; and

C. ability to make fine visual discrimination in using the tool.

Trainees are graded on:

A. the accuracy of their performance using the tool on known targets;

B. the time required to obtain readings; and

C. a written examination on the characteristics of each of the instruments.

The data available for analysis are course grades derived from these performance measures. The accuracy component of the grade was most heavily weighted in arriving at the final grade.

Table XLVII shows the relationships found for the Optical Tooling course. Younger workers appear to perform better in this training course than older workers. Since education does not correlate positively with performance (see XLVII-C) the lower educational level of older workers does not explain their poorer performance in this case.

Chart 8

Percent of Older and Younger Trainees
In Two Education Categories
For the "Optical Tooling" Course

		Age of Trainees	
		28-40	41 and Above
Years of Formal Education	12 or more	79	36
	7-11	21	64
		100%	100%
	N =	24	22

XLVII. Course One: Optical Tooling.
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

A. Age

Grade	28-40	41+
Good	79	36
Poor	21	64
	100%	100%
N =	24	22

B. Seniority

	0-12	13+
Good	59	56
Poor	41	44
	100%	100%
N =	17	16

C. Education

Grade	7-11	12+
Good	58	41
Poor	42	59
	100%	100%
N =	19	27

Course Two: "An Introduction to Electronics"

The second course, "An Introduction to Electronics," is designed for engineers. The need for this course stems from the growing use of electronic equipment in almost every phase of the Company's operations. The course is consequently intended to provide a general competence in electronics rather than competence in specific applications.

The course was given after the regular work day. Since the trainees are salaried engineers, they were not given overtime pay. However, trainees received two "indirect" forms of compensation according to the training department: first, they received recognition from their peers for having been selected for the course, and for having the increased knowledge implied by its completion; second, course credit is taken into consideration in the determination of subsequent pay increases.

While persons chosen to participate in this training course were free to refuse training, they were strongly motivated to take the course because of the above compensations. It was therefore necessary for the training department to set limits on how many individuals could attend. Each engineering department was given a quota to be maintained by the head of that department. Information is not available concerning the criteria used by department heads in selecting trainees. It is Company policy, however, to train the higher ranking, more "critical" employees first.

The trainees come from all engineering departments in the division (e.g., hydraulics, blue-print preparation, technical specifications, etc.). The same course was given to all, regardless of their department.

The age distribution of trainees in this course is shown in Chart 9. Although all of the trainees are classified as engineers, only 64% have college degrees in engineering.

Chart 9

Age Distribution of Trainees in the "Introduction to Electronics" Course

Age	f
18-24	1
25-34	15
35-44	29
45-61	8
	53

Seven different academic degrees are represented in the training group, but no one degree prevails in any department. The educational background of trainees is shown in Chart 10.

Chart 10

Educational Background of Trainees in the "Introduction to Electronics" Course

Number of Trainees With Various Academic Degrees		Number of Trainees with Varying Amounts of Non-Degree Academic Work	
BS	3	12 years	6
BSE (aeronautical)	8	13 years	4
BSE (electrical)	3	14 years	7
BSE (mechanical)	17	15 years	1
BSE (metallurgical)	1	16 years	1
CE	1		
MS	1		
	34		19

Total in Course: 53

The course was given to three groups. The second and third classes began simultaneously, but later than the first. The first group was composed of trainees of a somewhat higher level in the organization than the second two groups. The training department reports some variation in the specific material covered for the three groups. The final competence of trainees is essentially the same, however, for all groups. All groups are combined in the analysis, since we do not have information identifying trainees by group.

The classes met for two and one-half hours in the evenings, twice a week, for about 23 months--a total of 300 hours. Roughly 150 hours were devoted to classroom lectures and discussion, while laboratory work consumed the rest of the time.

Five examinations were given during the course, consisting both of paper-and-pencil tests and evaluations of laboratory work. Our analysis uses an average of all these assessments.

Table XLVIII shows the relationships found between performance in the course and age, seniority, and education. In the "D" section of the table, education is controlled in the manner described previously (page 51).

While the direction of results is consistent with the hypothesis that older people do less well, the size of the difference in performance scores between older and younger workers is small and cannot be considered significant.

Controlling for education appears to have no effect on the relationship between age and performance. This is probably attributable to the lack of relationship between age and education for this group of trainees.

XLVIII. Course Two: Introduction to Electronics.
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

A. Age

Grade	24-40	41+
Good	52	47
Poor	47	52
	100%	100%
N =	36	17

B. Seniority

	0-8	9+
Good	50	52
Poor	50	48
	100%	100%
N =	28	25

C. Education

Grade	12-16	BS+
Good	37	59
Poor	63	41
	100%	100%
N =	19	34

D. Age: Education held constant

	24-40	41+
Good	56	53
Poor	44	47
	100%	100%
N =	34	17

Course Three: Basic Electronics for Technical Writers

This course is concerned with basic electronics, and is directed at technical writers.

The course is designed to familiarize the writers with the new terminology necessitated by the increased use of electronic apparatus. The writers must have a good command of the technical vocabulary of electronics, as well as some understanding of the equipment which they are required to describe and explain in their jobs.

While participation in this course is voluntary, the information supplied in the training is essential for adequate job performance. The writers were therefore highly motivated to take the course in order to avoid the obsolescence of their skills. In addition, their supervisors urged all writers to enroll in the course.

The course was given for two hours in the evening, twice a week for about five months.

Chart 11 shows the age distribution of trainees in this course. The distribution is divided into categories which are different from those used previously because of the relatively atypical form of the distribution for this course.

Chart 11

Age Distribution of Trainees in
The "Basic Electronics" Course

Age	f
32-35	5
36-40	14
41-45	13
46-55	6
	38

The training methods used were lecture and discussion; no laboratory work was involved. Mathematics was minimized to the extent that this was possible.

Four essay tests were given during the course. The tests took the form of representative descriptions written by the trainee of the type he would have to write in his regular job. The descriptions ("answers") given by the trainees were scored by means of a standard check-list covering such factors as:

A. the quality (style) of writing;

B. the accuracy of the information presented;

C. the appropriateness of examples chosen; and

D. the appropriateness of the terminology used.

The analysis that follows is based on an average of these tests. However, 19% of the trainees took only two tests, and 21% took only three. Individuals missed tests for a variety of reasons: transfers, lay-offs, illness, etc. Information is not available to identify these reasons for particular trainees. Trainees with as few as two tests are included in the analysis.

Table XLIX presents the results for this course. While the difference between age groups is not very large, the direction of results is consistent with the hypothesis that the older workers do less well than the younger. Controlling for education does not appreciably change the pattern of results.

XLIX. Course Three: Basic Electronics (Technical Writers). Percent of trainees who received relatively high and low average grades as a function of various independent variables.

A. Age

Grade	32-40	41+
Good	53	42
Poor	47	58
	100%	100%
N =	19	19

B. Seniority

Grade	0-11	12+
Good	50	47
Poor	50	53
	100%	100%
N =	18	19

C. Education

Grade	8-12	13+
Good	44	55
Poor	56	45
	100%	100%
N =	25	11

D. Age: Education held constant

Grade	32-40	41+
Good	57	47
Poor	43	53
	100%	100%
N =	14	19

Course Four: Electronic Technician Transition and Development

The previous courses have been concerned with "updating" the skills of trainees. Training affected only part of the total job of the trainee; no immediate differences in pay or job title came about as a result of the training. The present course is designed to prepare employees for an entirely new job created by the increased use of electronic equipment in the division. Essentially, the job involves the maintenance and repair of advanced electronic apparatus. Shortly after completion of the training the men were assigned the new title of "Industrial Electronics Technician" and received a pay increase of roughly 15¢ per hour.

In selecting trainees for the course, some fifty men holding the position of "Maintenance Electrician" were given a screening examination on electricity and elementary electronics. This exam assessed their knowledge of AC and DC circuits, vacuum tubes, and transistors; in addition, mathematical questions (through basic algebra) were asked.

The twenty highest scoring individuals on the screening examination were taken into training. All but seven of these men had some previous contact with the maintenance of the less complicated types of electronic equipment. The twenty trainees were divided into two classes of ten each. Two men subsequently left the course. One individual dropped because of illness, while another was promoted to a higher paying job while in the course.

Training took place in the three and one-half morning hours of the work day, five days a week, for four months. (The second group had forty hours less training than the first, due to the experience gained by the trainers in consolidating the material of the course.)

The course involved lecture presentation of electronic theory at a detailed level, and laboratory work with the test equipment and components which would be used on the job. The training task was primarily intellectual, although a certain amount of manual dexterity and fine sensori-motor coordination was required.

Written examinations and graded laboratory exercises were used to assess the performance of the trainees. An average of some fifteen such grades are used in the analysis.

The trainers report that older men in the course (especially one, age 61) tend to do less well on the mathematical aspects of the training, but that they have a valuable backlog of experience which aids them in trouble-shooting. Older men are also reported to have trouble in making the fine adjustments which are necessary. In general, the instructors indicated that they would hesitate for these reasons to take a man age 55 or older into this course.

Chart 12 shows the age distributions of trainees in Course Four.

Chart 12

Age Distribution of Trainees in the "Electronic Technician Transition and Development" Course

Age	f
18-24	1
25-34	6
35-44	9
45-61	2
	18

The relationships found in this course are displayed in Table L. Although the number of cases is small, the direction of results suggests that the older trainees do less well in the course than the younger ones. However, this direction of results seems explicable in terms of the educational advantage which the younger trainees possess. When education is controlled, older workers do not seem to do less well than the younger. The apparent reversal of direction in Table L is probably due to the strong relationship between age and education for this group. Chart 13 indicates the relationship between age and education found here.

Chart 13

Per Cent of Older and Younger Trainees in Two Education Classifications

		Age 23-35	Age 36-61
Years of Formal Education	8-11	13	44
	12-15	87	56
		100%	100%
	N =	8	9

L. Course Four: Electronic Technician Transition and Development
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

A. Age

Grade	23-35	36+
Good	67	33
Poor	33	67
	100%	100%
N =	9	9

B. Seniority

	0-6	7+
Good	67	33
Poor	33	67
	100%	100%
N =	9	9

C. Education

Grade	8-11	12+
Good	40	50
Poor	60	50
	100%	100%
N =	5	12

D. Age: Education held constant

	23-35	36+
Good	33	62
Poor	67	38
	100%	100%
N =	6	8

Course Five: Blueprint Reading

This course was given to machinists. It was designed to increase their skill in reading blueprints.

The machinists had been experiencing difficulty in analyzing the prints for one of the new weapon systems being constructed in the division. Consequently, their general foreman requested the training department to initiate a course in print reading.

The general foreman selected the men who would attend the course. In part, his decision was based on performance on an initial examination in print reading that was developed and administered by the training department.

The course lasted two hours a day for seven days, or a total of fourteen hours. The trainees carried on their regular work duties when not attending the course. The age distribution of trainees in Course Five is shown in Chart 14.

Chart 14

Age Distribution of Trainees in
The "Blueprint Reading" Course

Age	f
18-24	1
25-34	4
35-44	2
45-61	10
	17

With regard to content, the course consisted of explanations of the various symbols used in blueprints, and the manner in which the symbols should be translated into the final product.

Two examination scores are available. Test I is the screening examination mentioned above, which was given before training began. Test II is the final (and only) examination in the course. These exams are concerned essentially with the interpretations of blueprints.

Table LI presents the data for this course. Although the number of cases is small, the direction of results for Test I apparently favors the younger workers. However, this is <u>not</u> true for Test II. Furthermore, when education is held constant, older workers do not seem to do less well in training than younger workers.

LI. Course Five: Blueprint Reading.
Percent of trainees who received relatively high and low average grades as a function of various independent variables.

A. Age

Test I Grade	20-49	50+
Good	78	25
Poor	22	75
	100%	100%
N =	9	8

B. Education

Test I Grade	4-11	12+
Good	50	57
Poor	50	43
	100%	100%
N =	10	7

C. Age

Test II Grade	20-49	50+
Good	44	50
Poor	56	50
	100%	100%
N =	9	8

D. Seniority

Test II Grade	0-7	8+
Good	56	37
Poor	44	63
	100%	100%
N =	9	8

E. Education

Test II Grade	4-11	12+
Good	40	57
Poor	60	43
	100%	100%
N =	10	7

F. Age: Education held constant

Test II Grade	20-49	50+
Good	57	67
Poor	43	33
	100%	100%
N =	6	6

Course Six: Welding

Changes in welding technology made necessary several courses for welders.

There are two major reasons for the changes in welding technology. The first is the use of new, exotic metals; among these are alloys of titanium, zirconium, Rene 41, and PH15-7HO. In addition, very light gauge steels are sometimes used. Conventional welding technology cannot be applied to these metals. The second reason is the introduction of very critical dimensional requirements both with respect to weld size and to overall assembly dimensions. The small margin of error is illustrated by the facts that (1) two metal tubes welded together end to end must not differ from an overall specified length by more than ten ten-thousandths of an inch; (2) geometric planes of plates welded together must not exceed a two degree angle.

As many as 70% of welds may be X-rayed for defects. It should be noted that due to the cost of materials, mistakes in welding can be very expensive.

In general, the new process which the welder employs is more complex than the old. This fact has several implications.

A. Welders must know the technology of gases and have some competence in metallurgy. For example, they must know what brings about distortions in metals in order to prevent their occurrence. Formerly, a warped section might be straightened with a hammer. This degree of crudeness cannot be tolerated today.

B. The welding equipment itself is more complex. The welder must attend to a larger number of variables in achieving the proper regulation of temperature, gas flow, and speed of weld.

C. The complexity of the process sometimes creates "tooling problems" (i.e., obstacles placed in the way of the welder). For example, (a) he may have to get into awkward positions; (b) the materials being welded may be entirely enclosed in a plastic envelope filled with an inert gas; the welder must weld through this enclosure; and (c) the entire section being welded may be maintained at a temperature of 600 degrees F. In this case the welder must wear special protective equipment.

D. The increased complexity referred to above requires not only mental comprehension, but increased amounts of physical coordination as well. In some cases the simultaneous use of four limbs may be required: one hand to hold the torch, a second to feed the welding filler, one foot to govern the movement of the material being welded, and the second to regulate amperage which must be changed as the weld proceeds.

E. New blueprint symbols must be learned.

Training is designed to provide welders with (1) the theory and background of the new welding methods; (2) familiarization with the new equipment to be worked on; and (3) familiarization with the new welding processes and welding techniques. The training involves about 20% classroom lecture and discussion, and 80% practice. In the "practice" section of the training, trainees are assigned standardized test jobs. Their performance on these jobs is carefully measured and appraised. A final performance score is assigned each trainee according to the number of hours he needs to meet standards set by the United States Air Force.

Considerable variation exists in the number of hours required by trainees to meet standards. Some may complete the course in as few as twenty hours, while others may require one hundred and twenty hours. Such wide variation is explained in part by the differences in experience which trainees may have prior to training.

Trainees may "flunk out" if it becomes obvious after several tests that they will not be able to meet Air Force requirements within a reasonable time.

The majority of trainees have been associated with welding, but not all have been working primarily as welders. Welding was not classified by the Company as a skill or craft in the past. As a result of the requirements of the new technology, however, welding has achieved official recognition as a craft. The title "weldor" has been created to signify this new job-classification. Trainees who successfully complete the training courses are certified as weldors. Such certification is potentially of use outside the Company as well as within it. The union has been instrumental in achieving the new classification. However, the union played no part in training nor in selecting workers for training. The new and higher labor grade for welders has raised the status of welding in the union-management agreement; a higher pay rate has been a result of the new classification.

Workers may either apply for training on a voluntary basis, or they may be recommended by their supervisors. They are selected on the basis of their performance on a preliminary welding test. Age may be a consideration in the selection of trainees: for example, if an applicant is over 55, he may be given an eye examination if this is considered necessary.

The new methods of welding were first introduced in 1946. The Company had approximately 125 persons engaged in welding at that time. Since 1946 approximately 90% of these people have been retrained. At present approximately 240 persons are engaged in welding; approximately 200 of these are in the classification of "weldor."

The data to be presented below cover four training courses. Course 6-A deals with metallic arc welding; Courses 6-B and 6-C are concerned with two slightly different methods of inert gas welding; Course 6-D deals with an inert gas process for welding titanium. The age distributions in the four courses are shown in Chart 14.

Chart 14

Age Distributions of Trainees in The Welding Courses

Age	Course 6-A: Metallic Arc	Course 6-B: Inert Gas I	Course 6-C: Inert Gas II	Course 6-D: Titanium
.... - 24	--	--	--	1
25 - 34	3	2	8	3
35 - 44	11	5	8	7
45 - 50	10	2	1	2
	24	9*	17**	13

*One trainee in Course 6-B also took Course 6-A
**One trainee in Course 6-C also took Course 6-B

Table LII presents the length of time taken by trainees to achieve certification. Since the age distributions differ somewhat among the courses, it is necessary to dichotomize differently from one to another.

Table LII

Percent of Older and Younger Welding Trainees Above and Below the Median Times Required for Certification in Four Courses

A. Course 6-A: Metallic Arc

		Age	
		27-44	45-50
Hours Needed to Achieve Certification	16-70	64	40
	71-140	36	60
		100%	100%
	N =	14	10

B. Course 6-B: Inert Gas I

	Age	
	30-40	41-47
8-37	75	40
37-104	25	60
	100%	100%
N =	4	5

C. Course 6-C: Inert Gas II

		Age	
		25-35	36-48
Hours Needed to Achieve Certification	18-50	50	56
	51-107	50	44
		100%	100%
	N =	8	9

D. Course 6-D Titanium

	Age	
	24-39	40-51
8-25.5	43	50
26-48	57	50
	100%	100%
N =	7	6

Only two of the four courses give results which are consistent in direction with the hypothesis that the older workers do less well than the younger. However, the above table does not consider the judgments made by instructors at the outset of training regarding how many hours each trainee should require for retraining. This judgment was essentially an estimate of the relevant experience which trainees had prior to training. It was assumed that trainees high in experience would qualify after less training than trainees with little experience. These judgments are available for trainees in only one of the courses--Course 6-D, Titanium Welding. Table LIII shows the relationship between age and performance in terms of the number of hours needed to qualify when relevant experience (as estimated by the instructors) is held constant. The results suggest that when relevant experience is controlled, older workers do less well than the younger.

Table LIII

Percent of Older and Younger Trainees in Course 6-D (Titanium) Who Perform Relatively Well and Relatively Poorly When Previous Experience is Held Constant

		Age	
		24-39	40-51
Performance	Good	57	33
	Poor	43	67
		100%	100%
	N =	7	6

Since education does not relate to age for the trainees in the welding courses, controlling for education does not appreciably alter the above pattern of results.

IV. An Airline

The introduction of turbine and jet aircraft into commercial operation involved a major technological change in the air transportation industry. The industry is accustomed to fairly rapid turnover in equipment, to a degree not common in many other industries. The shift to jets, however, fell outside the limits of "normal" change.

Our data come from one Company in the industry. The information deals with one of the many areas affected by the change: the modifications in aircraft overhaul and maintenance.

A. Background Information

The site providing the information in this section is the Central Maintenance Facility of one of the nation's largest airlines. The company as a whole employs some 27,000 people across the country. The Central Maintenance Facility employs approximately 4,300 individuals, of which 2,350 are mechanics (of varying job-levels and pay rates). The Facility is located in one of the larger metropolitan areas of a south western state.

Retraining data are available for some 1,200 individuals. All were men working in the maintenance and overhaul operations of the Facility. Roughly 200 of the workers took two or more courses; approximately 1,500 course grades are therefore available for the group. About 1,200 of the grades come from "Overhaul" courses; the rest come from "Maintenance" courses.

B. The Change

The most general statement that can be made about the commercial jet aircraft is that it is a more complex, refined, and demanding machine than the piston plane. The specifications used throughout the jet are much more rigid than in the older type; the various control systems (electrical and hydraulic) are more complex; the permissible amount of error is smaller. The difference is well indicated by the relative costs of the two planes: a jet airliner costs about five million dollars, with an addition million of ground equipment; a large piston plane costs about one million dollars, plus twenty thousand dollars of ground equipment.

Two examples may help illustrate the increased complexity of the jet plane. (1) The electrical circuit in the piston plane is a 28 volt DC system. In the jet, the circuit is basically a 220 volt AC system; in addition, some parts of the circuit are 110 AC, while still other parts employ the lower DC voltage. Beyond the additional knowledge and skill needed to cope with this system, the physical hazards of maintaining and overhauling the jet's electrical system are increased. (2) The hydraulic system provides a second example of the jet's increased complexity. On the old aircraft a 2,000 psi system is used. The jet uses a 3,000 psi system. The precision required in working on the newer system is considerably greater than on the old. More care also must be taken in order to insure a greater degree of cleanliness when working on the jet's hydraulic system.

It is important to note that the actual physical abilities and manual skills needed by a maintenance or overhaul worker are not much different for the two types of planes. An important aspect of the training for the new tasks is the acquisition of knowledge. Intellectual capacity is therefore relevant to developing the skills necessary to handle the new equipment. This is not meant to imply, however, that the new jobs require more intelligence than the old.

Retraining was necessary for two reasons: (1) the mechanics had to learn about the jet planes _per se_; (2) the maintenance and overhaul of the jets required the use of special tools and instruments. In addition to these reasons, continuing modifications in the aircraft _and_ in the maintenance and overhaul equipment necessitate further courses. Finally, _refresher_ courses are given to men who had been trained on jets but who had not worked on them for some time.

C. Introducing the Change

The change was introduced gradually. Two jets were received by the Airline to begin with; this number gradually increased to about thirty planes. Consequently, only a small number of the Facility's personnel were needed to work on the jets when they were first introduced. For this group the introduction of the jets required a rapid transition. Furthermore, the early training courses were started before delivery of the jet planes; this created some difficulty in training.

The proportion of employees qualified for the new work increased with time. About 95% of the employees are now qualified to work on jet aircraft.

Information about the change to jets was circulated both formally and informally within the Company prior to their arrival; in addition, an extensive advertising campaign preceded the introduction of the jets into commercial service.

The union agreement specifies that employees with the highest seniority be trained first. The agreement also states that an employee must receive at least seven days notice before the start of his particular training course. With these exceptions, the union had no part in planning for nor in implementing the change.

Training does not affect job classifications directly.

D. The Retraining Courses

The Training Department administered the training program. Vendor training was used occasionally when training on a particular aspect of the aircraft was needed immediately, and when the training staff was not yet qualified to provide this training. More often, a training staff man would go to the manufacturer to familiarize himself with the course material; he would then organize the course, submit a training proposal to the department requesting the training, and finally teach the course.

Date is available for over 200 courses dealing with every aspect of airplane maintenance and overhaul. The courses range from relatively brief "familiarization" sessions to courses covering in detail the most technical aspects of the plane. The courses for which examination grades are available range from six hours to 260 hours in duration.

In general, the courses take the following form. First, the equipment which is to be treated in the course is described. Second, pictures and other visual aids are used to illustrate the procedures employed in servicing the equipment. Both these phases occur in a classroom setting, and essentially on a lecture basis. In the next part of the course, in-service equipment is serviced. For courses concerned with overhaul operations, for instance, the equipment comes from a plane that is currently being overhauled. Upon completion of the operation, the equipment is tested on the appropriate testing devices and put into service on the plane from which it was taken.

The trainees receive grades from one or more written examinations which cover the material of the course. The examinations usually include multiple choice, true-false, and "fill-in" questions.

Each course is usually limited to ten or fewer individuals. In cases in which more than ten individuals had to be trained on a specific subject-matter, successive courses are given.

For analysis purposes, the courses have been divided into six different "levels" on the basis of how many hours are allotted for the course. Within each level, a wide variety of courses is taught. However, the difficulty of the courses can be considered fairly constant within levels since difficulty is primarily a function of the amount of material covered, rather than a function of the subject matter. Consequently, the six levels may be regarded as representing six levels of course difficulty. Chart 15 indicates the ranges in hours of courses within each level.

Chart 15

Number of Hours of Courses
Within Each Level

Level	Hours
1	6.0 - 8.0
2	8.5 - 24.0
3	26.0 - 40.0
4	40.5 - 80.0
5	80.4 - 160.0
6	164.0 - 284.0

With the exception of the above-mentioned successive courses covering the same material, each course covers different subject matter.

Chart 16 shows the median ages of trainees in courses within each level.

Chart 16

Distribution of Median Ages of
Trainees in Courses by Levels, in Percents

Median Age	1	2	3	4	5	6	Total
25-29	---	---	4.5	6.1	9.5	7.4	4.8
30-34	---	15.6	20.0	12.2	47.7	14.8	17.5
35-39	12.5	33.3	28.8	48.8	33.3	40.8	38.2
40-44	75.0	35.5	35.6	25.6	9.5	37.0	31.1
45-49	12.5	15.6	11.1	4.9	---	---	7.5
50-55	---	---	---	2.4	---	---	0.9
	100%	100%	100%	100%	100%	100%	100%
$N_{courses}$ =	8	45	45	82	21	27	228
$N_{individuals}$ =	39	286	268	476	140	140	1349

Because of the large number of courses, no attempt will be made to identify any particular course. However, a few course titles are listed below, in order to illustrate the general nature of the training. The hours allocated for the course and its level are also indicated in Chart 17.

Chart 17

Representative Course Titles

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

Tables LIV and LV present summaries of the relationships between age and performance on the course examination(s). In both tables, the datum is a course, rather than individuals in a course. The large number of courses (over 200) together with the small number of trainees within each course (about six, on the average) dictated the following methods of analysis. Each course is examined in terms of whether the older 50% of workers within it tend to fall above the median course grade more often, equally often, or less often than the younger workers. Courses in which the total range in grades is less than five points, and/or the total range of ages is less than five years are not included. The results of this analysis for courses within each level are shown in Table LIV. Second, the frequencies with which the grade of the oldest worker in each course falls among the upper 50% of grades in that course is computed, together with the corresponding frequency for the youngest worker. Cases in which two persons share the role of oldest (or youngest) worker and in which these persons fall into different halves of the grade distribution are dropped from the analysis. The data are shown in Table LV.

The general trend of the data suggest that older workers do less well in those aspects of the training courses which are measured by the written tests. Unfortunately, data are not avilable concerning the educational background of the trainees. It seems reasonable to expect, however, that the older workers suffer some educational disadvantage; this may contribute to the above differences.

LIV.. An Airline. Percent of courses in which the relationship between age and performance is positive, zero, or negative.

	Positive	Zero	Negative	Total Percent	N Courses	N Individuals
Level 1	75.0	12.5	12.5	100%	8	39
Level 2	20.0	11.1	68.9	100%	45	286
Level 3	28.8	4.5	66.7	100%	45	268
Level 4	29.3	15.9	54.8	100%	82	476
Level 5	23.8	14.3	61.9	100%	21	140
Level 6	33.3	18.5	48.2	100%	27	140
				TOTAL	204	1349

LV. An Airline. Percent of courses in which the oldest and youngest trainees are above or below the median grade.

Level 1

	Youngest Trainee	Oldest Trainee
Above Median	57	75
Below Median	43	25
	100%	100%
N =	7	8

Level 2

	Youngest Trainee	Oldest Trainee
Above Median	76	31
Below Median	24	69
	100%	100%
N =	42	42

Level 3

	Youngest Trainee	Oldest Trainee
Above Median	72	33
Below Median	28	67
	100%	100%
N =	39	42

Level 4

	Youngest Trainee	Oldest Trainee
Above Median	57	39
Below Median	43	61
	100%	100%
N =	75	75

Level 5

	Youngest Trainee	Oldest Trainee
Above Median	72	31
Below Median	28	69
	100%	100%
N =	18	19

Level 6

	Youngest Trainee	Oldest Trainee
Above Median	61	50
Below Median	39	50
	100%	100%
N =	23	22

V. General Summary

1. Older workers tend on the average to perform less well in training than younger workers. This seems to apply to retraining tasks which involve very simple and routine mechanical skills as well as to tasks which place a heavy emphasis on intellectual skills.
2. Although older workers perform less well on the average than younger workers, a great deal of overlap between groups is apparent. Many older workers do as well as many younger workers; some do better. Furthermore, the relationship between age and performance does not apply to all of the courses included in this study. In a number of courses, no difference is found.
3. Chart 18 is a summary of results in three of the four research sites: the Telephone Company, the Oil Refinery, and the Aircraft Manufacturing Company. Part 1 of the chart indicates the number of performance measures in which the direction of results favors the older trainees, the younger trainees, or neither. Part 2 provides the results of this directional analysis in relation to performance measures corrected for the educational level of trainees. Results from the airline are not shown since data on education are not available.

These data suggest that education is an important factor in the learning of new tasks brought about by technological change. One of the reasons that older workers may be doing less well in training is that they are at an educational disadvantage. When education is equated for older and younger workers in training courses involving strong intellectual components, the older worker is more likely to perform as well as the younger. Attention should be given in further research to the implication of education (in its various forms) for the adaptability of workers to technological change.

Chart 18

Number of Training Performance Measures
On which Older Workers do Less Well,
Better, or the Same as Younger Workers

1. Education not held Constant

Measures on Which Older Workers Do:	Telephone Company	Oil Refinery	Aircraft Manufacturing Company	Total N	Total %
Less Well	7	11	6	24	80
Better	1	2	3	6	20
The Same as Younger Workers	--	--	--	--	--
					100%
Number of Measures	8	13	9	30	
Number of Trainees	629	82*	235	946	

2. Education Equated for Older and Younger Workers

Measures on Which Older Workers Do:	Telephone Company	Oil Refinery	Aircraft Manufacturing Company	Total N	Total %
Less Well	7	5	3	15	56
Better	---	5	4	9	33
The Same as Younger Workers	1	2	---	3	11
					100%
Number of Measures**	8	12	7	27	
Number of Trainees**	601	81	182	864	

*Instrumentation Trainees are not included in this total.

**The N's are slightly less than in Part 1 of this Chart because of lack of information on education for specific trainees. Three courses were eliminated because information on education was lacking for most of the trainees in those courses.

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