# Quality Control of Preparatory Operations, Microfilming, and Coding

## I. INTRODUCTION

From the standpoint of production, the Bureau of the Census in the conduct of mass statistical programs operates in a manner similar to a manufacturing establishment. It is directly engaged in the employment of resources, both human and machine, to produce an end product—statistical tabulations and tables.

The major statistical program conducted by the Bureau is the decennial census authorized by the Constitution of the United States. Article 1, Section 2, of the Constitution provides that "the actual enumeration shall be made within three years after the first meeting of the Congress of the United States and within every subsequent term of ten years, in such a manner as they shall by law direct." The decennial census provides population counts which are used to determine the number of representatives to which each State is entitled in the House of Representatives of the U.S. Congress. It also provides a range of social and economic information on the distribution, composition, and activities of the population—income, migration, urban-rural distribution, labor force participation, years of school completed, and others—and on its housing.

The 1960 Censuses of Population and Housing required processing of data on enumeration schedules representing about 54 million households including some 180 million persons in about 272,000 enumeration districts. In addition, sample schedules representing about 45 million persons were processed.

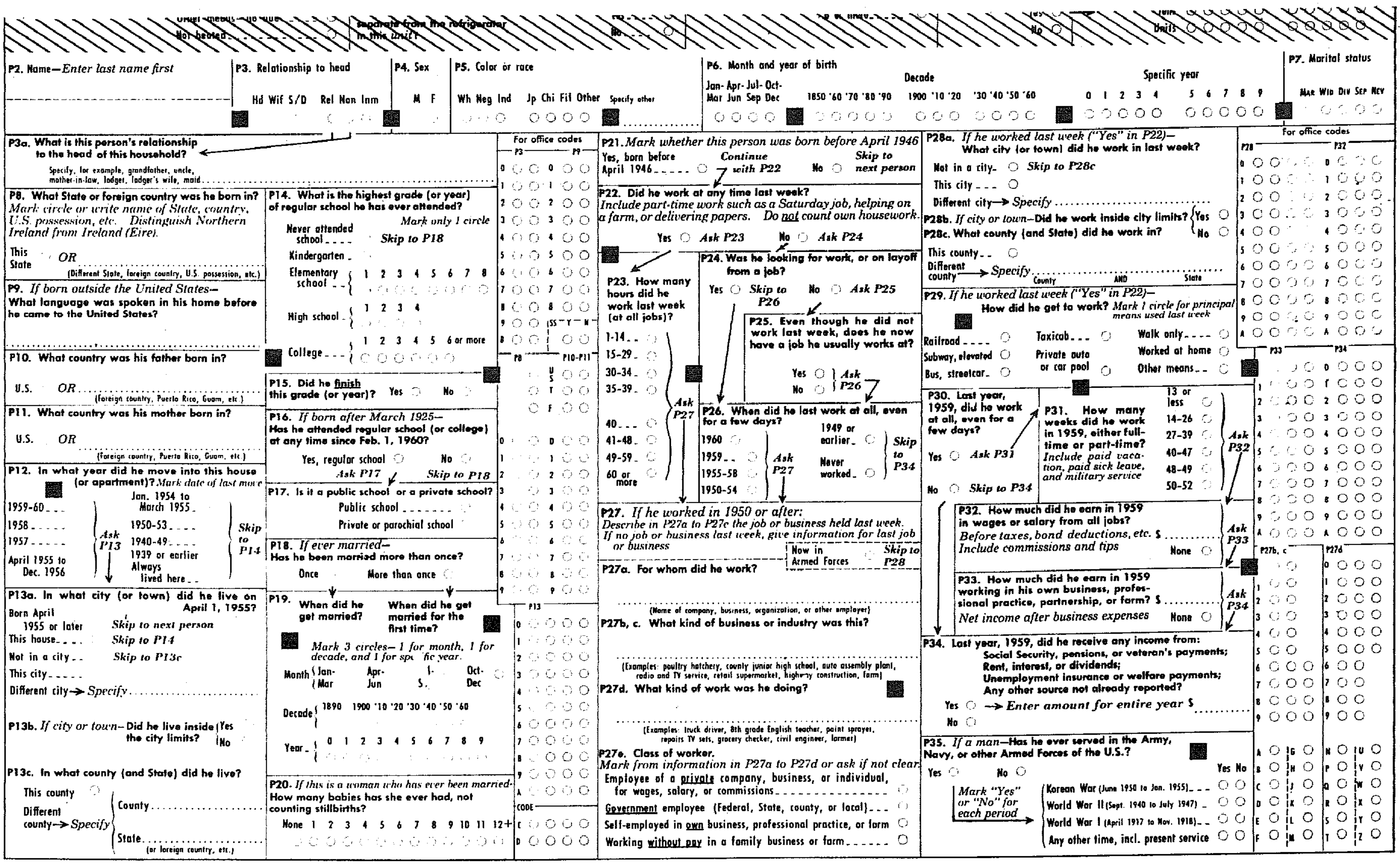
As a result of the effective use of new techniques, the U.S. Summary report on "Number of Inhabitants" for the 1960 Census of Population was issued in June 1961, nine months ahead of the comparable publication date of the 1950 census, and other reports were typically advanced in publication date by 6 to 18 months. These techniques were: (1) use of sampling to collect about three-fourths of the information obtained in the censuses, including all items that called for manual coding before tabulation; (2) enumeration of the population on two separate schedules, one for the 100-percent data and a second schedule for the sample data, so that the 100-percent data could be processed and published while the sample data were being coded; (3) the use of FOSDIC, a high-speed electronic device, as a means for direct transfer of data from microfilm of the enumerated schedules to magnetic tape; and (4) the use of electronic computers for processing the data, and high-speed printers for printing out the data from magnetic tape directly onto sheets which could be used as reproduction copy for printing and publication.

In 1960, a two-stage approach was used in the enumeration of about 80 percent of the population and housing units—the first stage for items of information collected on a 100-percent basis, i.e., for all households and housing units in the enumeration district (ED), and the second stage for items collected for a sample of households and housing units. The other 20 percent of the population and housing units, in less densely settled areas of the country, were enumerated in a single stage; both the 100-percent and sample information were obtained when the enumerator made his canvass of every household and housing unit in the ED. By April 1, 1960, the Post Office Department had delivered to each household a questionnaire called an Advance Census Report which contained the questions asked on a 100-percent basis and which was to be filled in and held until an enumerator visited the household. When the enumerator called on the household, he transcribed the information from the Advance Census Report to the official census schedule. In two-stage areas, as the enumerator made his round to collect stage I information he left a Household Questionnaire at every fourth household, to obtain further and more detailed information about a 25-percent sample of households and housing units. The respondent was asked to complete this second form and to mail it to the local census office in the postage-free envelope supplied him. When the questionnaire was received in the census office, an enumerator transcribed the information from the Household Questionnaire to the official schedule. He reviewed the information furnished by the respondent, and, if necessary, completed or corrected it, getting additional information by personal visit or by telephone.

The official census schedules filled by the enumerators were especially prepared for processing on an electronic machine which was developed by the U.S. Bureau of Standards and the Bureau of the Census. This machine, the Film Optical Sensing Device for Input to Computers, or FOSDIC, reads information from microfilm of specially printed and marked schedules and transfers the data to magnetic tape which can be processed by high-speed computers. On these specially designed census schedules, known as FOSDIC schedules, most of the information was recorded by filling in the appropriate circles (see illustration 1).

The use of high-speed electronic equipment such as FOSDIC and the computers resulted in saving time and money in the conduct of the large-scale data processing required for the 1960 censuses. Manual punching of cards, as well as the need for transferring data from card to tape, were eliminated except for some small special jobs. However, making effective use of high-speed equipment, as well as the primary need for acceptable quality of final results, imposed strict standards on the quality of input fed into the machine. Consequently, the tools of quality control assumed great importance in the whole data-processing operation.

A sequence of controls was established to assure that the quality of the printed schedule itself and the image of it reproduced on microfilm met the specifications for the successful operation of FOSDIC. The printing of census schedules and the assembly and binding of the schedules into enumeration books was controlled carefully in order to minimize the failures of FOSDIC to adjust on index marks, to read circles, or to read whole frames. The microfilming of census schedules containing information from the enumeration was controlled to make sure that meaningful marks on the schedules showed up sufficiently on the microfilm to enable FOSDIC to read them, and to avoid reprocessing of a large volume of information, which would have increased costs considerably and would have set back the time schedule for completion of the job.



P2. Name—*Enter last name first*

P3. Relationship to head: Hd Wif S/D Rel Non Inm

P4. Sex: M F

P5. Color or race: Wh Neg Ind Jp Chi Fil Other Specify other

P6. Month and year of birth: Jan-Apr-Jul-Oct- Mar Jun Sep Dec; Decade 1850 '60 '70 '80 '90 1900 '10 '20 '30 '40 '50 '60; Specific year 0 1 2 3 4 5 6 7 8 9

P7. Marital status: Mar Wid Div Sep Nev

P3a. What is this person's relationship to the head of this household? Specify, for example, grandfather, uncle, mother-in-law, lodger, lodger's wife, maid.

P8. What State or foreign country was he born in? *Mark circle or write name of State, country, U.S. possession, etc. Distinguish Northern Ireland from Ireland (Eire).* This State OR (Different State, foreign country, U.S. possession, etc.)

P9. *If born outside the United States*—What language was spoken in his home before he came to the United States?

P10. What country was his father born in? U.S. OR (Foreign country, Puerto Rico, Guam, etc.)

P11. What country was his mother born in? U.S. OR (Foreign country, Puerto Rico, Guam, etc.)

P12. In what year did he move into this house (or apartment)? *Mark date of last move* 1959-60; 1958; 1957; April 1955 to Dec. 1956 — *Ask P13*; Jan. 1954 to March 1955; 1950-53; 1940-49; 1939 or earlier; Always lived here — *Skip to P14*

P13a. In what city (or town) did he live on April 1, 1955? Born April 1955 or later — *Skip to next person*; This house — *Skip to P14*; Not in a city — *Skip to P13c*; This city; Different city→*Specify*

P13b. *If city or town*—Did he live inside the city limits? Yes No

P13c. In what county (and State) did he live? This county; Different county→*Specify* County; State (or foreign country, etc.)

P14. What is the highest grade (or year) of regular school he has ever attended? *Mark only 1 circle* Never attended school — *Skip to P18*; Kindergarten; Elementary school 1 2 3 4 5 6 7 8; High school 1 2 3 4; College 1 2 3 4 5 6 or more

P15. Did he finish this grade (or year)? Yes No

P16. *If born after March 1925*—Has he attended regular school (or college) at any time since Feb. 1, 1960? Yes, regular school — *Ask P17*; No — *Skip to P18*

P17. Is it a public school or a private school? Public school; Private or parochial school

P18. *If ever married*—Has he been married more than once? Once; More than once

P19. When did he get married? When did he get married for the first time? *Mark 3 circles—1 for month, 1 for decade, and 1 for specific year.* Month Jan-Mar Apr-Jun Jul-Sep Oct-Dec; Decade 1890 1900 '10 '20 '30 '40 '50 '60; Year 0 1 2 3 4 5 6 7 8 9

P20. *If this is a woman who has ever been married*—How many babies has she ever had, not counting stillbirths? None 1 2 3 4 5 6 7 8 9 10 11 12+

For office codes: P3, P9, P8, P10-P11, P13, CODE

P21. *Mark whether this person was born before April 1946* Yes, born before April 1946 — *Continue with P22*; No — *Skip to next person*

P22. Did he work at any time last week? *Include part-time work such as a Saturday job, helping on a farm, or delivering papers. Do not count own housework.* Yes — *Ask P23*; No — *Ask P24*

P23. How many hours did he work last week (at all jobs)? 1-14; 15-29; 30-34; 35-39; 40; 41-48; 49-59; 60 or more — *Ask P27*

P24. Was he looking for work, or on layoff from a job? Yes — *Skip to P26*; No — *Ask P25*

P25. Even though he did not work last week, does he now have a job he usually works at? Yes / No — *Ask P26*

P26. When did he last work at all, even for a few days? 1960; 1959; 1955-58; 1950-54 — *Ask P27*; 1949 or earlier; Never worked — *Skip to P34*

P27. *If he worked in 1950 or after: Describe in P27a to P27c the job or business held last week. If no job or business last week, give information for last job or business* Now in Armed Forces — *Skip to P28*

P27a. For whom did he work? (Name of company, business, organization, or other employer)

P27b, c. What kind of business or industry was this? (Examples: poultry hatchery, county junior high school, auto assembly plant, radio and TV service, retail supermarket, highway construction, farm)

P27d. What kind of work was he doing? (Examples: truck driver, 8th grade English teacher, paint sprayer, repairs TV sets, grocery checker, civil engineer, farmer)

P27e. Class of worker. *Mark from information in P27a to P27d or ask if not clear.* Employee of a private company, business, or individual, for wages, salary, or commissions; Government employee (Federal, State, county, or local); Self-employed in own business, professional practice, or farm; Working without pay in a family business or farm

P28a. *If he worked last week ("Yes" in P22)*—What city (or town) did he work in last week? Not in a city — *Skip to P28c*; This city; Different city→*Specify*

P28b. *If city or town*—Did he work inside city limits? Yes No

P28c. What county (and State) did he work in? This county; Different county→*Specify* County AND State

P29. *If he worked last week ("Yes" in P22)*—How did he get to work? *Mark 1 circle for principal means used last week* Railroad; Subway, elevated; Bus, streetcar; Taxicab; Private auto or car pool; Walk only; Worked at home; Other means

P30. Last year, 1959, did he work at all, even for a few days? Yes — *Ask P31*; No — *Skip to P34*

P31. How many weeks did he work in 1959, either full-time or part-time? *Include paid vacation, paid sick leave, and military service* 13 or less; 14-26; 27-39; 40-47; 48-49; 50-52 — *Ask P32*

P32. How much did he earn in 1959 in wages or salary from all jobs? *Before taxes, bond deductions, etc.* $ *Include commissions and tips* None — *Ask P33*

P33. How much did he earn in 1959 working in his own business, professional practice, partnership, or farm? $ *Net income after business expenses* None — *Ask P34*

P34. Last year, 1959, did he receive any income from: Social Security, pensions, or veteran's payments; Rent, interest, or dividends; Unemployment insurance or welfare payments; Any other source not already reported? Yes →*Enter amount for entire year* $; No

P35. *If a man*—Has he ever served in the Army, Navy, or other Armed Forces of the U.S.? Yes No. *Mark "Yes" or "No" for each period* Korean War (June 1950 to Jan. 1955); World War II (Sept. 1940 to July 1947); World War I (April 1917 to Nov. 1918); Any other time, incl. present service

For office codes: P28, P32, P33, P34, P27b, c, P27d

GPO : 1959 OF—516133

Figure 1.— FOSDIC Schedule for Sample Data (Population Panel)

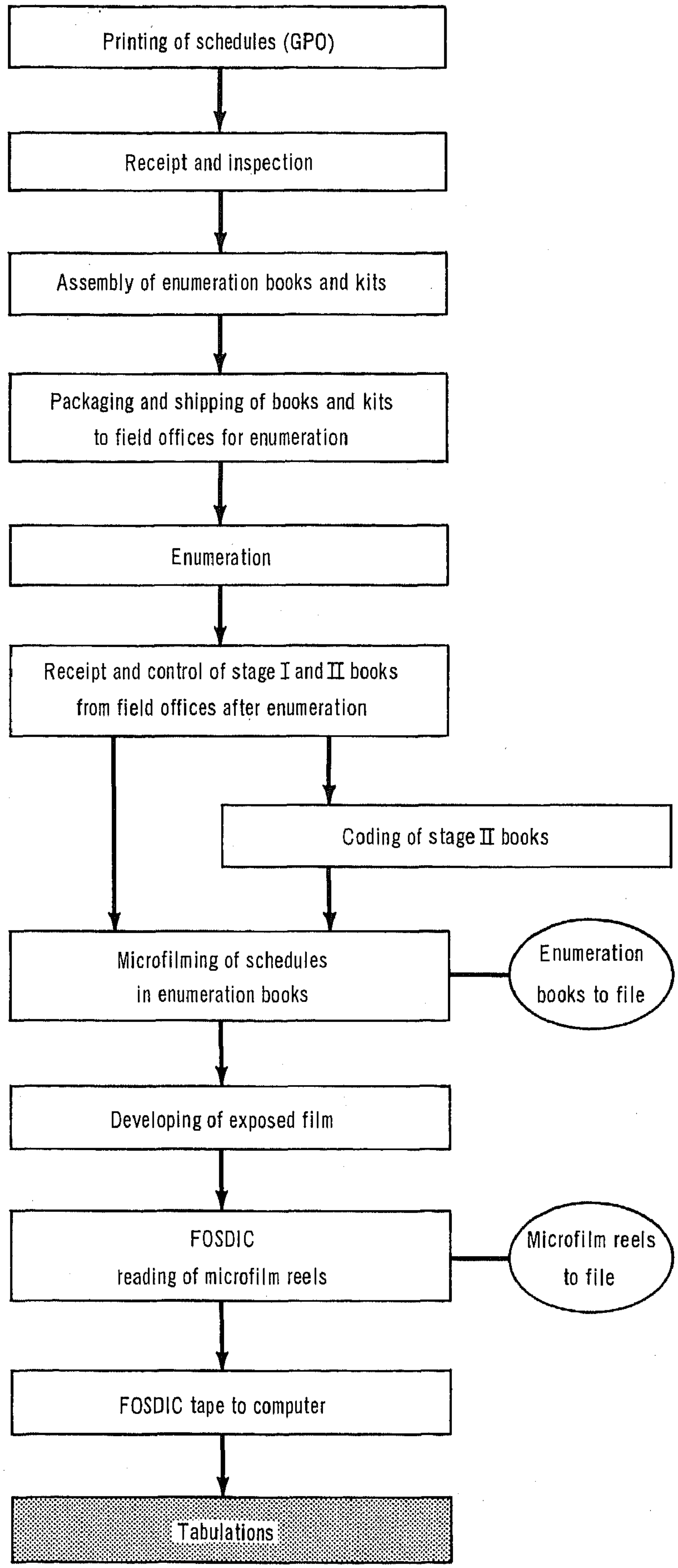



**Figure 2.—Flow Chart of Major Processing Operations for the 1960 Censuses of Population and Housing**

Quality control programs described in this report[1] are confined to those for the following operations:

1. Preparatory operations, (a) the printing of census schedules, (b) the assembly and binding of the schedules into enumeration books, and (c) the preparation and assembly of materials into enumerator portfolios and crew leader kits for shipment to field offices.

2. Microfilming operations, which included the filming of census data recorded in enumeration books and the shipment and development of the microfilm.

3. Coding of responses on some of the characteristics of persons enumerated in the sample.

## II. QUALITY CONTROL OF PREPARATORY OPERATIONS

Quality control plans were instituted in three major areas of preparatory operations for the 1960 census enumeration: (1) the printing of FOSDIC schedules, (2) their assembly into enumeration books for use by the enumerators, and (3) the preparation and assembly of portfolios and kits of material for enumerators and crew leaders, respectively, for use in their training and in the field enumeration.

For the first, the quality control procedures were designed to provide assurance that the quality of enumeration books conformed to the specifications required for processing the census data on FOSDIC. For the second, quality control procedures were to provide assurance that portfolios and kits of material to be used by enumerators and crew leaders contained the correct type and quantity of materials.

The printing and bookbinding job, which involved producing more than 956,000 enumeration books, may be viewed as a sequence of related production processes. The work in process at each stage of production became the input to a subsequent one, finally culminating in the completed enumeration book. On its way to becoming part of a book, a FOSDIC schedule went through the following operations:

1. Printing at the Government Printing Office in Washington, D.C.
2. Shipment to the Decennial Census Operations Office, Jeffersonville, Ind., where skids containing schedules were received and checked in and defective products were removed
3. Cutting sheets of schedules into six separate pages
4. Punching holes in left-hand margin of the pages
5. Collation, for insertion in stage II enumeration books, of schedules to be used for 5-percent and 20-percent samples, respectively, of households and housing units
6. Assembly of schedules, instruction sheets, front covers, and back covers to form enumeration books
7. Insertion of wire binding loops
8. Packaging books in cartons ready for shipment to the field

### Printing FOSDIC Schedules

The quality of printing impressions on FOSDIC schedules was of vital importance to the efficient operation of FOSDIC. Planning for good quality input to FOSDIC began with the search for suitable paper and printing inks to produce census schedules which were to be marked by the enumerators, then microfilmed, and then "read" on the microfilm by FOSDIC.

Printing of census schedules was done by the Government Printing Office (GPO). The 1960 census printing job was not the first of its kind done by the Government Printing Office. However, it was the first of its kind of this magnitude.

In the quality control procedure, major concern was for defects that persisted, creating a large number of defective schedules and requiring an adjustment of the process, rather than for random defects that occurred and then disappeared as printing continued. Correction of the process was achieved by informing GPO of defects observed in a sample and having the printing plate corrected or removed. Removal of defective schedules was carried out in the Census Operations Office at Jeffersonville, Ind.

Unknown in a job of this magnitude was the useful life of a printing plate. For small-scale printing, the problem of creating a single usable plate with the accuracy of dimensions required for processing on FOSDIC had been substantially solved. However, it seemed possible that over a longer period a plate could deteriorate because of sporadic events such as the breaking of a FOSDIC circle or could deteriorate gradually both in thickness of the print and in the variability of thickness within one impression. Fortunately, because of the use of an improved copper plate, worry over gradual deterioration proved to be groundless.

The bulk of the printing was done with 61 plates. Special printing of schedules for Alaska and Hawaii was done with several different additional plates, but the number of schedules produced on these plates was too small to consider in estimating the life of plates for this type of printing job.

In order to assure the quality of printing needed for use of FOSDIC in the data processing, a hybrid type of quality control plan was developed. This plan provided for correcting the printing process by replacing a printing plate or making an adjustment in it when presses turned out defective products. In addition, it provided for improving outgoing quality by replacing defective schedules with acceptable ones. Sample inspection was made in Washington by Census Bureau personnel of a pair of consecutive sheets selected from each 5,000 impressions (each sheet contained six page positions). A pair of consecutive sheets was inspected so that printing defects which might have affected many schedules could be distinguished from defects due, for example, to variations in paper. As one press printed "fronts" and another "backs," a visual inspection and a FOSDIC reading inspection were made of microfilmed copies of both the back and front of each sample sheet.

In visual inspection, a defective sheet was defined as one containing one or more of the following defects:

1. Dark, light, broken, or missing circles
2. Ink spots, visible to the naked eye, within 1/8 of an inch of a circle or index mark
3. Light index marks (by comparison with a Munsel reflectance chart)
4. White spots, larger than 1/32 of an inch, within index marks

[1]There was also a quality control program to assess and control the quality of the work of the field enumerator. The development and operation of this phase of the quality control program will be treated in another report.

In FOSDIC reading, a check was made to determine whether--

1. All index marks could be read
2. Calibration was acceptable
3. Intensity and range of intensity of circles fell between specification limits

In addition, the FOSDIC readings served as a check on the visual inspection to locate defects not picked up readily by human inspection.

As sample sheets were inspected, defectives were identified by skid[2] and page position so that they could be removed from skids after shipment to Jeffersonville. Whenever a defect was observed in the sample inspection, the Government Printing Office was informed within an hour so that correction could be made in the process at the press site. The Government Printing Office also conducted a visual inspection so that defectives which were not observed in the Bureau's quality control inspection could be identified for removal from skids in Jeffersonville.

Approximately 57 million schedules were printed on the Government Printing Office presses during a period of 6 months. Production began near the end of July 1959 and continued into January 1960.

The procedure called for inspecting the back of each page independently of the front. When a pair of backs or a pair of fronts contained a printing defect, the pair was rejected. When a defect occurred on one of a pair but not on the other, the pair was accepted as the defect was attributed to the paper or to some cause other than printing. Since the back of a page was printed on a different press from the front, the occurrence of a printing defect on the front and back of the same page was unlikely. Consequently, the number of pairs of fronts rejected and the number of pairs of backs rejected were independent.

Table 1 shows the defective rate for pairs of front and of back page positions. The overall rate of defectives is the sum of the rates for backs and for fronts; the defective rate found in the sample was 2.2 percent of page positions.

**Table 1.--PAIRS OF PAGE POSITIONS REJECTED IN QUALITY CONTROL INSPECTION OF PRINTING, BY TYPE OF SCHEDULE**

(Combined results of visual and FOSDIC inspection)

| FOSDIC schedule | Number of sample pairs of page positions | Sample pairs rejected | | | |
|---|---|---|---|---|---|
| | | Fronts of schedules | | Backs of schedules | |
| | | Number | Percent | Number | Percent |
| Total | 11,400 | 60 | 0.5 | 195 | 1.7 |
| 60PH-1 | 2,094 | 15 | 0.7 | 6 | 0.3 |
| 60PH-2 | 1,188 | 7 | 0.6 | 35 | 3.0 |
| 60PH-3, 5 percent sample | 1,002 | 6 | 0.6 | 5 | 0.5 |
| 60PH-3, 20 percent sample | 4,020 | 12 | 0.3 | 126 | 3.1 |
| 60PH-4, 5 percent sample | 534 | 0 | 0.0 | 6 | 1.1 |
| 60PH-4, 20 percent sample | 2,154 | 12 | 0.6 | 13 | 0.6 |
| Other forms[1] | 408 | 8 | 2.0 | 4 | 1.0 |

[1]Included are: 60PH-1NY (New York), 60PH-2NY (New York), 60PH-1AL (Alaska), 60PH-2AL (Alaska), 60PH-1HA (Hawaii), and 60PH-2HA (Hawaii).

As the following table shows, 46 percent of the total pairs of rejected page positions fell into the classification of "heavy-print." Of the total rejections, the largest number occurred on pairs of backs, and of the 195 pairs of backs, 53 percent fell into the heavy-print category. In locating "heavy-print" rejects, FOSDIC played a significant role in the inspection scheme. In the case of fronts, it located nine pairs not found in visual inspection; and in the case of backs, it found 79 of 104 rejected pairs. The sensitivity of the paper in conjunction with the inking is among the causes of heavy print.

As a measure of the production life of a plate, the number of sample periods that a plate lasted before it was changed or before it completed its production run was used. The exponential distribution was used as the theoretical model describing the production-to-failure of a printing plate (the number of schedules produced before it had to be replaced). In effect, the 61 plates represented a sample drawn from a universe of all possible plates for a printing process when the rule for rejecting a plate was the occurrence of a printing defect which could be corrected only by plate replacement.

A plate was retired when usable schedules could no longer be reproduced from it. For example, in one case, according to a report of the results of visual inspection of one type of FOSDIC schedule, Plate 9 was used for the sheets on skids 155-810 through 222-943. There were 117 rejects. The printing defects consisted of a constant change between heavy print, light index marks, and broken circles. The plate was retired and a new one was substituted for it.

The data on change of plates can be ordered in such a way that the plate with the shortest life, as measured by the number of sample inspections of schedules at approximately equal intervals, comes first; the plate with the next shortest life comes next; and so forth until the plate with longest life comes last. Specifically, the model has been applied where the characteristic "X" is the number of sample periods before failure of a plate. It appears from table 3 and charts 1 and 2 that the exponential distribution fits the printing life distribution of these plates reasonably well.

[2]A skid of 5,000 printed sheets contained 10,000 front and back impressions, each having six page positions. This amounted to 60,000 pages.

## Table 2.—PAIRS OF PAGE POSITIONS REJECTED IN QUALITY CONTROL INSPECTION OF PRINTING, BY TYPE OF DEFECT AND MEANS OF INSPECTION

| Type of defect | Total rejected | | Fronts of schedules | | | Backs of schedules | | |
|---|---|---|---|---|---|---|---|---|
| | Percent | Number | Total | Visual inspection | FOSDIC inspection | Total | Visual inspection | FOSDIC inspection |
| Total | 100.0 | 255 | 60 | 45 | 15 | 195 | 107 | 88 |
| Heavy print | 46.3 | 118 | 14 | 5 | 9 | 104 | 25 | 79 |
| White spots in index marks | 15.7 | 40 | 14 | 14 | - | 26 | 20 | 6 |
| Ink spots | 11.4 | 29 | 5 | 2 | 3 | 24 | 24 | - |
| Broken circles | 10.2 | 26 | 4 | 4 | - | 22 | 22 | - |
| Light print (including light index marks) | 9.0 | 23 | 8 | 8 | - | 15 | 15 | - |
| Print show-through | 4.7 | 12 | 9 | 6 | 3 | 3 | - | 3 |
| Missing circles | 2.7 | 7 | 6 | 6 | - | 1 | 1 | - |

- Represents zero.

## Table 3.—NUMBER OF SAMPLE PERIODS BEFORE FAILURE OF PRINTING PLATES USED FOR FOSDIC SCHEDULES

| Number of sample periods[1] | Number of printing plates used during period | Expected number of plates based on exponential distribution[2] | Proportion of plates expected to fail during sample period | Proportion of plates expected to survive sample period |
|---|---|---|---|---|
| Total | [3]61 | 61.0 | 1.000 | |
| 0 to 10 | 17 | 21.7 | 0.356 | 0.644 |
| 10 to 20 | 17 | 14.0 | 0.229 | 0.415 |
| 20 to 30 | 9 | 9.0 | 0.148 | 0.267 |
| 30 to 40 | 10 | 5.7 | 0.093 | 0.174 |
| 40 to 50 | 4 | 3.8 | 0.062 | 0.112 |
| 50 to 60 | 2 | 2.4 | 0.040 | 0.072 |
| 60 to 70 | 0 | 1.6 | 0.026 | 0.046 |
| 70 to 80 | 1 | 1.1 | 0.018 | 0.028 |
| 80 to 90 | 0 | 0.5 | 0.009 | 0.019 |
| 90 to 100 | 0 | 0.4 | 0.007 | 0.012 |
| 100 to 110 | 0 | 0.3 | 0.004 | 0.008 |
| 110 to 120 | 1 | 0.2 | 0.003 | 0.005 |
| 120 and over | 0 | 0.3 | 0.005 | 0.000 |
| Mean number of sample periods per plate: 22.9 | | | | |

[1] A sample period was about 4 hours.

[2] Based on this formula: x, number of sample periods to failure for a plate. θ, mean number of sample periods per plate. P(x), the probability that a plate fails before T sample periods.

[3] Excludes plates used in production of schedules for Alaska and Hawaii, because the number of schedules produced on these was too small.

On the average, a printing plate lasted through more than 22.9 sample periods. The interim between samples was roughly 4 hours; a rough estimate of the average productive life of a plate, therefore, is 92 hours.

For the 61 plates, table 4 shows the production of printed sheets per plate.

Removal of defective schedules.—Skids of printed schedules were received and stored in Jeffersonville until defective schedules were removed. Inspectors were furnished with a list from Washington of known defectives designated by skid number, fronts (distinguished from backs by the wide left-hand margin of the schedule), backs (narrow left-hand margin), the half of the skid containing the defectives, and a general description of the defects. Each of the packages on the designated half of the skid was examined visually. If the defective was found in the package, the entire package of 1,000 sheets was destroyed, and the following packages in the skid were inspected and, if necessary, destroyed, until the defect was no longer found.

The number of schedules removed from production because they contained printing defects as defined in the sample inspection plan totaled 1,449,000. This number comprised 2.6 percent of the 56,712,000 schedules produced. The distribution of defects among the schedules removed from production is shown in table 5.

In addition to the quality control inspection of a sample of schedules selected from the printing inspection, GPO technicians identified 669,000 more schedules which were removed from skids. Actually, this number is an understatement of the total defective schedules identified by GPO, for some of the schedules identified in the Census Bureau's sample inspection were identified by GPO as well.

An additional 90,000 schedules were removed because printing was either blurred or upside down. These were found in the process of both the GPO inspection and the Census Bureau sample inspection. For all reasons combined, a total of 2,208,000 schedules were removed for printing defects of all types (see table 6).

**Chart 1.—THEORETICAL AND OBSERVED NUMBER OF PRINTING PLATES FAILING DURING PRINTING OF FOSDIC SCHEDULES**

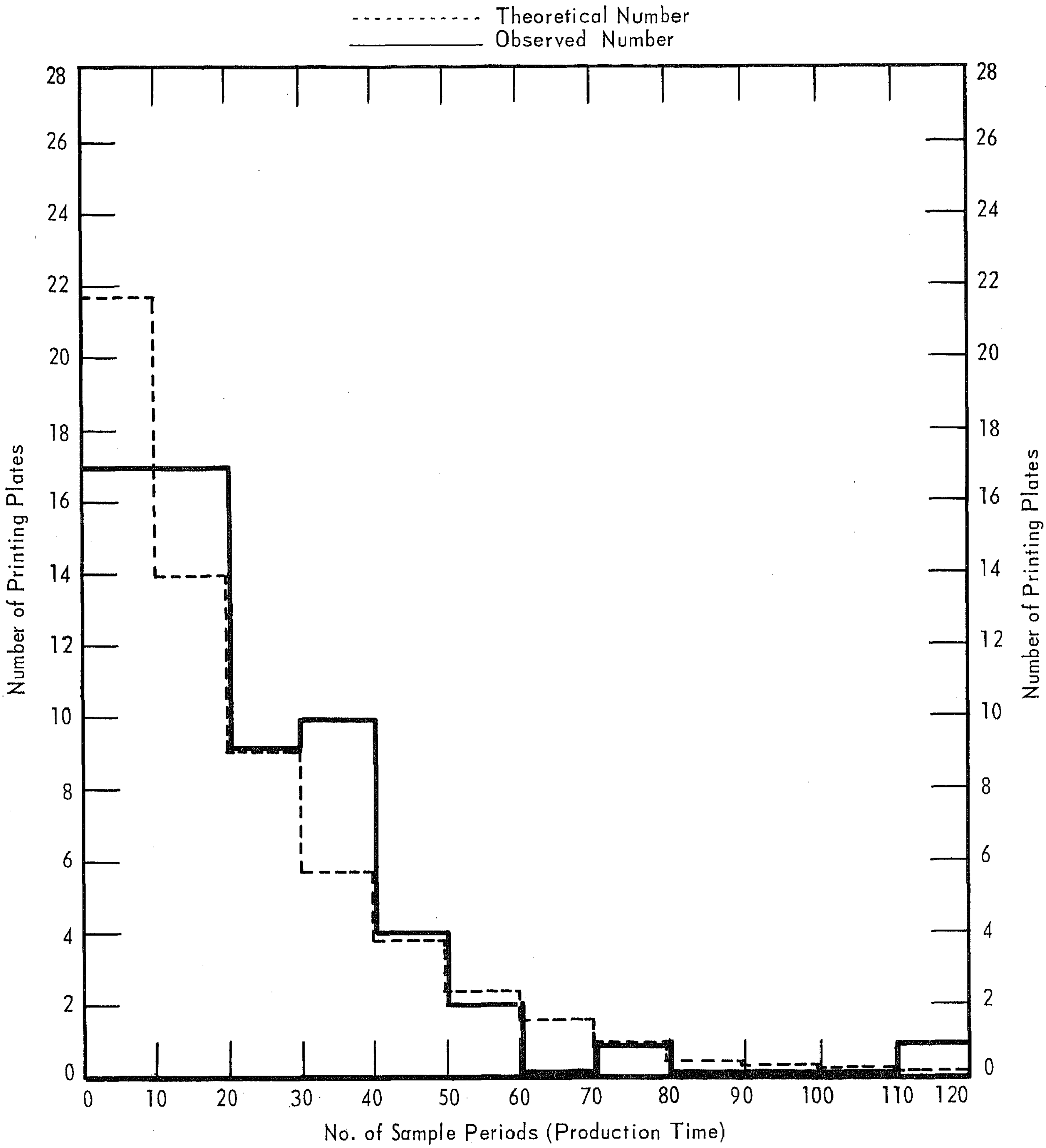


**Chart 2.—THEORETICAL CURVE SHOWING PROBABILITY OF A PRINTING PLATE'S EXCEEDING "X" NUMBER OF SAMPLE PERIODS**

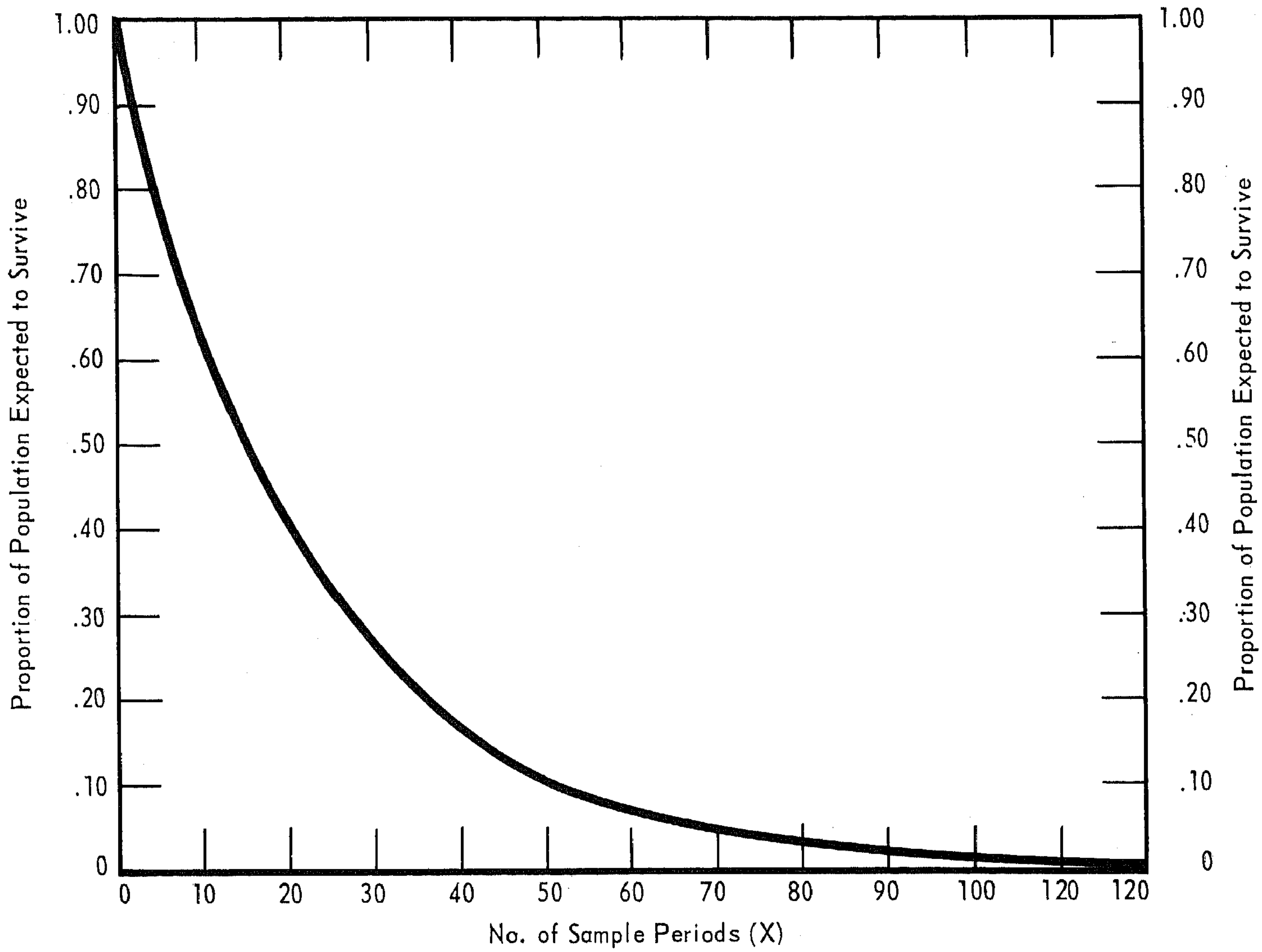



**Table 4.—NUMBER OF SHEETS PRINTED PER PLATE BY TYPE OF SCHEDULE DURING 1960 CENSUSES**

| FOSDIC schedule | Fronts of sheets | | | Backs of sheets | | |
|---|---|---|---|---|---|---|
| | Number of plates | Number of sheets (thousands) | Average number of sheets per plate (thousands) | Number of plates | Number of sheets (thousands) | Average number of sheets per plate (thousands) |
| Total | 27 | 4,220.0 | 156.5 | 34 | 4,725.0 | 139.0 |
| 60PH-1 | 7 | 872.5 | 124.5 | 7 | 870.0 | 124.5 |
| 60PH-2 | 4 | 500.0 | 125.0 | 3 | 495.0 | 165.0 |
| 60PH-1NY (New York) | 1 | 55.0 | (1) | 1 | 55.0 | (1) |
| 60PH-2NY (New York) | 1 | 87.5 | (1) | 1 | 87.5 | (1) |
| 60PH-3, 5-percent sample | [2]14 | [2]2,705.0 | [2]193.0 | 2 | 417.5 | 209.0 |
| 60PH-3, 20-percent sample | | | | 12 | 1,680.0 | 140.0 |
| 60PH-4, 5-percent sample | | | | 3 | 222.5 | 74.0 |
| 60PH-4, 20-percent sample | | | | 5 | 897.5 | 179.5 |

[1]Only one plate used.
[2]The fronts of the sheets contained only population items, which were identical on these four schedules; only the housing items on the backs of the sheets varied from one to another of the four types of schedules.

**Table 5.—FOSDIC SCHEDULES DISCARDED AFTER QUALITY CONTROL INSPECTION OF THE PRINTING, BY TYPE OF PRINTING DEFECT**

| Type of printing defect | Number (thousands) | Percent of total | Percent from sample inspection[1] |
|---|---|---|---|
| Total | 1,449 | 100.0 | 100.0 |
| Heavy print and read-through | 759 | 52.4 | 51.0 |
| White spots in index marks | 244 | 16.8 | 15.7 |
| Broken and missing circles | 166 | 11.5 | 12.9 |
| Ink spots | 122 | 8.4 | 11.4 |
| Light print (including index marks) | 158 | 10.9 | 9.0 |

[1]Based on total pairs of page positions rejected; see table 2.

**Table 6.—SCHEDULES DISCARDED BECAUSE OF PRINTING DEFECTS, BY TYPE OF DEFECT**

| Type of defect | Number of schedules (thousands) | Percent of schedules produced | Percent of total discarded |
|---|---|---|---|
| Total produced | 56,712 | 100.0 | ............ |
| Total discarded | 2,240 | 4.0 | 100.0 |
| Printing rejects | 2,208 | 3.9 | 98.6 |
| Printing defects identified in Census Bureau sample inspection | 1,449 | 2.6 | 64.7 |
| Printing defects identified by GPO | 669 | 1.2 | 29.9 |
| Blurred and upside-down printing | 90 | 0.1 | 4.0 |
| Shipping damage | 32 | 0.1 | 1.4 |

A relatively small number of schedules were removed because of shipping damage--about 32,000--amounting to less than 0.01 percent of the schedules produced.

### Inspection of the Cutting Process

The printing at GPO was "six up," meaning six page positions (fronts or backs of schedules) were printed on a press simultaneously in one impression. These page positions had to be cut apart by the GPO within a 1/8-inch tolerance in order that the holes to be placed in the margins for book assembly would correctly place the index marks on the microfilmed pages for FOSDIC reading.

A preliminary analysis of the cutting process was made in the summer of 1959 based on a sample of 1,392 schedules selected after cutting. Measurements were made from the margin to the outer edge of the sheets, near the center of each edge. The distribution of variation from specified size is shown in table 7. The sample measurements indicated that about 0.9 percent of the cuts would yield a defective schedule.

After receiving and staging, skids of schedules having no printing defects as well as those from which printing defectives had been removed were inspected for cutting defects. A skid contained 10 layers of six packages each. In one layer there were six packages of 1,000 sheets, printed front and back. Each package corresponded to a page position on the "six up" impression. When a skid was opened, the top and bottom sheets from each of the two corner packages in one row of three page positions

**Table 7.—SIZE VARIATIONS OF A SAMPLE OF FOSDIC SCHEDULES SUBJECTED TO THE CUTTING PROCESS**

| Variation from specified schedule size (in inches) | Schedules measured | |
|---|---|---|
| | Number | Percent |
| Total | 1,392 | 100.0 |
| -5/32 | 1 | 0.1 |
| -4/32 | 11 | 0.8 |
| -3/32 | 166 | 11.9 |
| -2/32 | 168 | 12.1 |
| -1/32 | 106 | 7.6 |
| 0 | 591 | 42.5 |
| 1/32 | 229 | 16.4 |
| 2/32 | 114 | 8.2 |
| 3/32 | 6 | 0.4 |
| Defective pages (varying 4/32" or more from specified page size) | 12 | 0.9 |

and the top and bottom sheets of the middle package in the other row of three page positions were selected for inspection. Since the three page positions selected had sides in common with those not selected, an inspection of three page positions sufficed.

A check of the cutting was made by laying each of three page positions with no sides in common out of the six page positions on a shadow box. The shadow box was hollow with fluorescent lights on the inside and frosted glass covering the top, and had the outline of a nearly perfect sheet etched in black on the top with 1/8th inch tolerance marks running along the perimeter and with etched index marks for purposes of alignment. The inspector placed sheets over the outline on the glass of the shadow box and checked to see that they fell within tolerance marks. After checking the cutting, he checked for other defects mentioned earlier, such as incorrect shade of printing, white dots in black index marks, mutilated sheets, and others.

The procedure constituted a 100-percent inspection of lots, in which a lot was the six packages of 1,000 sheets each in a layer. In effect, the inspection of top and bottom sheets from each of three packages was an inspection of all sheets in the lot since they were cut by the same cutter. If all six sheets from each layer were without defects, the layer was accepted. If an improperly cut sheet was found, the packages in the layer were inspected on a 100-percent basis and all defective sheets were removed.

Of the 54,472,000 schedules subjected to cutting inspection prior to holepunching, 389,000 were removed, amounting to approximately 0.7 percent of the FOSDIC schedules.

### Collation of Stage II FOSDIC Schedules

Prior to collation, holes were punched in the left-hand wide margin of FOSDIC forms. There was no inspection of this operation other than visual inspection on the part of the machine operator of the holepuncher and the stacker. Improperly punched forms were replaced by properly punched ones. This operation applied to both stage I and stage II FOSDIC schedules.

The collation operation, however, applied only to stage II FOSDIC schedules. Since some housing items were obtained for a 5-percent sample and some for a 20-percent sample of housing units, different schedules were used for the two samples. (Items which appeared on both schedules were thereby collected for a 25-percent sample.) Collation involved integrating the 5-percent and 20-percent sample schedules in a 1-to-4 ratio for each enumeration book. The job of combining the 20-percent and 5-percent sample schedules was done manually. The collation operation required the services of 21 persons, 9 collators on each side of a conveyor belt, 2 suppliers (1 for each row of 9 collators), and 1 person at the end of the line. The collators placed one 5-percent schedule on top of four 20-percent schedules and repeated this until the total number of schedules in the stack reached approximately 100, then placed the stack on the conveyor belt. Stacks were conveyed to the end of the belt where they were dumped into a jogger to aline the forms within the stack. The person at the end of the line stacked schedules in carts for movement to the book assembly area.

The quality control inspector selected his sample from the conveyor belt just as the unit containing five forms was ready to drop into a jogger. The sample was drawn from lots of 200 units at the rate of 1 in 20 units, or 10 units per lot. Each unit in the sample was inspected to determine if it had a 5-percent sample schedule followed by four 20-percent schedules. If one or more defective units were found, the lot of 200 units was inspected on a 100-percent basis and the incorrect number and sequence of schedules was corrected, and the lot was then placed on the cart for movement to the next operation. If no defective units were found in the sample, the lot was passed, and placed on the cart.

The characteristics of the lot acceptance sampling plan for quality control of the collation are shown in table 8. The operating characteristic curve and the average outgoing quality curve of the lot acceptance plan are shown in charts 3 and 4.

**Table 8.—CHARACTERISTICS OF LOT ACCEPTANCE SAMPLING PLAN FOR QUALITY CONTROL OF COLLATION OF 5-PERCENT AND 20-PERCENT SAMPLE SCHEDULES**

(Lot size, 200 units; sample size, 10 units; acceptance number, 0)

| Fraction defective | Probability of accepting lot | Average outgoing quality |
|---|---|---|
| .000 | 1.000 | .000 |
| .001 | .990 | .001 |
| .002 | .980 | .002 |
| .003 | .970 | .003 |
| .004 | .961 | .004 |
| .005 | .951 | .005 |
| .010 | .904 | .009 |
| .020 | .817 | .016 |
| .030 | .737 | .022 |
| .040 | .665 | .027 |
| .050 | .599 | .030 |
| .100 | .349 | .035 |
| .150 | .197 | .030 |
| .200 | .107 | .021 |
| .300 | .028 | .008 |
| .400 | .006 | .002 |
| .500 | .001 | .001 |

The collation began with the week ending September 26, 1959. During a period of 65 workdays, 36.7 million schedules were collated into 7.34 million units. An additional 805,000 schedules were used as a reserve and collated as required thereafter. Collation progressed at an average of 112,923 units per day.

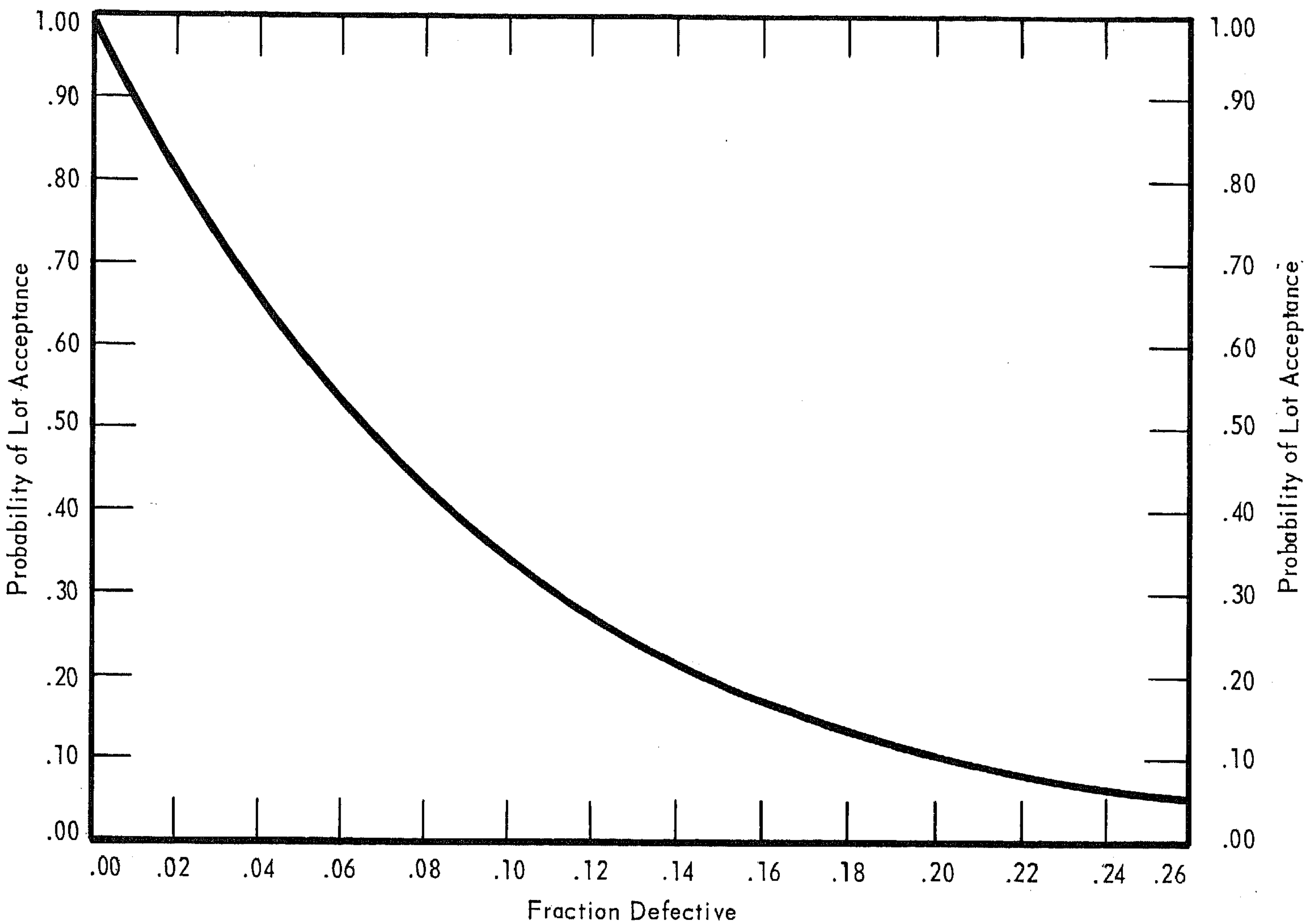
The first 2 percent of production (161,200 units) was inspected on a 100-percent basis. The remaining 7,178,800 units were subjected to a 5-percent sample inspection. Results of the inspection are shown below.

### Assembly into Enumeration Books

The assembly operation produced an enumeration book with a front cover, a back cover, an instruction sheet, and the required number of schedules held together by an unclosed binder wire running from top to bottom of the book. The operation involved two steps: (1) An operator placed together a back cover, a front cover face down, and a green instruction sheet face down; (2) another operator used a spooning device, or spindle, which he inserted a given distance into a pile of sheets through the holes in the margins, to pick up approximately the required number of schedules for the enumerator book type identified on the cover, and placed the sheets on top of a set of covers and instruction sheets. A set of schedules, covers, and instruction sheets was placed at right angles to the one under it to facilitate handling at the wire-insertion stage.

## Chart 3.—OPERATING CHARACTERISTIC CURVE OF COLLATION LOT ACCEPTANCE SAMPLING PLAN

(n = 10; a = 0)




### Table 9.—PROCESS AVERAGE AND AVERAGE OUTGOING QUALITY RESULTING FROM LOT ACCEPTANCE SAMPLING PLAN FOR QUALITY CONTROL OF COLLATION

| Item | 100-percent inspection | Sample inspection |
|---|---|---|
| Lots subject to inspection | 806 | 35,894 |
| Number of units subject to inspection | 161,200 | 7,178,800 |
| Number of units inspected | 161,200 | 358,940 |
| Number of defective units | 1,894 | 973 |
| Percent of units defective | 1.2 | 0.3 |
| Process average[1], percent (weighted) | ... | 0.3 |
| Average outgoing quality, percent (weighted) | ... | 0.3 |

[1]Process average = $\frac{N_1 P_1 + N_2 P_2}{N}$ where

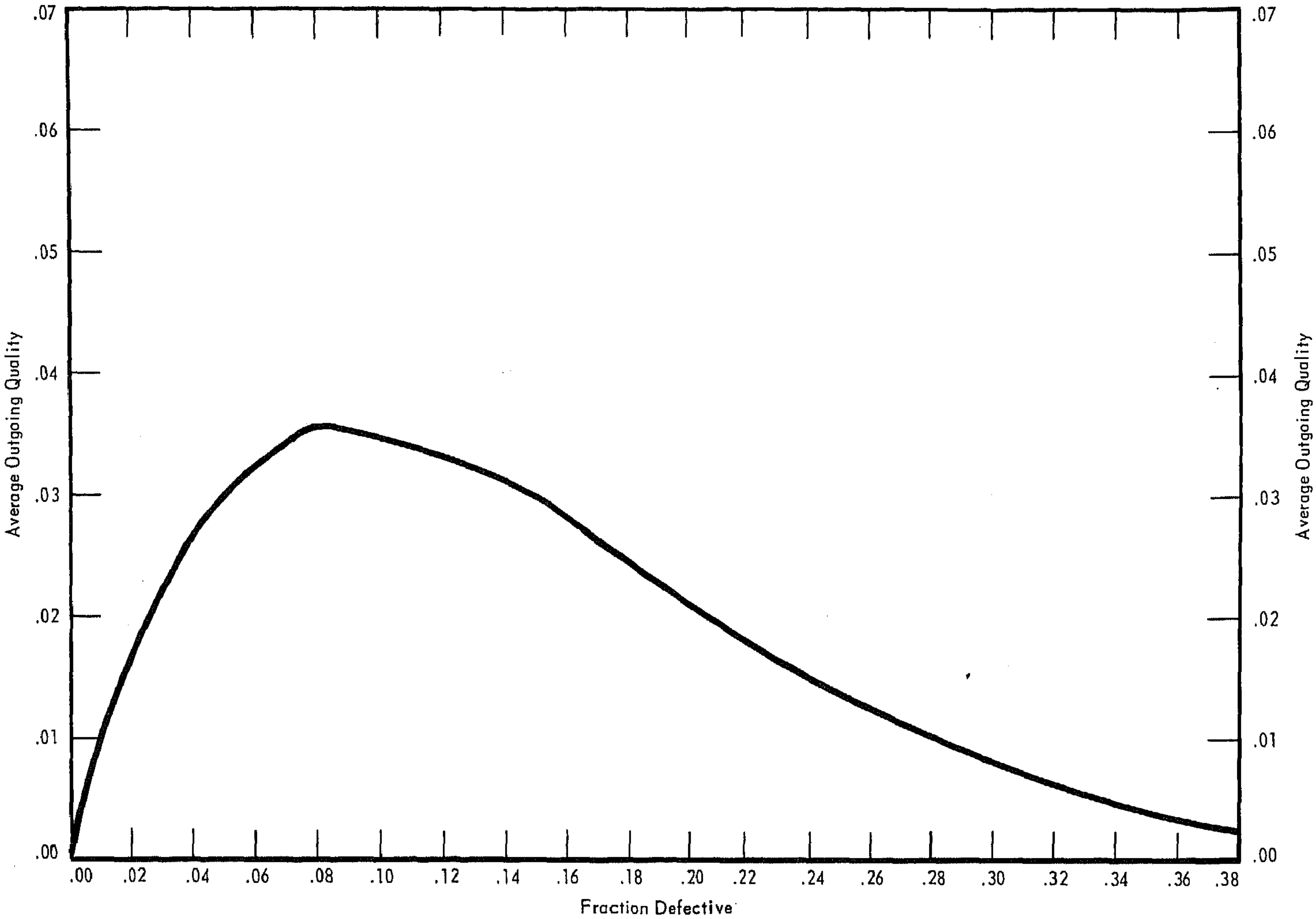
$N_1$ is number of units subject to 100-percent inspection,

$P_1$ is fraction defective in 100-percent inspection,

$N_2$ is number of units subject to sample inspection, and

$P_2$ is fraction defective in sample inspection.

Chart 4.—AVERAGE OUTGOING QUALITY CURVE OF COLLATION LOT ACCEPTANCE SAMPLING PLAN




Quality was checked by means of process control of each of the spooners. Each hour the quality control inspector pulled five random samples from the work of each spooner before the sets produced by him were rolled to the wire-insertion operator. A physical count of the number of pages per book was made. If the count was not within tolerance for the type of book being assembled, the supervisor was notified and the spoon was checked. Correction was made by resetting the spoon when required or reinstructing the operator of the spooning device. Tolerances established for the enumeration books were as follows: stage I, large books—50 pages ± 15; small books—25 pages ± 8; stage II, large books—90 pages ± 15; small books—40 pages ± 8.

The spooning operation yielded a process average of 1.8 percent outside tolerances. The percent of books having page counts outside tolerance varied by type as shown in table 10.

During the processing, a total of 40 different spooners worked in the spooning operation. Of this number, 14 worked sufficient time to have 100 or more books sample inspected; the average percent of books having page counts outside tolerance for this group was 0.8. In contrast, those operators who had less than 100 books inspected under the sampling plan had an average of 10.4 percent defective, as shown in table 11.

Table 10.—ENUMERATION BOOKS WITH PAGE COUNTS OUTSIDE TOLERANCE

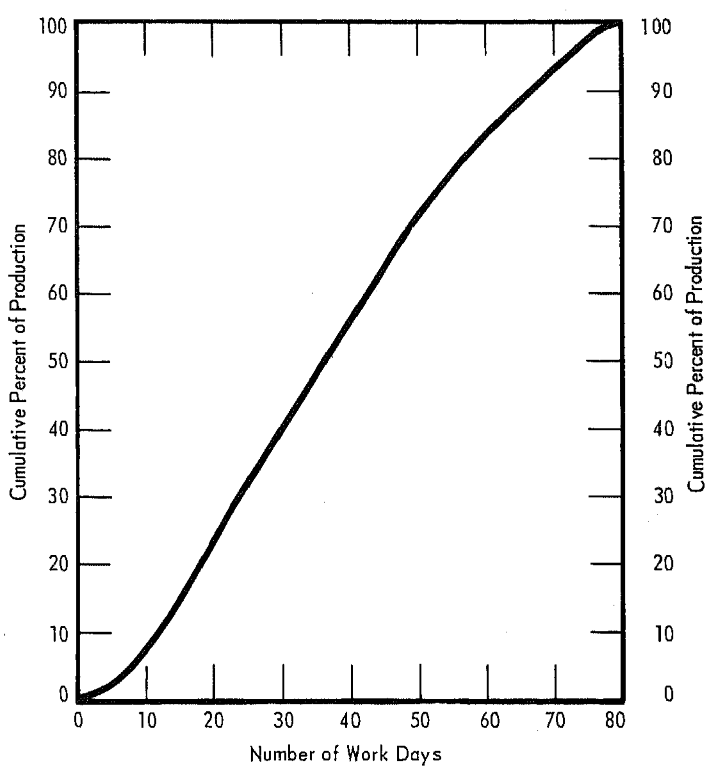
| Basic book size (in pages) | Number of books in sample | Books with page counts outside tolerance | |
|---|---|---|---|
| | | Number | Percent |
| All sizes | 7,178 | 127 | 1.8 |
| 25-page books | 1,591 | 25 | 1.6 |
| 40-page books | 2,202 | 26 | 1.2 |
| 50-page books | 1,930 | 76 | 3.9 |
| 90-page books | 1,455 | 0 | 0 |

**Table 11.—ENUMERATION BOOKS WITH PAGES OUTSIDE TOLERANCES, BY SPOONING OPERATOR**

| Operator | Number of books in sample | Number of books outside tolerances | Percent defective |
|---|---|---|---|
| Total........... | 7,178 | 127 | 1.8 |
| Operators (14) with 100 or more books in sample, total........ | 6,487 | 55 | 0.8 |
| 1................. | 173 | [1]23 | 21.5 |
| 2................. | 1,707 | 8 | 0.5 |
| 3................. | 674 | [2]16 | 2.4 |
| 4................. | 874 | 1 | 0.1 |
| 5................. | 121 | 0 | 0.0 |
| 6................. | 119 | 1 | 0.8 |
| 7................. | 214 | 1 | 0.5 |
| 8................. | 115 | 0 | 0.0 |
| 9................. | 233 | 0 | 0.0 |
| 10................. | 506 | 4 | 0.8 |
| 11................. | 525 | 1 | 0.2 |
| 12................. | 115 | 0 | 0.0 |
| 13................. | 120 | 0 | 0.0 |
| 14................. | 991 | 0 | 0.0 |
| Operators (26) with less than 100 books in sample............... | 691 | 72 | 10.4 |

[1]50-page books.
[2]12 of these 16 were 40-page books.

**Chart 5.—CUMULATIVE PERCENT OF BOOKS ASSEMBLED BY SPOONING PROCESS, WEEKS ENDING SEPTEMBER 5 THROUGH DECEMBER 22, 1959**




In the group having 100 or more books inspected on a sample basis, two operators were responsible for 39 of the 55 defective books. One operator had to be reinstructed in setting the spoon for 50-page books; all of his defective books were in the 50-page book category. Of the 16 books found outside tolerances for the other operator, 12 were in the 40-page book category.

Table 12 provides an estimate of the average number of pages per book for each book size and type.

The assembly of books by means of the spooning process began with the week ending September 5, 1959. By December 22, 1959, 948,000 books were assembled. On the average, 12,000 books were spooned per day. Cumulative production is shown in chart 5.

## Binding Enumeration Books

The binding operation involved inserting a strip of wire loops by hand in the holes in the margin of each assembled enumeration book, closing the strip of wire loops, then flipping the green instruction sheets and front yellow cover into proper place. This operation was a terminal one in a sequence and a continuous sample plan was used to inspect books prior to packaging and assembling them in shipment lots.

A continuous sample plan starts with 100-percent inspection of units in the order of production. When the ith consecutive defect-free unit is reached, a systematic sample of 1 in k is inspected. As soon as a sample unit is found to be defective, 100-percent inspection is reverted to and the cycle is repeated. This type of plan assures that the maximum expected outgoing fraction defective is less than a value which is determined by assigning fixed values to "i" and "k". In this operation, "i" was 50 and "k" was 50 ($f = 1/k = 1/50 = 2\%$). Fifty books were inspected in succession, and if no defects were found inspection continued on a 1-in-50 basis. Whenever a defective book was discovered, inspection was made on a 100-percent basis until 50 successive books were found to be free of defects.

**Table 12.—ESTIMATED AVERAGE NUMBER OF PAGES PER ENUMERATION BOOK BY TYPE AND SIZE OF ENUMERATION BOOK, BASED ON SPOONING CHECK SAMPLES**

| Enumeration book size and type | Number of books in sample | Average number of pages per book | Standard deviation | Coefficient of variation (percent) | Coefficient of variation of estimated average (percent) |
|---|---|---|---|---|---|
| 25-page books: | | | | | |
| 60PH-1 schedules[1] | 907 | 25.7 | 2.8 | 10.9 | 0.4 |
| 60PH-2 schedules[2] | 584 | 24.9 | 1.7 | 6.8 | 0.3 |
| 60PH-2NY schedules[2] | 100 | 24.5 | 2.0 | 8.2 | 0.8 |
| 50-page books: | | | | | |
| 60PH-1 schedules[1] | 1,427 | 48.4 | 5.9 | 12.2 | 0.3 |
| 60PH-2 schedules[2] | 503 | 50.8 | 2.8 | 5.5 | 0.2 |
| 40-page books: | | | | | |
| 60PH-3 schedules[3] | 1,482 | 39.7 | 2.7 | 6.8 | 0.2 |
| 60PH-4 schedules[4] | 720 | 40.6 | 2.3 | 5.7 | 0.2 |
| 90-page books: | | | | | |
| 60PH-3 schedules[3] | 1,161 | 88.7 | 2.3 | 2.6 | 0.1 |
| 60PH-4 schedules[4] | 294 | 88.1 | 2.2 | 2.5 | 0.1 |

[1]Schedules containing questions asked on a 100-percent basis outside large cities.
[2]Schedules containing questions asked on a 100-percent basis in large cities.
[3]Schedules containing questions asked for a 25-percent sample outside large cities.
[4]Schedules containing questions asked for a 25-percent sample in large cities.

For purposes of this inspection plan, a defective book was defined as one containing one or more of the following eight defects:

- Improperly closed strip of wire loops
- Upside-down instruction sheet
- Upside-down FOSDIC schedule
- Front or back cover improperly punched
- FOSDIC schedules punched through the narrow margin
- Improper sequence of 5-percent and 20-percent sample schedules in a stage II book
- Illegible or insecurely fastened front cover
- Illegible or insecurely fastened instruction sheet

When a defective book was found it was removed and replaced. The nondefective portions were salvaged.

The inspection plan provided for an average outgoing quality limit of approximately 4.1 percent. Characteristics of the plan are shown in table 13. The results are shown in table 14.

After inspection, books were packed in cardboard cartons, wired, stacked on skids by book type and size, and moved to the storage warehouse for shipment.

**Table 13.—CHARACTERISTICS OF CONTINUOUS PRODUCTION SAMPLING PLAN FOR INSPECTION OF BINDING OPERATION**

(Percent. Interval (i) = 50; sampling fraction (f) = 2%)

| True percent defective (P) | Average fraction expected to be inspected (AFI)[1] | Percent expected to be passed under sampling (Pa)[2] | Average outgoing quality (AOQ)[3] |
|---|---|---|---|
| 0 | 2.0 | 100.0 | 0.0 |
| 1 | 3.3 | 98.7 | 1.0 |
| 2 | 5.3 | 96.6 | 1.9 |
| 3 | 8.6 | 93.3 | 2.7 |
| 4 | 13.6 | 88.2 | 3.5 |
| 5 | 21.0 | 80.6 | 4.0 |
| 6 | 31.0 | 70.4 | 4.1 |
| 7 | 43.4 | 57.7 | 4.0 |
| 8 | 56.8 | 44.1 | 3.5 |
| 9 | 69.4 | 31.2 | 2.8 |
| 10 | 79.7 | 20.7 | 2.0 |
| 12 | 92.3 | 7.9 | 0.9 |
| 14 | 97.6 | 2.4 | 0.3 |
| 16 | 99.0 | 1.0 | 0.2 |
| 18 | 99.8 | 0.3 | 0.0 |
| 20 | 100.0 | 0.0 | 0.0 |

[1] $AFI = \frac{f}{(1 - f)(1 - P)^i + f}$

[2] $Pa = \frac{(1 - P)^i}{(1 - f)(1 - P)^i + f}$

[3] $AOQ = (1 - AFI)\,P$

**Table 14.—PROCESS AVERAGE AND AVERAGE OUTGOING QUALITY RESULTING FROM CONTINUOUS PRODUCTION SAMPLING PLAN TO CONTROL QUALITY OF BINDING OPERATION**

| Item | Number or percent |
|---|---|
| Enumeration books subject to inspection........ | 956,400 |
| Enumeration books inspected.................... | 44,853 |
| 100-percent inspection...................... | 26,298 |
| Sample inspection........................... | 18,555 |
| Percent inspected............................ | 4.7 |
| Process average[1]............................ | 1.7 |
| Average outgoing quality[2]..................... | 1.6 |

[1]Estimated from average fraction inspected curve.
[2]Computed by means of following formula: AOQ = (1 - AFI) x fraction defective.

### Cost of Preparing the Enumeration Books

Man-hour and production figures were maintained for the preparation of enumeration books for the period from August 25 through December 22, 1959. Production figures included the cutting inspection and the collation, assembly, binding, and packaging operations as well as the quality control inspection. Not included are printing and removal of defective schedules from skids. It is estimated that it required on the average 3.9 minutes to prepare a book, at a cost of 12.2 cents. These figures include time away from work—vacation and sick leave—by employees assigned to the book assembly job, and salary paid for this time. Excluding time and cost of employee leave, 3.2 minutes were required to prepare a book, at a cost of 9.8 cents for the work. Quality control inspection required 0.3 minutes per book, at a cost of 0.9 cents. Production and quality control together required 4.2 minutes per enumeration book at a cost of 13.1 cents.

### Assembly of Materials for Crew Leaders and Enumerators

As a distinct operation, items such as the enumeration book, household questionnaires, pencils, etc., were assembled into portfolios for enumerators and kits for crew leaders. During the week ending on February 19, 1960, the assembly of enumerator portfolios and crew leader kits was completed. Inspection of this assembly operation was based on a continuous production sampling plan providing for an average outgoing quality limit of approximately 2 percent. The sampling unit was an enumerator portfolio or a crew leader kit.

The assembly of kits and portfolios was a conveyor-belt operation which required the services of 20 persons in conjunction with 18 tables for materials. In the case of enumerator portfolios (which were the largest part of the assembly operation and the one on which detailed records were kept), the operation produced a box with two enumerator portfolios completely stuffed with materials in approximately 20 seconds. The operation was conducted as follows: (a) A cardboard carton containing two empty enumerator portfolios was set in motion at one end of the belt; (b) nine stuffers along one side of the belt placed materials in one portfolio at the same time that nine stuffers on the other side of the belt placed materials in the other portfolio. For one type of enumerator portfolio, for example, the following materials were put into each of the two portfolios by the stuffers on each side of the conveyor belt:[3]

- 1st stuffer—25 60PH-7 Household Questionnaires
- 2nd stuffer—25 60PH-7 Household Questionnaires
- 3rd stuffer—25 60PH-7 Household Questionnaires
- 4th stuffer—25 60PH-7 Household Questionnaires
- 5th stuffer—60 60PH-9 Extra Person Forms (for persons in households too large to be enumerated on one 60PH-7)
- 6th stuffer—25 60PH-10 Individual Census Reports
- 7th stuffer—25 60PH-12 Notices of Enumeration (to be left at housing units where no one was at home)
- 8th stuffer—Pad of F-221 forms (Notice of Census Taker's Call), pad of scratch paper, 15 addressed manila envelopes (3-5/8" x 8-3/8"), two No. 2-1/2 pencils, pencil sharpener
- 9th stuffer—2 packs, 50 to a pack, of addressed manila envelopes (6-3/4" x 9")

The quality control inspection of this operation required two persons, one on each side of the conveyor belt. As the cardboard cartons passed each inspector, sample portfolios or kits were selected in accordance with the provisions of the sampling plan and were inspected without being physically removed from the assembly line unless they were defective. Cartons were kept in sequence on the conveyor line to prevent a portfolio or kit in a group designated for a specific city from being placed with an incorrect group. Check was made to see that the correct materials were present in approximately the correct quantities, and that the envelopes were correctly addressed. As each carton (sample and nonsample) passed an inspector, he stamped it with the shipping designation number to insure identification for correct shipment.

After the cartons passed the inspectors, they were removed from the conveyor belt by a closer who bent the flap on each portfolio, closed it in briefcase style, fastened it, and pushed the carton to a packer. Packing required three persons. Each took a carton containing two completely assembled portfolios, closed the carton by taping it, and stacked the cartons 48 to a skid according to destination number.

Inspection procedure.—A Dodge continuous production inspection plan, with an interval of 75 and a sampling fraction of 5 percent, was used for the quality control of the assembly of enumerator portfolios and crew leader kits. That is, when 75 consecutive kits had been inspected on a 100-percent basis without discovering a defective one, inspection on a sample basis was begun. The procedure under sample inspection involved inspecting the next kit and every 20th kit thereafter. When, in the course of sample inspection, a kit containing a defect was found, the inspector reverted to 100-percent inspection until another 75 consecutive kits were found to be free of defects. Defective kits were set aside and corrected. The average fraction inspected, average outgoing quality, and operating characteristic curve (percent expected to be passed under sampling) for inspection of enumerator portfolios are shown in charts 6, 7, and 8 and table 15.

Results of the inspection.—Of the estimated 166,690 enumerator portfolios subject to the quality control inspection, 6.3 percent were inspected; the incoming percent defective averaged about 0.2 percent, providing an average outgoing quality of about the same magnitude.

[3]The enumeration books were not included in the enumerators' portfolios but were instead sent to the crew leaders.

**Table 15.–CHARACTERISTICS OF THE SAMPLING INSPECTION PLAN FOR ASSEMBLY OF ENUMERATOR PORTFOLIOS**

(In percentages. Interval 75; sampling fraction 5%)

| True percent defective | Average fraction expected to be inspected | Percent expected to be passed under sampling | Average outgoing quality |
|---|---|---|---|
| 0.1 | 5.4 | 99.7 | 0.01 |
| 0.5 | 7.1 | 97.7 | 0.5 |
| 1.0 | 10.5 | 94.4 | 0.9 |
| 2.0 | 19.3 | 84.9 | 1.6 |
| 3.0 | 34.1 | 69.4 | 2.0 |
| 4.0 | 52.9 | 48.4 | 1.9 |
| 5.0 | 71.2 | 30.0 | 1.4 |
| 6.0 | 84.5 | 16.7 | 0.9 |
| 7.0 | 92.4 | 7.4 | 0.5 |
| 12.0 | 99.7 | 0.3 | 0.04 |

**Chart 6.—QUALITY CONTROL OF THE ASSEMBLY OF ENUMERATOR PORTFOLIOS: AVERAGE FRACTION INSPECTED**

(i = 75; f = 5 percent)

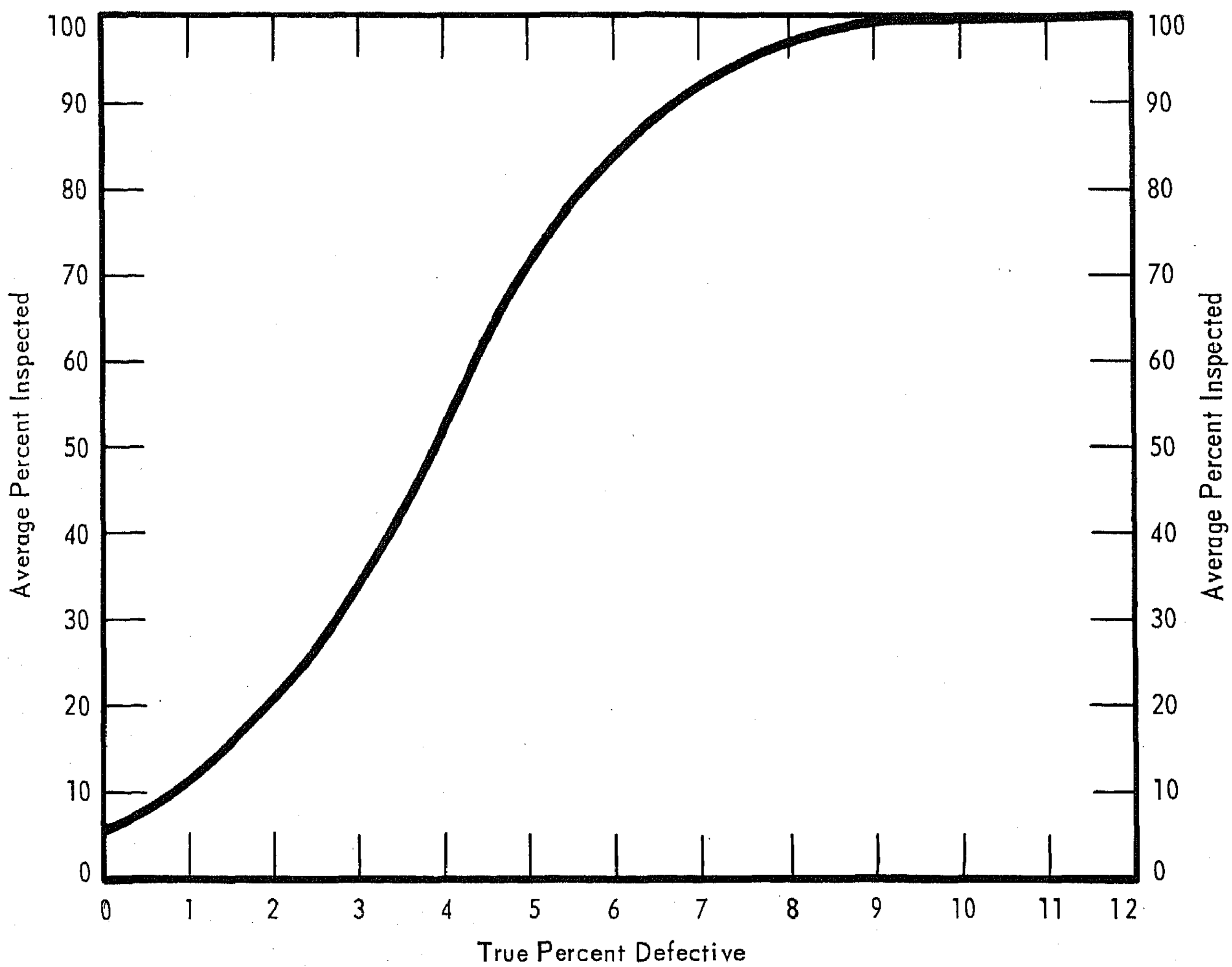
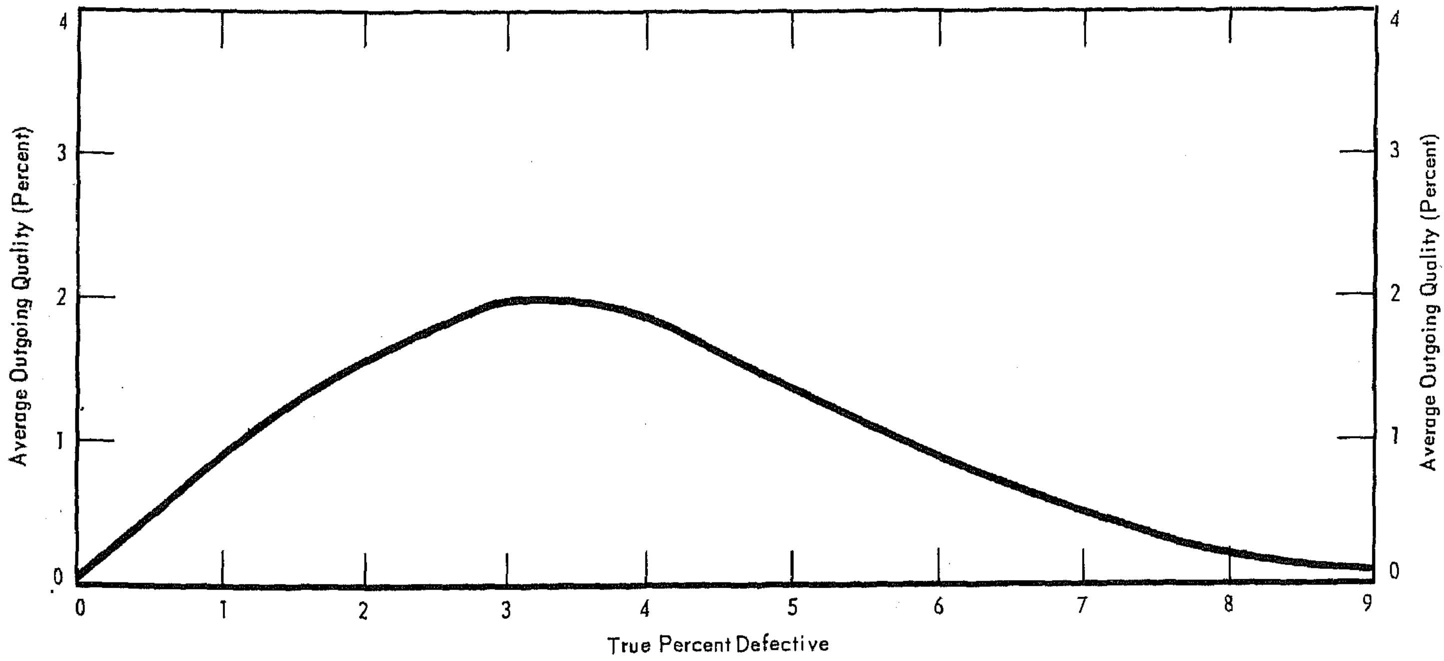


Chart 7.—QUALITY CONTROL OF THE ASSEMBLY OF ENUMERATOR PORTFOLIOS: AVERAGE OUTGOING QUALITY

(i = 75; f = 5 percent)




A total of 36,060 crew leader kits were subject to inspection. Of this number, about 9.7 percent were inspected. The process average was approximately 1 percent, and the inspection yielded an average outgoing quality of about 0.9 percent, as shown in table 16.

For purposes of the inspection plan, a defective portfolio or kit was defined as one containing (1) incorrect materials, i.e., the materials in the kit did not correspond to the official list of types and quantities of materials for each portfolio or kit, or (2) incorrectly addressed envelopes.

Summary

A summary of the quality control of the preparatory operations is provided in table 17.

Table 16.—PROCESS AVERAGE AND AVERAGE OUTGOING QUALITY RESULTING FROM CONTINUOUS PRODUCTION SAMPLING PLAN FOR QUALITY CONTROL OF ENUMERATOR PORTFOLIO AND CREW LEADER KIT ASSEMBLY

| Item | Enumerator portfolios | Crew leader kits |
|---|---|---|
| Number required | 169,114 | 36,137 |
| Number subject to inspection plan | 166,690 | 36,060 |
| Number inspected | 10,548 | 3,494 |
| 100-percent inspection | 2,330 | 1,780 |
| Sample inspection | 8,218 | 1,714 |
| Percent inspected | 6.3 | 9.7 |
| Process average, percent[1] | 0.2 | 1.0 |
| Average outgoing quality, percent[2] | 0.2 | 0.9 |

[1]Estimated from average fraction inspected curve.
[2]Computed by means of following formula: AOQ= (1 - AFI) x fraction defective.

Chart 8.—QUALITY CONTROL PLAN OF THE ASSEMBLY OF ENUMERATOR PORTFOLIOS: OPERATING CHARACTERISTIC CURVE, PERCENT EXPECTED TO BE PASSED UNDER SAMPLING

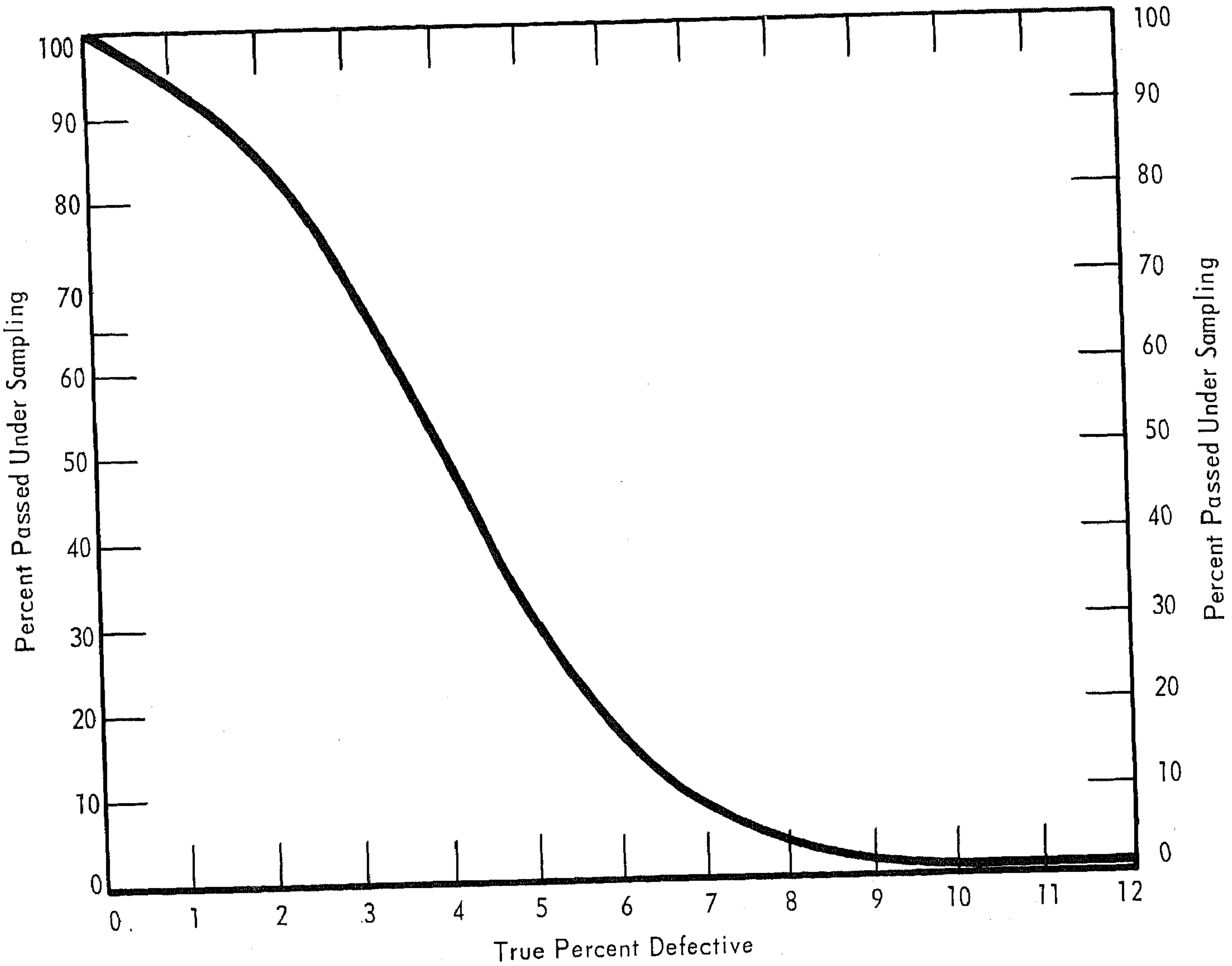


**Table 17.—SUMMARY OF QUALITY CONTROL OF PREPARATORY OPERATIONS**

| Operation | Unit | Workload | Sampling inspection | | | | | Rejected products | | Average outgoing quality (percent) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Type of plan | Sampling unit | Number in sample | Number defective | Process average (percent) | Number | Percent | |
| Printing.............. | Schedule[1] | 56,712,000 | Hybrid-process control and acceptance | Pairs of page positions | 11,400 | 255 | 2.2 | [2]1,449,000 | [2]2.6 | (3) |
| Fronts............. | .......... | .......... | ......... | ......... | ....... | 60 | 0.5 | .......... | ..... | ......... |
| Backs.............. | .......... | .......... | ......... | ......... | ....... | 195 | 1.7 | .......... | ..... | ......... |
| Cutting............... | Schedule[1] | 54,472,000 | ......... | ......... | ....... | ...... | ....... | 389,000 | 0.7 | (3) |
| Collation of 5-percent and 20-percent sample schedules. | Schedule[1] | 37,505,000 | Lot acceptance[4] | Unit of 5 schedules | 358,940 | 973 | 0.3 | (5) | (5) | 0.3 |
| Assembly (spooning operation. | Books | 956,400 | Process control | Book | 7,178 | 127 | 1.8 | .......... | ..... | ......... |
| Bookbinding........... | Books | 956,400 | Continuous production sampling plan | Book | [6]44,853 | (7) | 1.7 | .......... | ..... | 1.6 |
| Enumerator portfolios.. | Kits | 169,114 | (same) | Portfolio | [6]10,548 | (7) | 0.2 | .......... | ..... | 0.2 |
| Crew leader kits....... | Kits | 36,137 | (same) | Kit | [6]3,494 | (7) | 1.0 | .......... | ..... | 0.9 |

[1]Front and back impression.
[2]In addition to these schedules rejected as a result of sampling inspection, 669,000 (1.2 percent) were rejected because of printing defects identified by the Government Printing Office; 90,000 (0.1 percent) were rejected because of blurred and upside-down printing; and 32,000 (0.1 percent) were rejected because of shipping damage.
[3]Zero systematic error; unknown random error.
[4]806 lots, or 161,200 units consisting of one 5-percent and four 20-percent schedules, were inspected on 100-percent basis prior to beginning sampling plan.
[5]Estimated 1,077 lots corrected, about 3-percent of lots inspected (based on expected percent of lots rejected when true percent defective is 0.3 percent).
[6]Includes number inspected on 100-percent basis and on sample basis.
[7]Not required for estimating process average.

## III. QUALITY CONTROL OF MICROFILMING OPERATIONS

After completion of the field work for the 1960 censuses, the enumeration books containing the completed schedules were sent to the Decennial Census Operations Office in Jeffersonville, Ind., for check in, coding of some of the sample items on stage II schedules, and microfilming. The stage I schedules were microfilmed first, while the responses on the stage II schedules were being coded. Twenty-six cameras were assigned to microfilming stage I schedules; for stage II schedules, the number of cameras was reduced to 22. Cameras were operated on a two-shift basis. When microfilming work units were completed, they were shipped by air to a commercial company in Washington, D.C., for developing under controlled conditions before being fed into FOSDIC.

A sequence of controls was instituted to insure that the quality of the filming process met the standards required for the successful operation of FOSDIC.

The elements of the quality control program for the microfilming were directly related to the sequence of steps taken by FOSDIC in accepting or rejecting a frame of microfilmed census schedule on the basis of various electronic reading checks and adjustments: (1) FOSDIC checked the position of the microfilmed schedule sheet by adjusting on the tilt marks at the left-hand edge of the sheet, (2) checked for gain and background (related to contrast and density of the film), (3) checked for vertical alinement by adjusting on the index marks at the top of the sheet, (4) checked smaller black index marks on the left-hand edge for horizontal alignment of the sheet, and (5) checked the circles located in a specific area of the sheet for proper threshold. If the result of these checks fell within machine tolerances, FOSDIC proceeded to scan the sheet for information.

If the distance between adjacent exposures was too narrow, FOSDIC could not adjust for reading and would skip over frames until it came to a frame where it could adjust, resulting in a loss of the information on the schedules in the omitted frames. For control of the spacing, the distance between exposures was required to be 3.5 inches plus or minus 1 inch (on microfilm the distances are about 1/28th of these dimensions). This requirement was imposed during tests conducted before a camera was accepted for production. During microfilm production, at least once during each work shift, a "dip test," which consisted of exposing and developing a small test reel of microfilm at the camera site, was conducted for each camera. The film was inspected for proper camera focus, camera alignment, and other factors. However, major emphasis was placed upon the results of measurements of a random sample of spaces between adjacent frames.

The density of the film was required to be within prescribed tolerance limits so that an impulse indicating that a circle had been read would be transmitted to the FOSDIC counter. This signal was contingent upon the degree to which incident light was transmitted through the film. The time limit between exposure and development had to be controlled closely in order to prevent a drop in density sufficient to bring it below specification limits.

At the end of each reel of microfilm an exposure was made of a gray scale with four chips of graduations of known reflectance. The end of the reel, containing the exposures of the chips, was cut off after film development and a check was made of the density of the chips on a densitometer. Density readings were plotted against reflectance to determine if contrast had deteriorated. When contrast deterioration was encountered, action was taken to correct it; experience indicated that under most circumstances cleaning of the lens would restore proper contrast.

As a check on operator performance during the initial weeks of the camera operation, a sample of reels was designated for first priority of developing and FOSDIC reading; then visual inspection of each reel was made for such operator defects as filming of hands, filming books upside down, missed data sheets, etc.

## Research on Camera Performance

About 6 months prior to the census, studies were conducted to provide information on the behavior of the type of photographic equipment selected for microfilming the decennial census schedules. Preliminary findings were obtained on the behavior of one camera with respect to spacing between exposures and density of film exposures.

Spacing between exposures.—Tests were made to ascertain whether or not the camera could be made to provide approximately uniform distances between exposures, within predictable limits for sustained performance.

It was important that the camera behave in a controlled manner in the spacing of exposures for two basic reasons: (1) Unless there were at least 2.5 inches between frames, FOSDIC would skip one or a number of exposures; and (2) if spacing were not relatively uniform, work units for processing could not be standardized and consequently film would not be used efficiently.

Three tests of the camera in Washington were made to determine if it could be set by the camera technician to provide approximately uniform distances between exposures. In conducting the test, a stage I enumeration book consisting of 50 pages was placed on the microfilm camera bed. The technician set the camera at the position that he deemed appropriate to provide spacing between exposures of the same size as the space under the shadow bar. This process of adjusting the spacing mechanism is not a precise one but involves trial and error. When in the judgment of the technician the machine was set properly, the reels were run. A reel containing 106 feet of film was loaded into the camera. Allowing 2 feet of film for threading and eight cranks and one blank exposure to prevent fogging, approximately 100 feet of film were available for exposure. Each completed reel provided about 900 exposures from which a sample of spaces was selected for measurement.

For the first test, the camera was set for an average spacing of 2.5 inches between exposures. Five reels of film were exposed to the same two pages of the enumeration book. The operator used the foot pedal for each exposure. After the film was developed, every 30th space was measured to the nearest 1/1000th of a millimeter. Two persons measured each of the sample spaces independently. The first person notched each space he measured, enabling the second person to locate the same space.

The results of this first test showed that the mean spacing between exposures in each reel was lower than the target of 2.5 inches, with the mean for each successive reel lower than the last one (see table 18). As the foot

**Table 18.—MEAN SPACING BETWEEN EXPOSURES IN MICROFILMING TEST**

(Inches)

| Reel number | Test 1 | | | | Test 2 | | | | Test 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number of spaces measured | Operator 1 | Operator 2 | Mean | Number of spaces measured | Operator 1 | Operator 2 | Mean | Number of spaces measured | Operator 1 | Operator 2 | Mean |
| 1 | 30 | 2.11 | 2.13 | 2.125 | 29 | 3.47 | 3.48 | 3.475 | 26 | 3.57 | 3.60 | 3.590 |
| 2 | 30 | 1.99 | 2.03 | 2.008 | 29 | 3.50 | 3.50 | 3.496 | 28 | 3.51 | 3.58 | 3.545 |
| 3 | 30 | 1.72 | 1.73 | 1.725 | 29 | 3.14 | 3.17 | 3.152 | 28 | 3.66 | 3.68 | 3.675 |
| 4 | 30 | 1.57 | 1.54 | 1.555 | 29 | 3.43 | 3.46 | 3.445 | 29 | 3.69 | 3.72 | 3.705 |
| 5 | 30 | 1.45 | 1.46 | 1.457 | 29 | 2.69 | 2.67 | 2.683 | 25 | 3.74 | 3.72 | 3.730 |
| Mean | ........ | 1.768 | 1.779 | 1.774 | ........ | 3.246 | 3.254 | 3.250 | ........ | 3.63 | 3.66 | 3.645 |
| | Standard deviations | | | | | | | | | | | |
| 1 | 30 | 0.38 | 0.30 | 0.343 | 29 | 0.13 | 0.12 | 0.124 | 26 | 0.09 | 0.12 | 0.102 |
| 2 | 30 | 0.17 | 0.18 | 0.175 | 29 | 0.26 | 0.24 | 0.255 | 28 | 0.14 | 0.11 | 0.125 |
| 3 | 30 | 0.27 | 0.36 | 0.320 | 29 | 0.32 | 0.32 | 0.322 | 28 | 0.22 | 0.23 | 0.225 |
| 4 | 30 | 0.21 | 0.20 | 0.207 | 29 | 0.27 | 0.27 | 0.272 | 29 | 0.24 | 0.22 | 0.228 |
| 5 | 30 | 0.18 | 0.17 | 0.175 | 29 | 0.33 | 0.24 | 0.288 | 25 | 0.23 | 0.24 | 0.236 |
| Mean | ........ | 0.254 | 0.253 | 0.254 | ........ | 0.276 | 0.247 | 0.262 | ........ | 0.184 | 0.181 | 0.183 |
| Adjusted sample standard deviation* | ........ | ..... | ..... | 0.215 | ........ | ..... | ..... | 0.286 | ........ | ..... | ..... | 0.190 |

*Out-of-control sample standard deviation eliminated.

pedal was continuously used in taking exposures during this test, the decreasing gap between exposures was perhaps in part a reflection of a tendency on the part of the operator to decrease the time between exposures.

For the second test, the camera was set for an average spacing of 3.0 inches between exposures. The operator turned each page of the enumeration books and used a hand switch for each exposure. In other respects, the second test was the same as the first. After measurement of the sample of spacing between exposures, it was found that the means of the spacing for the reels were outside the control limits.

For the third test, the camera was set for an average spacing of 3.5 inches between exposures. In other respects, the third test was the same as the second with one exception: The roller was cleaned before each reel was filmed. In this test, all reel means were in control with the exception of one, which was suspect of measurement error since the mean for operator number 2 for the same reel was within control limits. In general, the process appeared to be approaching a better state of control, with a reduction in the standard deviation and with reel means within control limits.

Test results were from one camera, and each constituted less than 1 day's production run. The results could not be deemed representative of occurrences during an extended production run. When results of the three tests were analyzed, there was some doubt as to the ability to control spacing within narrow limits even though there appeared to be a tendency toward control in the last test. Under production conditions, the roller would not be cleaned thoroughly before each run, with the consequence that it would eventually become coated with emulsion salts and the film output would not be uniform. The initial setting for a mean spacing was not precise but was subject to trial and error.

In view of these considerations, and unless results from the acceptance tests to be run on a number of cameras dictated otherwise, it was recommended that the camera be set for a mean spacing such that the gap between exposures was not likely to be less than 2.5 inches. In terms of spacing on the microfilm, this amounted to about 1/28th of a mean of 3.5 inches. If an estimate of the standard deviation of 0.3 inches were used, three sigma would be at a lower limit of about 2.5 inches. If greater safety had been required, the mean would have had to be raised.

Density of film exposure.—Control charts were maintained to determine if density values obtained from the developed film used for the FOSDIC stage of inspection of printed forms fell within tolerance limits of 0.80 to 1.00. Finally, an analysis was made of the relationship between density and (1) illumination as measured by foot-candles, (2) voltage, and (3) the combined effect of illumination and voltage.

For purposes of proper operation of FOSDIC, tolerance limits for controlling the density of microfilm were tentatively established at 0.9 ± 0.1. These limits presumably provided a safety zone since densities as low as 0.6 and as high as 1.2 are at times acceptable to FOSDIC. Limits were changed to 0.9 ±0.15 prior to the filming of the actual census schedules.

Some of the factors which can affect density readings are the following:

Shutter speed.—The shutter speed on the type of camera used was preset at 0.042 seconds. Variation in shutter speed could affect density readings by a factor of ± 0.02. For practical purposes, this factor was treated as a constant.

Illumination level.—This variable is of importance in density readings. Control was through a light meter called a "barrier layer" photovoltaic cell. This consisted of a layer of a semiconductor between two metallic layers, the upper layer being either a grid or a transparent metallic film (gold, platinum, etc.). Light incident on these cells set up a potential that caused current to flow in the external circuit. The measure of illumination was in lumens per square foot or in foot-candles.

Developing solution.—The concentration, the temperature, and other elements in the development of exposed microfilm have an effect on density. However, this factor was controlled in the development laboratory of the camera company.

Type of paper.—The type of paper in the printing process was uniform, and its quality was controlled.

Extraneous light.—This factor was controlled by covering windows and other inlets of light.

Overhead light and type of camera bulb.—Light which increases the light intensity will affect the density reading. Results of tests indicated that fluorescent camera bulbs as contrasted with normal camera bulbs would increase density readings.

Camera lens.—Dirt and other extraneous matter on the lens affect the exposure and consequently the density. A set of rules for cleaning the lenses was devised and uniformly applied.

Voltage.—This constitutes input to illumination level, and if maintained at relatively uniform level the effect on density will be negligible. Fluctuations in voltage, however, can affect density, as test results showed.

Latent image fade.—The latent image is the image on the film in the interval between taking the photograph and developing the film. The density drops with time. The problem was one of scheduling the shipment of film from Jeffersonville so that the elapsed time between exposure in Jeffersonville and development in Washington would provide a density reading within tolerance limits.

It was found that changes in the camera operators' clothing affected the density, so that, for production microfilming, gray smocks were rented for the operators.

The tolerance limits for FOSDIC density were tentatively established between 0.8 and 1.0. A set of five randomly spaced exposures was selected from each roll of film used in the quality control inspection of the printing of census schedules. These selected exposures were read on the densitometer. Exposure was made at 50 foot-candles, and the temperature of the developing solution was read at approximately 80°F. The development of the film was under the same conditions.

For testing the density of the film, the blank sides of some FOSDIC schedules which had been printed on one side only were microfilmed. This permitted observation of the extent to which printing on the reverse side of the sheet showed through and affected the microfilmed image.

Table 19 shows the 40 samples of five readings from October 9 through November 11, 1959. Two sets of readings were taken each day. Density readings were read accurately to the nearest 0.01.

Two control charts were maintained to provide a graphic presentation of the success of the process in providing uniform density within tolerance specifications. On one, the average of a sample of five density readings was plotted at regular intervals (see chart 10). On the other, the range of the sample of five density readings was plotted at regular intervals (see chart 9).

Analysis of the control chart for film density ranges revealed the following:

1. The average range as computed from the 40 samples was less than the maximum allowable range. This indicated that the variation in the density of film from exposure to exposure was small enough to meet the tolerance specifications.

2. The ranges of samples of five fell within the upper range limit, providing evidence of stability in process variability.

**Table 19.—DENSITY READINGS OF SAMPLE OF MICROFILMED BLANK SIDES OF FOSDIC SCHEDULES 2 TO 4 HOURS AFTER EXPOSURE**

(Exposure at 50 foot-candles; temperature of development solution, 80°F.)

| Sample No. | Readings[1] | | | | | Mean | Range |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | |
| 1 | .91 | .91 | .94 | .94 | .97 | .934 | .06 |
| 2 | .82 | .82 | .82 | .87 | .84 | .834 | .05 |
| 3 | .87 | .88 | .88 | .98 | .90 | .902 | .11 |
| 4 | .85 | .87 | .88 | .87 | .87 | .868 | .03 |
| 5 | .95 | .90 | .91 | .91 | .96 | .926 | .06 |
| 6 | .88 | .89 | .87 | .82 | .89 | .870 | .07 |
| 7 | .93 | .92 | .89 | .93 | .91 | .916 | .04 |
| 8 | .94 | .95 | .92 | .96 | .95 | .944 | .04 |
| 9 | .82 | .83 | .83 | .79 | .81 | .816 | .04 |
| 10 | .83 | .87 | .88 | .88 | .86 | .864 | .05 |
| 11 | .79 | .82 | .80 | .81 | .81 | .806 | .03 |
| 12 | .84 | .82 | .83 | .85 | .85 | .838 | .03 |
| 13 | .87 | .88 | .85 | .85 | .86 | .862 | .03 |
| 14 | .81 | .81 | .83 | .83 | .84 | .824 | .03 |
| 15 | .86 | .88 | .88 | .90 | .94 | .892 | .08 |
| 16 | .95 | .95 | .95 | 1.02 | .93 | .960 | .09 |
| 17 | .87 | .91 | .95 | .96 | .96 | .930 | .09 |
| 18 | .93 | 1.03 | .98 | .98 | 1.04 | .992 | .11 |
| 19 | .97 | .94 | .95 | .96 | .97 | .958 | .03 |
| 20 | .88 | .89 | .88 | .90 | .92 | .894 | .04 |
| 21 | .97 | .94 | .95 | .96 | .96 | .956 | .03 |
| 22 | .95 | .95 | .94 | .95 | .96 | .950 | .02 |
| 23 | .87 | .84 | .83 | .87 | .90 | .862 | .07 |
| 24 | .80 | .82 | .80 | .88 | .85 | .830 | .08 |
| 25 | .80 | .84 | .83 | .86 | .90 | .846 | .10 |
| 26 | .82 | .82 | .84 | .87 | .89 | .848 | .07 |
| 27 | .87 | .92 | .89 | .90 | .92 | .900 | .05 |
| 28 | .79 | .84 | .85 | .87 | .83 | .836 | .08 |
| 29 | .81 | .80 | .85 | .85 | .90 | .842 | .10 |
| 30 | .86 | .89 | .87 | .84 | .84 | .860 | .05 |
| 31 | .86 | .84 | .89 | .88 | .89 | .872 | .05 |
| 32 | .87 | .88 | .86 | .87 | .87 | .870 | .02 |
| 33 | .78 | .78 | .80 | .84 | .84 | .808 | .06 |
| 34 | .85 | .85 | .85 | .85 | .85 | .850 | .00 |
| 35 | .82 | .82 | .84 | .80 | .81 | .818 | .04 |
| 36 | .84 | .82 | .81 | .83 | .83 | .826 | .03 |
| 37 | .88 | .80 | .86 | .89 | .88 | .862 | .09 |
| 38 | .88 | .88 | .87 | .89 | .88 | .880 | .02 |
| 39 | .84 | .85 | .86 | .86 | .86 | .854 | .02 |
| 40 | .87 | .80 | .84 | .86 | .87 | .848 | .07 |
| Mean | ... | ... | ... | ... | ... | .876 | .054 |

[1]Ratio of the amount of light at the film surface to the light passing through the film, expressed in logarithmic scale.

Chart 9.—CONTROL CHART OF RANGE OF FILM DENSITY READINGS

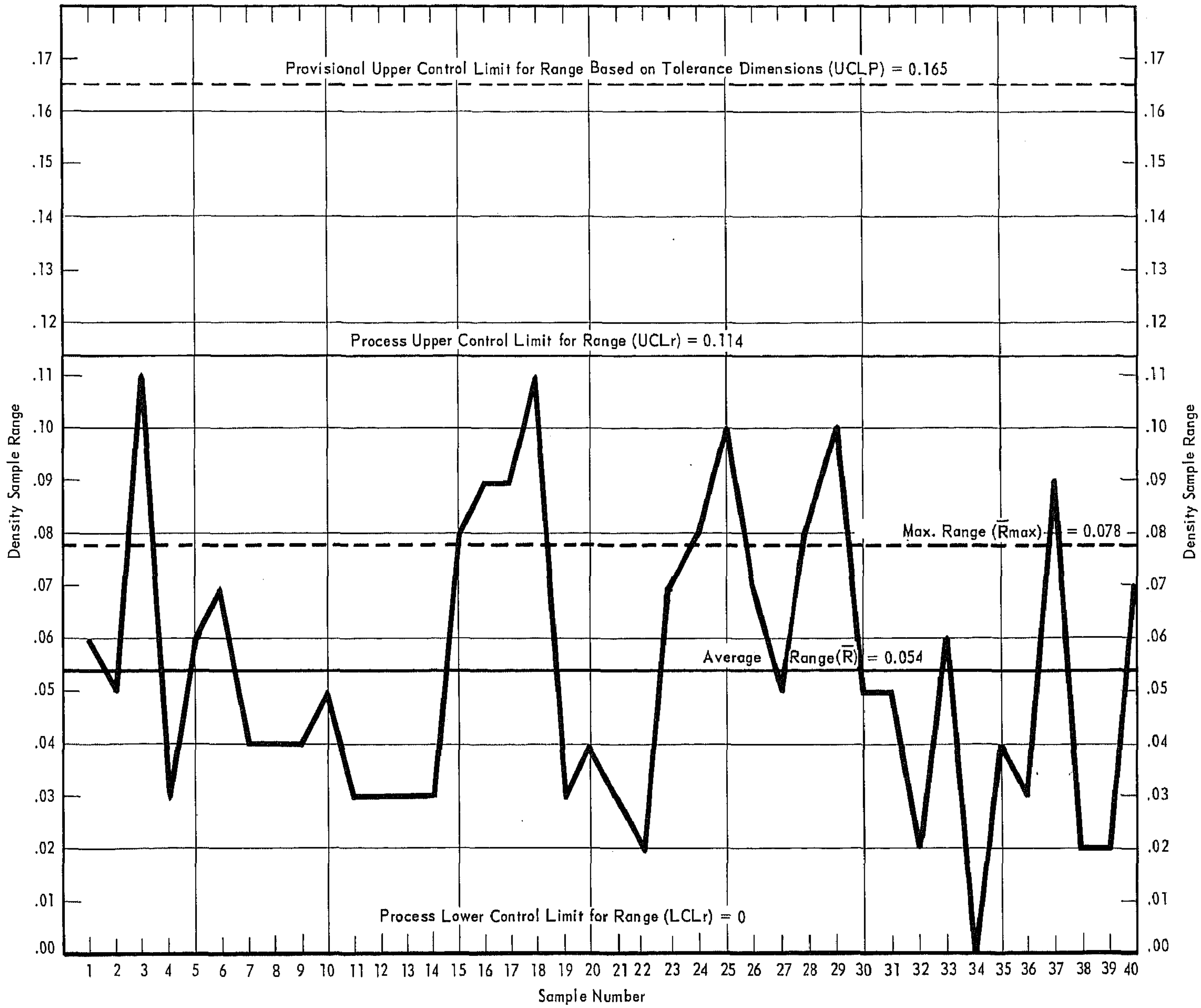
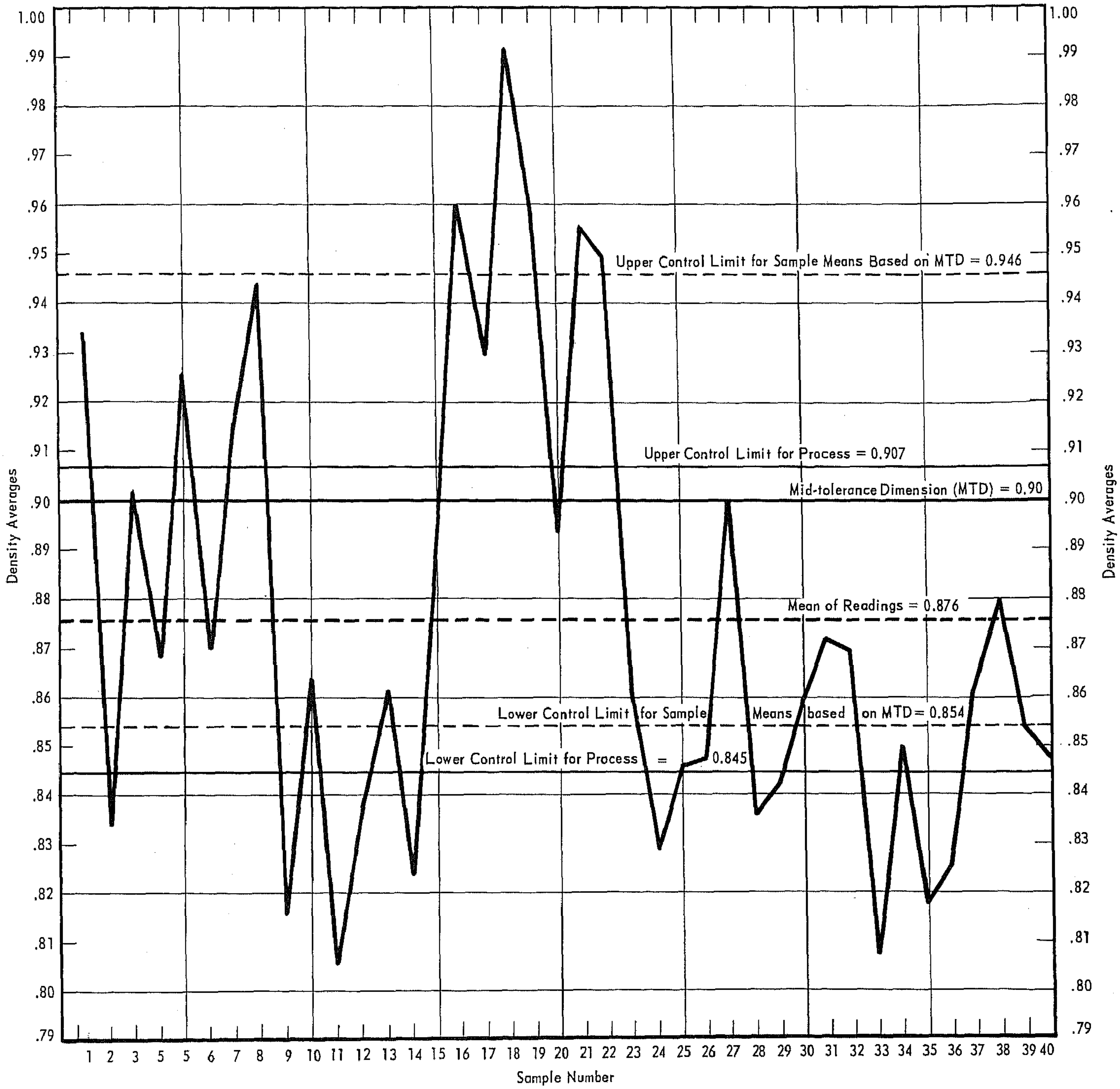


Chart 10.—CONTROL CHART OF AVERAGES (MEANS) OF FILM DENSITY READINGS



Analysis of the control chart for film density averages showed that—

1. The mean of the averages was considerably below the mid-tolerance dimension, indicating that the level at which the variables affecting density were controlled might be set too low.

2. The averages of samples of five fell below and exceeded the control limits for averages based on the process itself and for limits based on specifications. Thus, there was evidence of some assignable cause of variation preventing uniformity in behavior in the process.

3. There were test runs above and below the overall mean.

4. Of the 200 sample readings, 5 (2.5 percent) were less than 0.8, and 3 (1.5 percent) were 1.0. These runs provided additional evidence of variables in the camera process—wiping of the lens, illumination, etc.—which were not controlled.

Relationship of density, illumination, and voltage.—Sixty-five readings were taken on three variables: density (dependent variable), illumination as measured by foot-candles (independent variable), and voltage (independent variable). The following external conditions were maintained at constant levels: (1) Temperature of the room during exposure of the film was maintained at approximately 74° F.; (2) The time lapse between exposure of the film and development was 5-1/2 hours; (3) The camera was cleaned prior to photographing; (4) The temperature of the developing room at the commercial developing company was 75° F.; and (5) The developing solution was tested at a temperature of 80° F. Table 23 shows recorded readings of density for each variation in foot-candles and voltage.

A simple regression model was used to measure the expected change in density associated with a unit change in foot-candles or in voltage. Results of the study are as follows (see also tables 20, 21, and 22):

| Independent variable | Average change in density associated with unit change in independent variable | 95-percent confidence limits[1] | |
|---|---|---|---|
| | | Lower | Upper |
| Voltage.......... | .037 | .035 | .038 |
| Illumination..... | .032 | .031 | .033 |

[1]The true value of the regression coefficient is expected to be within the confidence limits shown in 95 percent of the bands computed from samples similarly selected under the conditions of the experiment.

Evidence from the study emphasized the importance of variation in voltage and illumination in explaining variation in density. However, as the independent variables were highly correlated and over 99 percent of the variation in foot-candles was explained by variation in voltage, emphasis was placed upon control of illumination because voltage could be controlled within small limits by use of a voltage stabilizer. Furthermore, it was evident from the experiment that variation in illumination within plus or minus 4 foot-candles would provide acceptable gray-scale readings.

**Table 20.—REGRESSION OF DENSITY ON VOLTAGE AND ON FOOT-CANDLES**

| Item[1] | Density ($X_3$) and voltage ($X_1$) | Density ($X_3$) and foot-candle power ($X_2$) |
|---|---|---|
| Square of correlation coefficient.............. | 0.99014 | 0.98917 |
| Correlation coefficient........................ | 0.99506 | 0.99457 |
| Unexplained variation.......................... | 0.00986 | 0.01083 |
| Sum of squares of the residuals................ | 0.03706 | 0.04071 |
| Estimated variance............................. | 0.00059 | 0.00065 |
| Regression coefficient......................... | 0.03676 | 0.03196 |
| Standard error of regression coefficient....... | 0.00046 | 0.00042 |
| Standard error of mean density................. | 0.00300 | 0.00315 |
| Standard error of constant..................... | 0.02720 | 0.01961 |
| Estimating equation............................ | $-1.24911 + 0.03676X_1$ | $-0.55326 + 0.03196X_2$ |

[1]See appendix for formulas.

**Table 21.—ANALYSIS OF VARIANCE OF VARIATION IN DENSITY EXPLAINED BY REGRESSION**

| Source of variation | Degrees of freedom | Density on voltage | | | Density on foot-candles | | |
|---|---|---|---|---|---|---|---|
| | | Sums of squares | Mean square | F[1] | Sums of squares | Mean square | F[1] |
| Regression.......... | 1 | 3.72194 | 3.72194 | 6308 | 3.71829 | 3.71829 | 5720 |
| Error............... | 63 | 0.03706 | 0.00059 | ....... | 0.04071 | 0.00065 | ....... |

[1]See appendix for formulas.

**Table 22.—RELATIONSHIP OF DENSITY, ILLUMINATION, AND VOLTAGE**

(Room temperature during photographing, 74°F; room temperature in development, 75°F; temperature of development solution, 80°F; time lapse between exposure and development, 5-1/2 hours; camera cleaned prior to photographing)

| Reading No. | Density after development ($X_3$) | Foot-candles at exposure ($X_2$) | Voltage at exposure ($X_1$) | Reading No. | Density after development ($X_3$) | Foot-candles at exposure ($X_2$) | Voltage at exposure ($X_1$) |
|---|---|---|---|---|---|---|---|
| 1........ | 0.52 | 34 | 48 | 36........ | 0.97 | 48 | 60 |
| 2........ | 0.51 | 34 | 48 | 37........ | 0.97 | 48 | 60 |
| 3........ | 0.50 | 34 | 48 | 38........ | 0.97 | 48 | 60 |
| 4........ | 0.51 | 34 | 48 | 39........ | 0.98 | 48 | 60 |
| 5........ | 0.50 | 34 | 48 | 40........ | 0.97 | 48 | 60 |
| 6........ | 0.56 | 36 | 50 | 41........ | 1.06 | 50 | 62 |
| 7........ | 0.57 | 36 | 50 | 42........ | 1.06 | 50 | 62 |
| 8........ | 0.56 | 36 | 50 | 43........ | 1.07 | 50 | 62 |
| 9........ | 0.56 | 36 | 50 | 44........ | 1.06 | 50 | 62 |
| 10........ | 0.56 | 36 | 50 | 45........ | 1.07 | 50 | 62 |
| 11........ | 0.65 | 38 | 52 | 46........ | 1.14 | 52 | 64 |
| 12........ | 0.64 | 38 | 52 | 47........ | 1.13 | 52 | 64 |
| 13........ | 0.65 | 38 | 52 | 48........ | 1.11 | 52 | 64 |
| 14........ | 0.66 | 38 | 52 | 49........ | 1.11 | 52 | 64 |
| 15........ | 0.65 | 38 | 52 | 50........ | 1.11 | 52 | 64 |
| 16........ | 0.75 | 40 | 54 | 51........ | 1.17 | 54 | 66 |
| 17........ | 0.75 | 40 | 54 | 52........ | 1.15 | 54 | 66 |
| 18........ | 0.75 | 40 | 54 | 53........ | 1.16 | 54 | 66 |
| 19........ | 0.75 | 40 | 54 | 54........ | 1.15 | 54 | 66 |
| 20........ | 0.75 | 40 | 54 | 55........ | 1.16 | 54 | 66 |
| 21........ | 0.85 | 42 | 56 | 56........ | 1.22 | 56 | 68 |
| 22........ | 0.84 | 42 | 56 | 57........ | 1.22 | 56 | 68 |
| 23........ | 0.85 | 42 | 56 | 58........ | 1.21 | 56 | 68 |
| 24........ | 0.83 | 42 | 56 | 59........ | 1.21 | 56 | 68 |
| 25........ | 0.83 | 42 | 56 | 60........ | 1.21 | 56 | 68 |
| 26........ | 0.86 | 44 | 58 | 61........ | 1.30 | 58 | 69 |
| 27........ | 0.86 | 44 | 58 | 62........ | 1.26 | 58 | 69 |
| 28........ | 0.87 | 44 | 58 | 63........ | 1.29 | 58 | 69 |
| 29........ | 0.85 | 44 | 58 | 64........ | 1.29 | 58 | 69 |
| 30........ | 0.84 | 44 | 58 | 65........ | 1.29 | 58 | 69 |
| 31........ | 0.95 | 46 | 59 | Total..... | 59.60 | 2990 | 3830 |
| 32........ | 0.95 | 46 | 59 | Mean...... | 0.9169 | 46.0000 | 58.9231 |
| 33........ | 0.93 | 46 | 59 | | | | |
| 34........ | 0.93 | 46 | 59 | Standard | | | |
| 35........ | 0.94 | 46 | 59 | deviation | 0.2405 | 7.4833 | 6.5099 |

Latent image fade.—The latent image fade is the decrease in density of the film in the interval between exposure and development. Five sets of readings were made at approximately 2-hour intervals. Tables 23 and 24 show mean density and decrements in density at various levels of illumination for 8-hour intervals beginning 24 hours after the film was exposed:

**Table 23.—MEAN DENSITY OF MICROFILM AT DIFFERENT INTERVALS AFTER EXPOSURE WITH DIFFERENT ILLUMINATION**

| Illumination (foot-candles) | Length of time after exposure | | | |
|---|---|---|---|---|
| | 24 hours | 32 hours | 40 hours | 48 hours |
| 74.5............. | 1.30 | 1.26 | 1.23 | 1.22 |
| 70.5............. | 1.20 | 1.16 | 1.13 | 1.12 |
| 65.5............. | 1.07 | 1.04 | 1.02 | 1.01 |
| 60.5............. | 0.95 | 0.90 | 0.88 | 0.87 |
| 55.5............. | 0.81 | 0.79 | 0.77 | 0.76 |
| 50.0............. | 0.68 | 0.64 | 0.62 | 0.60 |

Note.--Density is the ratio of the amount of light at the film surface to the light passing through the film, expressed in logarithmic scale.

**Table 24.—DECREMENTS IN DENSITY OF MICROFILM BY 8-HOUR INTERVALS**

| Illumination (foot-candles) | Total, 24 to 48 hours | Hours | | |
|---|---|---|---|---|
| | | 24 to 32 | 32 to 40 | 40 to 48 |
| 74.5............. | 0.08 | 0 04 | 0.03 | 0.01 |
| 70.5............. | 0.08 | 0.04 | 0.03 | 0.01 |
| 65.5............. | 0.06 | 0.03 | 0.02 | 0.01 |
| 60.5............. | 0.08 | 0.05 | 0.02 | 0.01 |
| 55.5............. | 0.05 | 0.02 | 0.02 | 0.01 |
| 50.0............. | 0.08 | 0.04 | 0.02 | 0.02 |

It appeared that approximately 32 hours between exposure in Jeffersonville and development at the camera company in Washington would provide a mean density of 0.90, if the illumination was set at approximately 60.5 foot-candles.

Findings.—A brief summary of findings of research on camera performance is presented below:

1. The thorough cleaning of the camera rollers before mounting each new reel of film seemed to stabilize the variation in the space between exposures and the mean space between reels.

2. The camera technicians could adjust the camera by trial and error, within a reasonably short time, using the dip test, to provide a spacing between exposures reasonably close to a given specification.

3. The commercial development laboratory had demonstrated that their development process was under control.

4. The range of density within reels indicated that the specification of ± 0.1 density could be maintained under process control.

5. The variation in the mean density between reels indicated that elements affecting this phenomenon were not under control. These elements were illumination (foot-candles), voltage, and time lag between exposure and development.

6. There was some evidence that the effect of time lag between exposure and development leveled off after 24 hours.

Recommendations.—The above findings were based on tests run over short periods of time on one camera. It was recommended that additional studies be conducted over longer periods of sustained operation with more cameras. It was recommended also that studies be made for the following specific purposes:

1. To arrive at specifications for illumination, normal expected time between exposure of film, control and packaging, shipping from Jeffersonville, Ind., to Washington, D.C., and unpackaging and development, and frequency with which dip tests should be taken to maintain camera control on spacing and focus.

2. To determine the relative accuracy of the buzzer alarm system on the camera which indicated when a given footage of unused film remained on the reel, and, in addition, as part of this study, to determine the average number of exposures to be taken on each reel.

On the basis of the experience gained during the tests, the following recommendations were made:

1. Camera operating instructions with a check list of important steps should be developed and tested.

2. An investigation should be made of available measuring instruments to facilitate fast and accurate measurements of spacing between exposures.

3. The availability of developing equipment for fast development of the short footage of film used for a dip test should be investigated.

4. Once density readings were in control in relation to the illumination provided by the camera lights, the overhead lights should be disconnected or removed to eliminate risk of having them turned on during filming.

### January 1960 Pilot Study

In January 1960, a pilot study was conducted to test under simulated operating conditions the plans and procedures to be applied during the 1960 censuses. One phase of this study was a test of proposed quality control plans for the cameras and the microfilming. Results from two areas of this operation which were of interest involved (1) control of spacing between adjacent exposures, and (2) measurements of gray-scale density (88.8-percent reflectance chip) as a predictor of the density of exposures within the reel.

The first phase of the pilot study consisted of filming and running through FOSDIC a total of 116 reels distributed among four cameras. The distances between adjacent exposures were maintained with considerable success. Tolerance dimensions were the same as those proposed for census processsing (3.5 inches ± 1 inch). Of 2,460 measurements made from the production of the four cameras (random samples of five measurements selected from each third of a reel), only two measurements were outside tolerances. In the case of the camera which had two measurements below tolerance, the dip test conducted prior to running the fourth production reel had shown the third sample measurement to be below tolerance. However, the person conducting the test was not fully aware of its purpose or the action to be taken, and consequently the camera was not immediately adjusted. The camera was taken out of production and the spacing corrected when the results of the dip test were reviewed. Beginning with the fifth reel produced on the camera, spacing measurements were in tolerance.

Measurement of density.—The density of each reel produced in the pilot study was measured on the basis of (a) the 88.8 percent reflectance chip of the gray scale microfilmed at the end of each reel, and (b) an exposure selected from the reel. The reflectance of the FOSDIC schedules was approximately the same as the 88.8 percent reflectance chips.

Analysis of the regression of schedule readings on gray-scale readings indicated that gray-scale readings explained from 73.3 percent of variation in document density for camera C to 86.2 percent of the variation for camera A (see table 25). The gray-scale density measurement was sufficiently correlated with schedule density to provide an indicator of the acceptability of a reel for FOSDIC processing.

Correlation coefficents range from 0.93 for camera A to 0.86 for camera C. Statistical test indicated that differences between them were due to sampling fluctuation, and consequently they were estimates of a common population correlation coefficient.

### Dip Tests

The dip test of the microfilm was designed as a precautionary control to insure that the camera equipment was functioning properly, that technicians were preparing the equipment for filming in accordance with instructions, and that camera operators were doing their job in accordance with established procedures. A dip test was made once during each 8-hour production shift in accordance with a time schedule established for each camera. A test reel of microfilm consisting of 46 exposures of FOSDIC schedules, an identification plate, and several reproductions of a template for testing tilt of the exposures was filmed.

The test film was developed in a dark room set aside in the building where the cameras were operating. When the strip of test film was developed it was given to the camera technician who placed it on the film reader. The film strip was first turned to the filmed identification information, from which the camera number, work unit, dip-test number, and other data were recorded on a form. The film strip was then rewound to the beginning and inspected

**Table 25.—REGRESSION OF SCHEDULE DENSITY ON GRAY-SCALE DENSITY: JANUARY 1960 PILOT STUDY**

| Item[1] | Camera A | Camera B | Camera C | Camera D |
|---|---|---|---|---|
| Number of readings | 28 | 29 | 32 | 27 |
| Mean gray-scale density | 0.8875 | 0.8907 | 0.8944 | 0.9130 |
| Mean document density | 0.8843 | 0.8824 | 0.8541 | 0.8637 |
| Intercept of regression line | -0.0629 | 0.1914 | 0.1216 | 0.1125 |
| Regression coefficient | 1.0671 | 0.7758 | 0.8190 | 0.8228 |
| Square of correlation coefficient | 0.8620 | 0.8087 | 0.7331 | 0.8228 |
| Correlation coefficient | 0.9295 | 0.899 | 0.856 | 0.907 |
| Sum of squares of residuals | 0.01602 | 0.01031 | 0.02162 | 0.01662 |
| Estimate of variance | 0.000616 | 0.000382 | 0.000721 | 0.000648 |
| Estimating equation | -0.0629 +1.0671X | 0.1914 +0.7758X | 0.1216 +0.8190X | 0.1125 +0.8228X |

[1]See formulas in appendix.

to determine if the camera was in proper focus. If it was out of focus, the microfilm unit supervisor was notified that the camera required adjustment. After adjustment of the camera, another dip test was made and the film was inspected for other types of defects.

The test technician was provided with a ruler graduated to the nearest 1/100th of an inch for measuring the distance between adjacent exposures. To select spaces for measurement, he used a chart which showed pairs of random spaces. He selected two spaces within each one-third (15 spaces) of the 45 spaces between exposures on the reel. In other words, he selected three samples of two random spaces from each dip-test reel. If any of the measurements were greater than 4.5 inches or less than 2.5 inches (as measured on the reader), the microfilm unit supervisor was notified immediately that spacing adjustment was required.

When other defects, such as tilt or a camera shadow bar needing cleaning, were observed in the inspection, a camera technician was called in to verify the defect and the camera was taken off the production line and corrected. Before a camera was placed in production after being rejected, the camera unit supervisor and a quality control inspector were required to initial a form showing the type of defect and the type of correction made as well as the fact the camera had successfully passed a dip test after the correction. In the dip-test inspection, a camera was rejected on the basis of any one of the following types of defects:

1. Operational defects—tilt beyond tolerances (misalignment leading to canted exposures), misplaced platten, or camera head reversed

2. Camera malfunctioning—improper focus (fogging), shutter failure, or film jam

3. Shadow bar imperfections—unclean shadow bar (leading to spots and shadows on exposure), or improper size of shadow bar

4. Spacing beyond tolerance dimensions—spaces less than 2.5 inches or greater than 4.5 inches between exposures, as measured on reader

Control charts were maintained by the Jeffersonville quality control staff to study the behavior of each camera in controlling the spacing.

During the period from May 3 through October 28, 1960, when the first run of stage I microfilming was virtually completed, a total of 3,463 dip tests were conducted on camera processing in Jeffersonville. This part of the processing took 26 weeks. Subsequently, production involving refilming was conducted until March 11, 1961. Stage II microfilming began about July 28, 1960, and the first run continued until March 11, 1961; refilming continued until May 5, 1961. However, dip test results were summarized on the basis of the first run and most of the refilming work occurring after March 11, 1961, was eliminated from the summary. During the period from July 28, 1960, through March 11, 1961, a total of 4,455 dip tests were conducted on cameras processing stage II FOSDIC books.

As shown in table 26, about 4.7 percent of the dip tests during stage I microfilming resulted in rejecting the reel because of some camera malfunctioning. During the microfilming of stage II enumeration books, this rate of rejection was about 4.1 percent.

**Table 26.—DIP TEST REJECTIONS, STAGE I AND STAGE II MICROFILMING, BY SHIFT**

| Item | Total | Night shift | Day shift |
|---|---|---|---|
| Stage I microfilming: | | | |
| Dip tests[1] | 3,463 | 1,581 | 1,882 |
| Rejections | 164 | 83 | 81 |
| Percent rejected | 4.7 | 5.2 | 4.3 |
| Stage II microfilming: | | | |
| Dip tests[2] | 4,455 | 2,176 | 2,279 |
| Rejections | 183 | 108 | 75 |
| Percent rejected | 4.1 | 5.0 | 3.3 |

[1]23-percent sample of microfilm reels.
[2]14-percent sample of microfilm reels.

In each stage of microfilming (stage I and stage II), the night shift rejection rate was higher than the day shift rate. The difference between the rejection rate of 5.2 percent for the stage I night shift and of the rejection rate of 4.3 for the day shift is about 3.5 standard errors of the difference. The difference between the rejection rate of 5.0 percent and 3.3 percent for the stage II night and day shifts respectively is about 2.8 standard errors of the difference. Table 27 shows that rejections for spacing, for tilt, and for improper focus contributed to the difference during stage I microfilming. Table 28 shows that rejections for tilt beyond tolerance contributed to the higher rate for the night shift during stage II microfilming.

The difference in the quality of microfilming during the night shift appears to have been at least partly due to the fact that the camera technician worked only during the

**Table 27.–DIP TEST REJECTIONS, STAGE I MICROFILMING, BY SHIFT AND REASON FOR REJECTION**

| Reason for rejection | Total | | Day shift | | Night shift | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Total | 164 | 100.0 | 81 | 100.0 | 83 | 100.0 |
| Spacing outside tolerance | 69 | 42.0 | 36 | 44.4 | 33 | 39.8 |
| Less than lower limit | 26 | 15.8 | 19 | 23.4 | 7 | 8.4 |
| Greater than upper limit | 43 | 26.2 | 17 | 21.0 | 26 | 31.4 |
| Alignment (tilt beyond tolerance) | 45 | 27.4 | 20 | 24.7 | 25 | 30.1 |
| Shadow bar unclean | 27 | 16.5 | 16 | 19.8 | 11 | 13.2 |
| Improper focus | 17 | 10.4 | 5 | 6.2 | 12 | 14.5 |
| Other | 6 | 3.7 | 4 | 4.9 | 2 | 2.4 |

**Table 28.–DIP TEST REJECTIONS, STAGE II MICROFILMING, BY SHIFT AND REASON FOR REJECTION**

| Reason for rejection | Total | | Day shift | | Night shift | |
|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent |
| Total | 183 | 100.0 | 75 | 100.0 | 108 | 100.0 |
| Spacing outside tolerance | 86 | 47.0 | 43 | 57.3 | 43 | 39.8 |
| Less than lower limit | 38 | 20.8 | 15 | 20.0 | 23 | 21.3 |
| Greater than upper limit | 48 | 26.2 | 28 | 37.3 | 20 | 18.5 |
| Alignment (tilt beyond tolerance) | 82 | 44.8 | 21 | 28.0 | 61 | 56.5 |
| Narrow margin on shadow bar | 5 | 2.7 | 4 | 5.4 | 1 | 0.9 |
| Shadow bar unclean | 6 | 3.3 | 6 | 8.0 | ...... | ........ |
| Other | 4 | 2.2 | [1]1 | 1.3 | [2]3 | 2.8 |

[1]Fragment of film in camera.
[2]Two shutter malfunctions; one film jam.

day shift, so that camera defects were not corrected as soon during the night shift. Also, some routine servicing of the cameras was done only during the day.

In both stage I and stage II microfilming, spacing outside tolerances and tilt beyond tolerance constituted the two major classes of defects. The alignment appeared to be more of a problem in stage II than in stage I microfilming. On the other hand, the focus defect prevalent during the stage I microfilming practically disappeared during stage II. (See tables 27 and 28.)

Those cameras that were used in both stages were reset and realigned in changing from stage I to stage II microfilming, and also had different operators and technicians working on them. As a result, a camera which was rejected infrequently during stage I in some cases performed at a much higher rejection rate in stage II. For example, during stage I, one camera had a rejection rate of 1.3 percent and was ranked first among the cameras operating in stage I. During stage II, this camera developed alignment trouble and was ranked number 9. Another camera changed from rank number 13 during stage I to rank number 1 during stage II.

On the average, a rejection of a reel because of a camera defect could be expected to occur during the day shift at intervals of 1-1/2 days as compared with a rejection of a camera in about 1-1/3 days during the night shift. The estimated number of days to rejection for a particular defect is given in table 29.

**Table 29.–AVERAGE NUMBER OF CAMERA PRODUCTION DAYS TO REJECTION OF REEL FOR CAMERA DEFECT**

| Defect | Day shift | Night shift |
|---|---|---|
| Spacing: | | |
| Below tolerance | 6.2 | 20.0 |
| Above tolerance | 7.1 | 4.6 |
| Improper focus | 25.0 | 8.3 |
| Unclean shadow bar | 7.7 | 10.0 |
| Other | 33.3 | 50.0 |

The process average for spacing was estimated as 0.6 percent. This means that, on the average, 6 of every 1,000 spaces between exposures were either more than the tolerance dimension of 4.5 inches or less than the tolerance dimension of 2.5 inches. On the critical side, an estimated 0.2 percent of the spaces were narrow, less than the tolerance dimension of 2.5 inches.

Table 30 shows the number of cameras by percent of spacing measurements outside tolerance.

**Table 30.—NUMBER OF CAMERAS WITH SPACING MEASUREMENTS OUTSIDE TOLERANCE IN DIP TESTS MADE DURING MICROFILMING**

| Estimated percent outside tolerance | Stage I | Stage II |
|---|---|---|
| Total | 26 | 22 |
| 0.0 | 6 | 4 |
| 0.1-0.3 | 6 | 6 |
| 0.4-0.6 | 4 | 6 |
| 0.7-0.9 | 3 | 2 |
| 1.0-1.2 | 5 | 0 |
| 1.3-1.5 | 1 | 1 |
| 1.6-1.8 | 1 | 1 |
| 1.9-2.1 | 0 | 0 |
| 2.2-2.4 | 0 | 0 |
| 2.5-2.7 | 0 | 0 |
| 2.8-3.0 | 0 | 2 |

### Density of Microfilm

The check made by FOSDIC of gain, which measures the relationship between darkness of the developed film and clear film, was affected by the smog condition and the density of the film. "Smog" is a clouded appearance of developed film which increases density and decreases contrast and sharpness of the image on the film. Density is a measure, expressed in common logarithmic scale, of the ratio of the amount of incident light at the film surface (determined by the intensity of the light and the distance of the film from the source illumination) to the light passing through the film. These in turn were affected by procedures provided for quality control of the illumination at the camera site during exposure of film, and of the time elapsing between exposure of film in Jeffersonville and developing in the laboratory in Washington.

The test for contrast and density determined whether the reel of film met standards for running on FOSDIC. Each shipment of reels of film from Jeffersonville to the laboratory in Washington, D.C., had with it a "Microfilm Camera Work Unit Check List" for each reel providing information on the work unit, stage, technician, shift, and date and time of last exposure. When the film was developed, the time of development and the date were recorded on the transmittal form. After development, the gray-scale chips were clipped from the end of the reel together with the identification plate showing work unit, etc., and sent to the quality control staff at the Bureau of the Census.

Density measurements were made of 4 gray-scale chips from each reel. Each gray-scale chip provided a density reading for a known reflectance level. The 88.8 percent reflectance chip provided a measure highly correlated with the density of the microfilmed schedules; the density of the reel was acceptable if this reading was within the dimensions of 0.90 ± 0.15. The acceptability of the reel as to contrast, a measure of the clarity of exposure, was based upon a consideration of density readings of the 61 percent and 88.8 percent reflectance chips and their comparison with a standard curve relating density and percent reflectance for the illumination level at which the film was exposed. As a camera lens became soiled from the accumulation of dust and dirt during use, it became necessary to increase the illumination level to provide an acceptable schedule density. When the difference between the density at the 88.8 percent reflectance level and at the 61 percent reflectance level decreased to about 0.3 or less as the illumination increased, the risk that FOSDIC would fail to distinguish properly between degrees of blackness was greatly increased. Consequently, when contrast reached that level, a reel was rejected. The 12.2 percent reflectance chip provided a measure of density equivalent to the smog condition, or cloudiness (sometimes called "fog"), of the developed film. When the degree of "smog" was high, the FOSDIC ability to distinguish degree of darkness was affected. The 25.2 percent reflectance chip provided an indication of the extent of scattered light and an indication whether the lens required cleaning.

During stage I microfilming, density readings were made of gray-scale chips from 14,939 reels. This represented a 100-percent inspection of the gray-scale chips at the end of each reel. On the other hand, as the 88.8 percent gray-scale chip density represented a measurement highly correlated with schedule density, each reading represented a random selection from a reel. Inspection resulted in a rejection of 531 reels, or 3.6 percent. An average of 575 reels were inspected each of the 26 weeks during which inspection of stage I microfilming was conducted; this amounted to 2,300 densitometer readings per week.

During the stage II microfilming, 30,910 reels were inspected. Inspection resulted in rejection of 654 reels, or 2.1 percent. An average of approximately 859 reels were inspected each of the 36 weeks during which readings were made. This amounted to an average of 3,436 readings of stage II microfilm gray scales per week.

The lower rejection rate prevailing during stage II resulted from the lessons learned during microfilming of the stage I data. As a result of the stage I experience, the following improvements occurred during the stage II operation:

1. More uniformity and timely change in light meter settings at the camera site.

2. More efficient maintenance, including cleaning of camera lenses

3. Regularity in the time elapsing between exposure and development of microfilm reels,

4. Identification during stage I processing of those cameras having the highest rejection rates and their elimination before the microfilming of stage II schedules

During stage II microfilming, rejections for poor contrast were eliminated, and the rejection rate for a combination of contrast and density dropped from 1.5 percent in stage I to 0.2 percent in stage II. The rejection rate for 88.8 percent chip density outside tolerances remained about the same, as shown in table 31.

**Table 31.—MICROFILM REELS REJECTED AFTER DENSITOMETER READINGS, STAGE I AND STAGE II**

(In percentages)

| Stage and shift | Reason for rejection | | | |
|---|---|---|---|---|
| | Total | Density | Contrast and density | Contrast |
| Stage I | 3.6 | 1.8 | 1.5 | 0.3 |
| Day shift | 3.9 | 1.7 | 1.9 | 0.3 |
| Night shift | 3.2 | 1.7 | 1.2 | 0.3 |
| Stage II | 2.1 | 1.9 | 0.2 | 0 |
| Day shift | 2.2 | 2.0 | 0.2 | 0 |
| Night shift | 2.0 | 1.9 | 0.1 | 0 |

During stage I microfilming, five cameras accounted for 56.8 percent of the reels rejected for density outside tolerances. These five cameras were removed from processing during stage II, and one camera was added, making a total of 22 cameras in stage II, compared with 26 cameras operating during stage I.

The performance of cameras depended upon human efficiency as well as mechanical functioning, and the human element appeared more important. The failure of reel density to meet standards may have been the result of the failure of the technician to set the light meter properly to provide the illumination called for, or failure of the developing technician to maintain uniform conditions required for film development.

In addition, the air carriers between Jeffersonville and Washington did not always leave and arrive on schedule, so that the time lag between exposure and developing was sometimes increased beyond the point of safety.

Table 32 summarizes the performance of the 21 cameras operating in both stage I and stage II microfilming. "Same" performance means that the difference between the rejection rates for stage I and stage II was not statistically significant; "improved" means the rate during stage II was significantly lower than the rate during stage I; and "deteriorated" means the rate in stage II was significantly higher than in stage I.

**Table 32.—PERFORMANCE OF 21 CAMERAS OPERATING DURING STAGE I AND STAGE II MICROFILMING**

| Performance as measured by density | Performance as measured by dip tests | | | |
|---|---|---|---|---|
| | Total | Same | Improved | Deteriorated |
| Total.......... | 21 | 15 | 4 | 2 |
| Same.............. | 12 | 8 | 2 | 2 |
| Improved.......... | 4 | 3 | 1 | 0 |
| Deteriorated....... | 5 | 4 | 1 | 0 |

Table 33 shows the mean values and standard deviations of readings of density of 88.8-percent reflectance chips. Density readings greater than 1.19 were eliminated from the calculations since they were attributed to extraneous factors such as the exposure of gray-scale chips to light in unwinding the reel or failures in the developing process.

**Table 33.—MEAN VALUES AND STANDARD DEVIATIONS OF READINGS OF DENSITY OF 88.8-PERCENT REFLECTANCE CHIPS ON MICROFILM**

| Stage and shift | Mean density | Standard deviation | Coefficient of variation (Percent) | Sample size |
|---|---|---|---|---|
| Stage I.......... | 0.877 | 0.062 | 7.1 | 14,884 |
| Day shift...... | 0.873 | 0.071 | 8.1 | 7,421 |
| Night shift.... | 0.880 | 0.066 | 7.5 | 7,463 |
| Stage II.......... | 0.882 | 0.068 | 7.8 | 30,898 |
| Day shift...... | 0.878 | 0.067 | 7.6 | 15,789 |
| Night shift.... | 0.887 | 0.059 | 6.7 | 15,109 |

Cumulative frequency distributions were plotted on probability paper. Charts were plotted separately for stage I and stage II for the combined day and night shifts. Both distributions plotted as straight lines except for slight bends at the tails.

**Table 34.—MEAN VALUES AND STANDARD DEVIATIONS OF DENSITY OF 88.8-PERCENT REFLECTANCE CHIPS ON MICROFILM DURING STAGE I FROM RANDOM SAMPLE OF REELS, BY SHIFT**

| Shift | Subsample | | |
|---|---|---|---|
| | Number of reels | Mean | Standard deviation |
| Total.................... | 3,227 | 0.877 | 0.066 |
| Day shift.................... | 1,678 | 0.874 | 0.067 |
| Night shift.................. | 1,549 | 0.881 | 0.064 |

Further analysis was made of the basic readings from random reels selected from each camera's production during each shift. Cumulative frequency distributions were plotted from this stage I subsample; these distributions provided evidence of approximate normality, although there was some distortion at the upper tail of the distribution. Means and standard deviations computed from the subsample approximate those shown in table 33 for stage I.

**Table 35.—STAGE I MICROFILM REELS BY DENSITY OF 88.8-PERCENT REFLECTANCE CHIPS AND BY SHIFT**

(A reel was rejected if the density of the 88.8-percent reflectance chip exceeded 1.05 or was less than 0.75)

| Density | Number of microfilm reels | | |
|---|---|---|---|
| | Total | Day shift | Night shift |
| Total inspected............. | 14,939 | 7,445 | 7,494 |
| Less than 0.60.................. | 1 | 1 | – |
| 0.60-0.64............ | 4 | 2 | 2 |
| 0.65-0.69............ | 59 | 43 | 16 |
| 0.70-0.74............ | 276 | 159 | 117 |
| 0.75-0.79............ | 1,377 | 755 | 622 |
| 0.80-0.84............ | 3,212 | 1,644 | 1,568 |
| 0.85-0.89............ | 4,649 | 2,292 | 2,357 |
| 0.90-0.94............ | 3,583 | 1,712 | 1,871 |
| 0.95-0.99............ | 1,348 | 650 | 698 |
| 1.00-1.04............ | 274 | 118 | 156 |
| 1.05................. | 10 | 6 | 4 |
| 1.06-1.09............ | 47 | 21 | 26 |
| 1.10-1.14............ | 25 | 8 | 17 |
| 1.15-1.19............ | 19 | 10 | 9 |
| More than 1.20................. | 55 | 24 | 31 |
| Number of chips outside tolerance..................... | 486 | 268 | 218 |
| Percent outside tolerance....... | 3.3 | 3.6 | 2.9 |
| Percent less than 0.75.......... | 2.3 | 2.8 | 1.8 |
| Percent greater than 1.05....... | 1.0 | 0.8 | 1.1 |

– Represents zero.

**Table 36.—STAGE II MICROFILM REELS BY DENSITY OF 88.8-PERCENT REFLECTANCE CHIPS AND BY SHIFT**

(A reel was rejected if the density of the 88.8-percent reflectance chip exceeded 1.05 or was less than 0.75)

| Density | Number of microfilm reels | | |
|---|---|---|---|
| | Total | Day shift | Night shift |
| Total inspected | 30,910 | 15,793 | 15,117 |
| 0.60-0.64 | 22 | 12 | 10 |
| 0.65-0.69 | 94 | 52 | 42 |
| 0.70-0.74 | 437 | 234 | 203 |
| 0.75-0.79 | 2,527 | 1,488 | 1,039 |
| 0.80-0.84 | 6,246 | 3,388 | 2,858 |
| 0.85-0.89 | 9,462 | 4,839 | 4,623 |
| 0.90-0.94 | 7,785 | 3,752 | 4,033 |
| 0.95-0.99 | 3,332 | 1,586 | 1,746 |
| 1.00-1.04 | 876 | 384 | 492 |
| 1.05 | 28 | 10 | 18 |
| 1.06-1.09 | 55 | 25 | 30 |
| 1.10-1.14 | 29 | 16 | 13 |
| 1.15-1.19 | 5 | 3 | 2 |
| 1.20 | 12 | 4 | 8 |
| Number of chips outside tolerance | 654 | 346 | 308 |
| Percent outside tolerance | 2.1 | 2.2 | 2.0 |

### Camera Operator Control

Defects generated by the camera operators as well as those attributable to the camera equipment itself or to other variables affecting microfilming required control in the early stages of processing. The method devised for control of the work of the camera operators was a process control sampling plan. Control was based on a systematic sampling of exposures from one reel selected at random from the production of each camera operator during each shift. These reels were given priority processing through FOSDIC. After the FOSDIC reading, the sample exposures were examined on a viewing scope for defects such as the following: (1) inclusion, in the exposure, of the operator's hand or part of the body, (2) faulty alignment, and (3) filming of moving pages.

Originally this plan was expected to operate throughout the entire production process. About halfway through stage I processing, the plan was set aside because once the operators were in control the incidence of operator faults was so low that it proved cheaper to detect them and take corrective action during the later processing stages. However, the operation of the process control plan for camera operators during the first half of stage I resulted in the removal of six of 52 operators as well as retraining of a number of the operators. The results of the control data compiled during the time of the plan's operation are as follows: Of the total of 62,580 exposures inspected in the sample, 5.7 percent were found to be defective. Of the 3,550 defectives, 37.4 percent were attributable to hands or body in exposure, 32.7 percent to faulty alignment, 7.1 percent to filming of moving pages, and 2.8 percent to other types of defect.

## IV. QUALITY CONTROL OF CODING

Before stage II enumeration books for sample households could be sent to microfilming, some of the information in them had to be coded. The coding was done on the FOSDIC schedules. Answer areas on the schedule were precisely positioned small circles. Coding was done by darkening the area inside the appropriate circles with a lead pencil. Many of the items on the schedule were precoded, i.e., the enumerator entered the response by darkening the appropriate circle. In other cases, however, there were so many possible responses to an item that the enumerator was instructed to write in the response, for later office coding. In the case of items such as "place of birth," providing for all possible responses on the schedule would have required too much space; in the case of other items, such as "occupation," the enumerator would have required lengthy training to code the item.

The coding operation was divided into two parts:

1. General coding.—The coding of information on place of birth, migration, place of work, income, and other subjects except industry and occupation.

2. Industry and occupation coding.—The coding of information on occupation, industry, and class of worker for members of the labor force and for persons not in the labor force who had worked since 1950.

### Methods of Verifying Coding Quality

Dependent verification.—In the 1950 and earlier censuses, coding operations were verified by having clerks who were more experienced and better trained review the work of the production coders and determine whether or not the codes assigned were correct. As the coding operation progressed during the 1950 census, the adequacy of this type of verification was questioned. The extent to which verifiers were missing coding errors was measured in two ways: (1) error planting, and (2) error noting, i.e., a specialist noted the errors made by the coder but the uncorrected work went to the verifier and a check was made to see how many of the noted errors he had found. These procedures provided the following estimates of the percent of coding errors missed in the 1950 census verification process:

| Method | General coding (Percent) | Industry and occupation coding (Percent) |
|---|---|---|
| Planted errors | 29 | 43 |
| Noted errors | 47 | 69 |

In contrast, verifiers failed to detect only about 5 percent of the errors made in the 1950 card-punching operation. Although coding verification differs from punching verification in that more judgment is required in determining errors because of cases of ambiguous codes, the striking difference between punching and coding verification is attributed largely to a tendency for the coding verifier to be influenced by the original coder's work, on the one hand, and the virtual independence of the verifier in the punchcard operations from any influence by the work of the original puncher.

Some additional research on the quality of coding was done during the processing of the 1950 census and during the intercensal period. The results led to the conclusion that dependent verification as a tool for controlling a process could produce misleading results. The proportion of cases in which the verifier disagreed when the original coder was correct was normally exceedingly small, but the proportion of cases in which verifier and coder agreed but in which both were wrong could range from 25 percent to 75 percent of all wrong cases. Consequently, a second system of either error noting or error planting is sometimes superimposed in an effort to control and measure the number of errors missed by the verifiers. Either errors are noted in a small sample of the work by an expert before the regular verifier sees it or errors may be deliberately introduced into the production just prior to verification.

Independent verification.—For the 1960 censuses, a system of three-way independent verification replaced the dependent verification used in earlier censuses. This system called for three independent codings of items for an identical sample of persons and then for a match of the coding results.

A special device called a "pench card" was used for independent verification of the coding. It is simply a card which duplicates the coding boxes and circles of the FOSDIC schedule except that the circles on the pench card are perforated and the index markings are cut out whereas the circles and index marks on the schedule are printed. The pench coder punched out perforated holes in the pench card with a stylus, while the coder of the FOSDIC schedule marked schedules with a pencil.

The three-way independent verification included four steps:

1. An enumeration book was assigned to a coder, who first selected a sample of households in the book and then coded on a "pench card" the information for each person included in the sample household.

2. The enumeration book and a second set of pench cards were given to a second coder who coded the information to these cards for the identical sample persons.

3. After completion of the second pench coding of a sample of the households in the enumeration books, the books were sent forward for production coding which was done by pencil marking of the appropriate FOSDIC circles on the schedules in the enumeration books.

4. After production coding, the two pench cards were laid over the coding in the enumeration books and matched.

Production coding and pench coding assignments were made on a random basis, with all clerks having the same training and experience. To identify those clerks whose quality deteriorated and to identify those coding classifications for which either additional training of coders or clarification of coding instructions was needed, a simple majority rule was adopted: If two clerks agreed on the code for a given description and the third disagreed, a quality demerit was assigned to the disagreeing clerk. In effect, a sample of "n" items was drawn with acceptance and rejection numbers based upon the number of items regarding which one clerk differed from the other two. In this manner the quality of both the pench-coders, who were in effect doing a verification job, and the production coders was measured. The number of demerits assigned to a coder did not necessarily measure the number of errors he made, but was highly correlated with errors. For simplicity in the following presentation, demerits are referred to as errors; the "error rate" in the 1960 census coding, however, actually was a "difference rate."

Two types of differences in coding were excluded from the computation of error rates. These were cases where each of the three coders assigned a different code to the same description, or where two of the three coders referred the item to a specialist for coding.

For control purposes, the coding operation was divided into two periods—the training period, and the post-training period.

Training period.—The purposes of verification during the training period were (1) to correct errors made by the coders, (2) to determine when coders were producing with a low enough error rate to be placed on process control, and (3) to provide information for on-the-spot training and for revising and refining both the training material and the coding instructions.

In the 1960 censuses, control of general coding quality during the training period was based on a 10-percent sample of households, and the codes assigned to each person were dependently verified in conjunction with an independently verified subset of that sample. In the case of industry and occupation coding, a 20-percent dependently verified sample was selected in conjunction with an independently verified subset. This higher sampling rate for industry and occupation coding was used because only about one-half of the persons in the sample households were eligible for industry and occupation coding.

The independent sampling rate for general coding was 1 in 80; for industry and occupation coding, 1 in 40. For control purposes, the lot for verification was defined as four enumeration districts which together contained a total of approximately 800 persons in the stage II sample. Quality decisions were made on both the dependently and independently verified samples (sample pairs). If a coder received a "reject" decision on either of the samples, the rejected lot was verified on a 100-percent basis. Before a coder could be transferred to the post-training work he was required to receive a specified number of consecutive "accept" decisions on both the dependent and independent samples.

As a training device during the training period, each error discovered in verification was discussed with the coder. This procedure contributed to a systematic upgrading of the quality of coders, and it is believed it shortened the time needed for coders to qualify for the post-training period.

Post-training period.—Three-way independent verification with a "point" system of quality control superimposed was used for controlling the quality during the post-training period. Under the point system, the coder was given an initial stake of three points. When a favorable quality decision was made, the coder received an additional point; when an unfavorable decision was made, he lost a point. When his point balance reached zero, he was either retrained or removed from the operation.

In order to avoid the possibility that a clerk whose quality was very good at the beginning of the operation might be retained although his quality had deteriorated grossly, an accounting adjustment was made for each coder after every tenth decision. If the coder had more than three points, his points were reduced to three; if he had three or fewer points he kept what he had. The point system had the advantage that its operating characteristics could be determined so that a coder making few errors had little chance of being removed from the operation whereas a coder making many errors was removed early.

The post-training period control was based on the results of the independent sample. In the case of industry and occupation coding, process control of the coder's performance was coupled with a system to correct work lots having exceptionally high error rates.

Improving quality of local area statistics.—A coder's work as a whole may stay in control while his coding of an occasional enumeration district has a high error rate. This is true because of the inherent variability in the quality of human production and because of the variability arising in decisions made from samples. To help guard against the effect of such poor quality coding on local area statistics, for the industry and occupation coding (which was the more difficult of the two types of coding), the sample results for each enumeration district coded by a particular coder were cumulated weekly to form a sample for a grand lot which tended to represent one or more local areas. If the sample estimate of the item coding error rate for the grand lot was 6 percent or greater (18 items in error per 100 coded persons), each enumeration district having one or more sample errors and included in the grand lot was verified on a 100-percent basis. If the item error rate for the enumeration districts that were 100-percent verified was reported to be 6 percent or greater, then all the other enumeration districts in the grand lot were verified on a 100-percent basis. Otherwise, no further 100-percent verification was done in the grand lot. The number of enumeration districts rejected and 100-percent verified under this provision was slightly less than 1 percent of all enumeration districts.

The characteristics of the system to control the quality of the coding operation are shown in table 37.

**Table 37.—SUMMARY OF CHARACTERISTIC OF SAMPLING PLANS FOR QUALITY CONTROL OF GENERAL CODING AND INDUSTRY AND OCCUPATION CODING**

| Period | Description | Type of control | General coding: Sampling rate | General coding: Typical sample size for one decision | General coding: Acceptance number | General coding: Action | Industry and occupation coding: Sampling rate | Industry and occupation coding: Typical sample size for one decision | Industry and occupation coding: Acceptance number | Industry and occupation coding: Action |
|---|---|---|---|---|---|---|---|---|---|---|
| Training | Hybrid, combining dependent and independent verification | Lots--Dependent verification | 1/10 | 84 | 4 | 100-percent verification if lot was rejected under either or both samples | 1/5 | 93 | 7 | 100-percent verification if lot was rejected under either or both samples |
| | | Lots--Independent verification | 1/80 | 11 | 1 | | 1/40 | 10 | 1 | |
| | | Coder--Dependent verification | 1/10 | 84 | 8 | Coder qualified after 4 successive "accepts" in both samples with a maximum of 12 sample pairs | 1/5 | 93 | 14 | Coder qualified after 5 successive "accepts" in both samples with a maximum of 25 sample pairs |
| | | Coder--Independent verification | 1/80 | 11 | 1 | | 1/40 | 10 | 1 | |
| Post-training | Process control using independent verification; point system superimposed; rejection of lots of industry and occupation coding with high error rates | Coder--Independent verification | 1/80 | 24 | 2 | Coder retrained or removed when point balance reached zero; sequence repeated after after 10 decisions | 1/40 | 22 | 3 | Coder retrained or removed when point balance reached zero; sequence repeated after 10 decisions |

### General Coding

The coder who assigned codes to general characteristics of persons in the stage II households had the following tasks:

1. To examine each item to be coded other than industry, occupation, and class of worker for persons on the schedules used for the 25-percent sample of households
2. To decipher the written description and translate it to a numeric code
3. To enter the code for the item in the corresponding box on the FOSDIC schedule by marking the appropriate circles

For each person in the household, the coder assigned codes when applicable to the following items (see population panel of FOSDIC schedule for 25-percent sample, illustration 1):

1. Relationship to head of household and family type (item P3)
2. Spanish surname, for persons in five southwestern States
3. Place of birth (item P8)
4. Mother tongue, for foreign born (item P9)
5. Parent's birthplace (items P10, P11)
6. Migration status, from question on place of residence on April 1, 1955 (item P13)
7. Place of work (item P28)
8. Income (items P32, P33, P34)

Problems not covered in the instructions to the coder were referred by him to a specially trained Technical Assistant.

Training period.--The decision to accept or reject a work lot was based on the results of both the independent and dependent verification samples during the training period. When the number of items in error in either or both samples exceeded the acceptance number for the lot, it was sent to a unit for 100-percent screening and correction. The error rate for the work lot excluded all items for a coded person for which one or more items contained a coder referral and for which the penchers agreed on the codes. Acceptance numbers corresponding to the numbers of coded persons in the samples used to make decisions to accept a work lot or coder are shown in table 38.

The operating characteristic curves for lot acceptance are shown in chart 11. The chart shows the probability that a lot would be accepted under three conditions: (1) The dependent verifier detected all the errors ($\pi = 1.00$); (2) the dependent verifier detected half of the errors ($\pi = 0.50$); (3) the dependent verifier detected none of the errors ($\pi = 0$).

The effect of the last curve is the same as if no dependent verification occurred. It is estimated that dependent verifiers actually missed roughly half of the errors to which they were exposed. Dependent verification did have an important role in the outgoing quality of work lots, as shown by chart 11.

In accepting or rejecting a coder, during the early part of the operations, a referral by him to a specially trained technical assistant was counted as an error if the other two coders agreed on the code for the item. Later it was decided that it was less costly to simply inform him that he was making too many referrals rather than to count this type of referral as an error and, in some cases, return to 100-percent verification because of the referrals.

Acceptance numbers for making a decision to accept or reject a coder are shown in table 38. Before a coder could be transferred to the post-training period, he was required to have 4 consecutive samples of his work accepted within a maximum of 12 pairs of samples. As previously described, an "accept" decision was made on the basis of both the independent and dependent samples. The probability of a coder's qualifying for the post-training work is shown in chart 12. This chart shows that if the dependent verifiers missed half the errors, dependent verification played a minor role in the control of coders.

Over the entire training period, there were 6.3 coded items in error per 100 coded persons. The number of characteristics assigned a code by a general coder could vary from 1 to about 10. In order to provide an estimate of the average error rate per item, an estimated average of 2.3 items per coded person was used. It is estimated that the average error rate per item was about 2.7 percent during the training period.

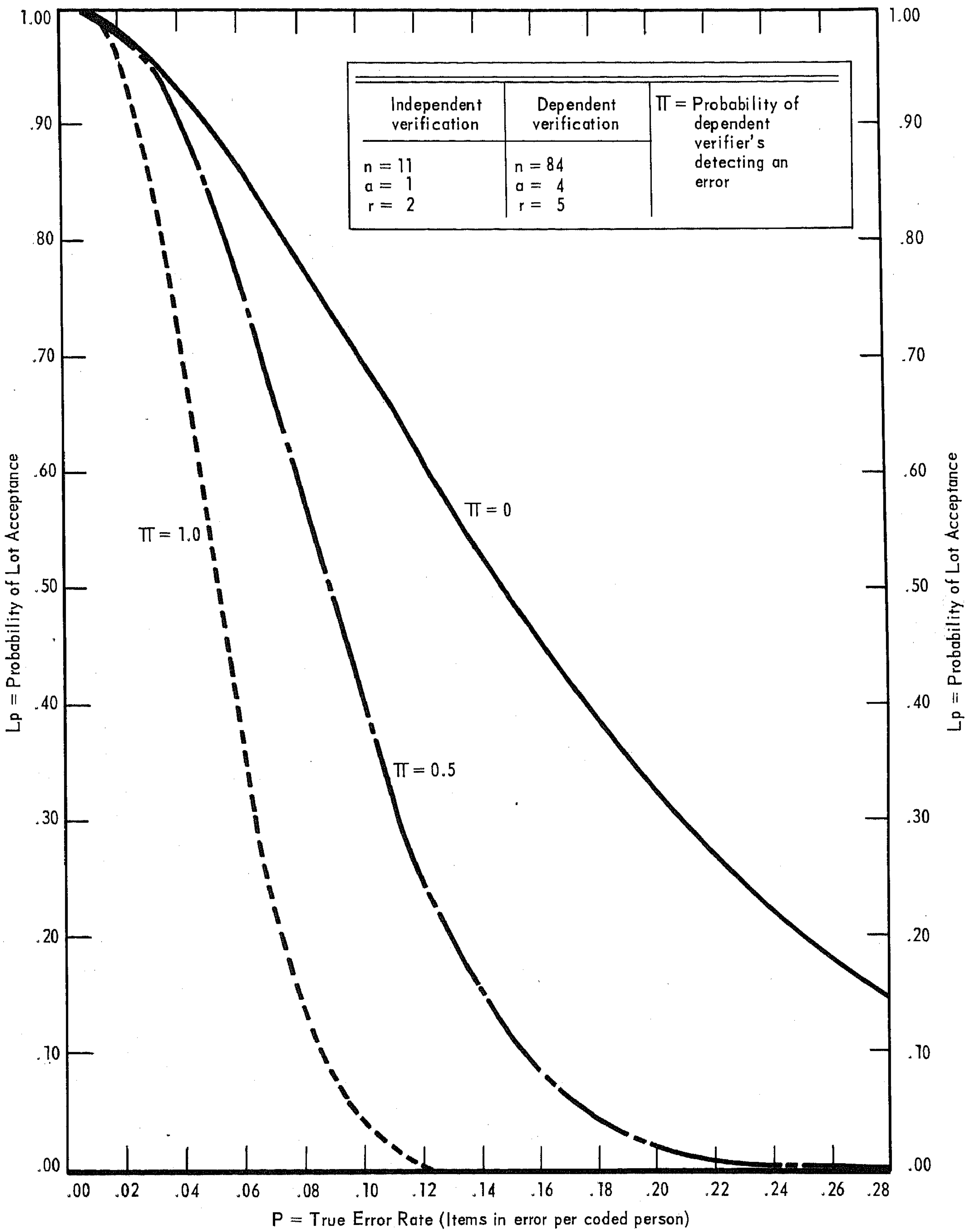
Post-training period.—When a coder had qualified, his work was verified by means of independent sample verification only. A point system mechanism was superimposed on the independent system to discriminate between good and poor quality coders. A decision was made on

**Table 38.—SAMPLE SIZES AND ACCEPTANCE NUMBERS FOR SINGLE LOT DECISIONS FOR LOTS AND CODERS: GENERAL CODING, TRAINING PERIOD**

| Independent verification (Pench-card system) | | Dependent verification | | | |
|---|---|---|---|---|---|
| Lots and coders | | Lots | | Coders | |
| Sample size[1] (coded persons) | Acceptance number[2] (items in error) | Sample size[1] (coded persons) | Acceptance number[2] (items in error) | Sample size[1] (coded persons) | Acceptance number[2] (items in error) |
| 8-14 | 1 | 65-73 | 3 | 65-73 | 7 |
| 15-20 | 2 | 74-87 | 4 | 74-87 | 8 |
| | | 88-107 | 5 | 88-103 | 9 |
| | | 108-117 | 6 | 104-107 | 10 |
| | | 118-127 | 7 | 108-123 | 11 |
| | | 128-147 | 8 | 124-133 | 12 |
| | | 148-153 | 9 | 134-147 | 13 |
| | | | | 148-153 | 14 |

[1]If the sample size was less than eight, the sample was cumulated with that of the succeeding lot.
[2]Rejection number was one greater than the acceptance number for each sample size.

## Chart 11.—PROBABILITY OF LOT ACCEPTANCE DURING CODER'S TRAINING FOR GENERAL CODING



## Chart 12.—PROBABILITY OF A CODER'S QUALIFYING FOR POST-TRAINING GENERAL CODING

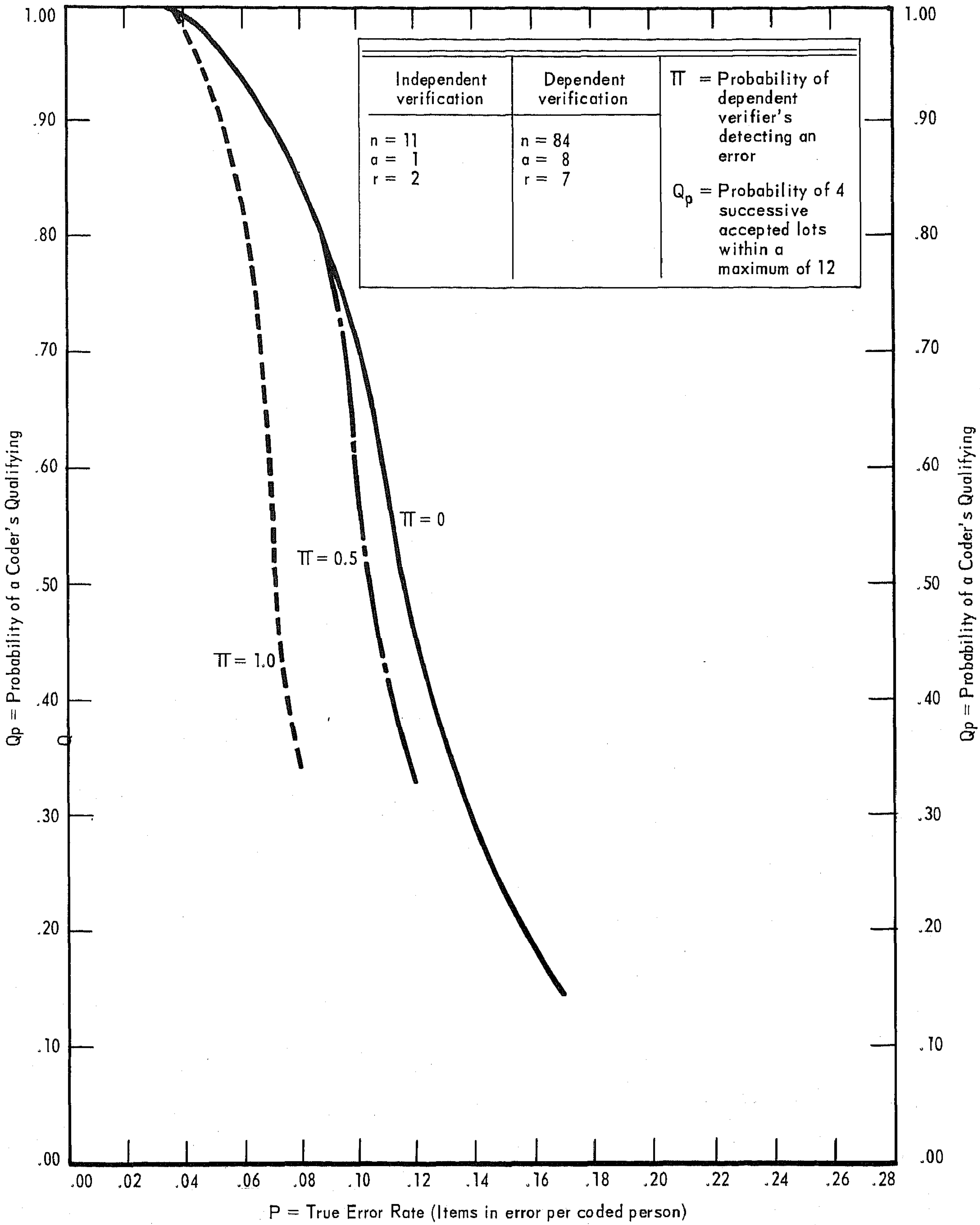


**Table 39.—QUALITY OF CODER AND PENCHER PRODUCTION BY TIME PERIOD: GENERAL CODING**

| Period | Percent of coded items in error[1] | | | | Cumulative number of persons in sample | | |
|---|---|---|---|---|---|---|---|
| | In-training coders | Trained coders | First penchers | Second penchers | In-training coders | Trained coders | Penchers |
| Total.............. | 2.7 | 1.8 | 2.4 | 1.6 | - | - | - |
| 5/22/60-6/24/60....... | 3.3 | 2.3 | 3.1 | 2.4 | 3,917 | 114 | 4,031 |
| 6/25/60-7/29/60....... | 2.9 | 2.1 | 2.8 | 1.6 | 16,736 | 10,187 | 26,923 |
| 7/30/60-8/26/60....... | 2.5 | 2.0 | 3.5 | 2.6 | 23,246 | 41,853 | 65,099 |
| 8/27/60-9/30/60....... | 1.5 | 2.0 | 3.2 | 2.2 | 24,389 | 85,108 | 109,497 |
| 10/1/60-10/28/60...... | 0.7 | 1.8 | 1.7 | 1.6 | 24,454 | 120,161 | 144,615 |
| 10/29/60-11/25/60..... | - | 1.8 | 2.5 | 1.4 | 24,454 | 149,698 | 174,152 |
| 11/26/60-12/9/60...... | - | 2.0 | 1.6 | 1.3 | 24,454 | 165,517 | 189,971 |
| 12/10/60-12/30/60[2].... | 2.3 | 1.6 | 2.1 | 1.4 | 25,268 | 183,940 | 209,161 |
| 12/31/60-1/27/61[2]..... | 1.2 | 1.6 | 2.0 | 1.3 | 25,733 | 217,486 | 243,172 |
| 1/28/61-2/24/61....... | - | 1.6 | 1.6 | 1.2 | 25,754 | 246,950 | 272,657 |
| 2/25/61-3/31/61....... | - | 1.6 | 1.7 | 1.0 | 25,754 | 272,069 | 297,776 |
| 4/1/61-4/7/61......... | - | 1.3 | 1.2 | 0.5 | 25,754 | 275,212 | 300,919 |

- Represents zero.
[1]Estimated by using 2.3 items in error per coded person for whom errors were found.
[2]New coding unit.

the basis of the number of items in error in a sample of 24 coded persons (i.e., persons with one or more items coded on the FOSDIC schedule) to credit or demerit a coder. Each coder received three points when he qualified for independent sample verification under the pench card system. If one or two items in error were found in the sample from his work lot, he received a credit. However, when the number of items in error exceeded two, he lost a point. At the end of the sequence of 10 decisions made on the basis of the samples independently verified, an accounting was made of the coder's point position. A coder who had a net point score of three or more reverted to an initial balance of three points for the next production span consisting of 10 independent samples. On the other hand, a coder who had a net point score of one or two began the next sequence with that balance. A coder who had a net point score of zero was removed from the operation or retrained. Table 40 shows the probabilities of remaining in the operation for a stated number of ED's (enumeration districts) for coders having given error rates.

For general coding, the average number of error items per 100 coded persons was 4.1 for trained coders. The average error rate per item is estimated at 1.8 percent.

### Industry and Occupation Coding

The industry and occupation coder coded the answers to the following four questions for each person in the labor force and for persons not in the labor force who had worked in 1950 or later:

1. For whom did he work? (item P27a)
2. What kind of business or industry was this? (item P27b, c)
3. What kind of work was he doing? (item P27d)
4. Was he (a) an employee of a private company, (b) an employee of a Federal, State, county, or local government, (c) self-employed in own business, professional practice, or farm, or (d) working without pay in a family business or farm? (item P27e)

Each of the codes assigned by him was required to be consistent with the written answers, unless there was an obvious inconsistency in the written answers, and to be consistent with each of the other codes. If the responses on the schedule were inconsistent, the problem was referred to a specially trained technical assistant. The complexity of the job is indicated by the fact that many thousands of different responses had to be coded into 149 industry categories and 296 occupation categories, and that the information provided on the schedule was not always complete and consistent.

Training period.—In general, the rules for decisions to accept or reject an industry and occupation work lot or coder during the training period were similar to those for general coding. There were differences in the sample sizes and acceptance numbers required for a decision. Table 41 provides acceptance numbers used. The work lot assigned to a coder consisted of four enumeration books, each containing information about a minimum of 800 persons. (If there were not that many persons entered in the enumeration book, it was combined with another enumeration book in making up the work lots.)

Operating characteristics of the sampling plan for lot acceptance are shown in chart 13. The probability of a coder's qualifying for the post-training period is shown in chart 14. The coder's qualification was based on acceptance of five consecutive samples in a maximum of 25. Curves are charted for the cases in which the dependent verifier found and reported (1) all errors to which he was exposed, (2) half of the errors, and (3) none of the errors. The effect of the last curve is the same as if there were no dependent verification. It is estimated that dependent sample verifiers failed to detect half or more of the errors to which they were exposed.

Dependent verification had a minor role in the control of coders, as chart 14 shows. However, it did have an important role in the outgoing quality, as chart 13 shows.

As a training device during the training period, each error discovered in verification was discussed with the coder. As previously indicated, this feedback procedure contributed to a systematic upgrading of the quality of coders, and it is believed that it shortened the training time needed for coders to qualify for the post-training period. Before corrective action was taken, there were one or more errors in coding of items on industry, oc-

Table 40.—PROBABILITY OF A CODER'S CONTINUANCE, BY ERROR RATE AND NUMBER OF ENUMERATION BOOKS CODED: GENERAL CODING, POST-TRAINING PERIOD

| Coder's error rate (P)[2] | Probability of coder's receiving a credit point per decision (Lp) | Number of enumeration books coded[1] | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 85 | 170 | 255 | 340 | 425 | 510 | 595 | 680 | 765 | 850 | 935 | 1020 | 1105 | 1190 | 1275 | 1360 | 1445 |
| .00 | 1.000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .01 | .998 | 1.00 | 1.00 | 1.00 | 0.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .02 | .988 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .03 | .966 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .04 | .931 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .05 | .884 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .06 | .828 | 1.00 | .99 | .99 | .99 | .99 | .98 | .98 | .98 | .97 | .97 | .97 | .97 | .96 | .96 | .96 | .95 | .95 |
| .07 | .766 | .98 | .96 | .94 | .92 | .90 | .89 | .87 | .85 | .83 | .82 | .80 | .79 | .77 | .75 | .74 | .72 | .71 |
| .08 | .699 | .94 | .88 | .83 | .78 | .73 | .69 | .65 | .61 | .57 | .54 | .51 | .48 | .45 | .42 | .40 | .37 | .35 |
| .09 | .632 | .88 | .77 | .68 | .60 | .52 | .46 | .40 | .35 | .31 | .27 | .24 | .21 | .18 | .16 | .14 | .12 | .11 |
| .10 | .564 | .78 | .60 | .47 | .36 | .28 | .22 | .17 | .13 | .10 | .08 | .06 | .05 | .04 | .03 | .03 | .02 | .02 |
| .11 | .499 | .65 | .42 | .28 | .18 | .12 | .07 | .05 | .03 | .02 | .01 | .00 | | | | | | |
| .12 | .437 | .51 | .26 | .13 | .07 | .04 | .02 | .01 | .01 | .00 | | | | | | | | |
| .13 | .380 | .39 | .15 | .06 | .02 | .01 | .00 | .00 | .00 | | | | | | | | | |
| .14 | .327 | .27 | .07 | .02 | .01 | .00 | .00 | | | | | | | | | | | |
| .15 | .280 | .18 | .03 | .01 | .00 | .00 | | | | | | | | | | | | |
| .16 | .237 | .12 | .01 | .00 | .00 | | | | | | | | | | | | | |
| .17 | .200 | .07 | .01 | .00 | | | | | | | | | | | | | | |
| .18 | .167 | .05 | .00 | .00 | | | | | | | | | | | | | | |
| .19 | .139 | .03 | .00 | .00 | | | | | | | | | | | | | | |
| .20 | .115 | .02 | .00 | | | | | | | | | | | | | | | |

[1]There were 10 decisions for each successive 85 enumeration books coded. Each enumeration book contained entries for between 400 and 1,200 persons.
[2]Based on items in error per coded person.

## Chart 13.—PROBABILITY OF LOT ACCEPTANCE DURING CODER'S TRAINING FOR INDUSTRY AND OCCUPATION CODING

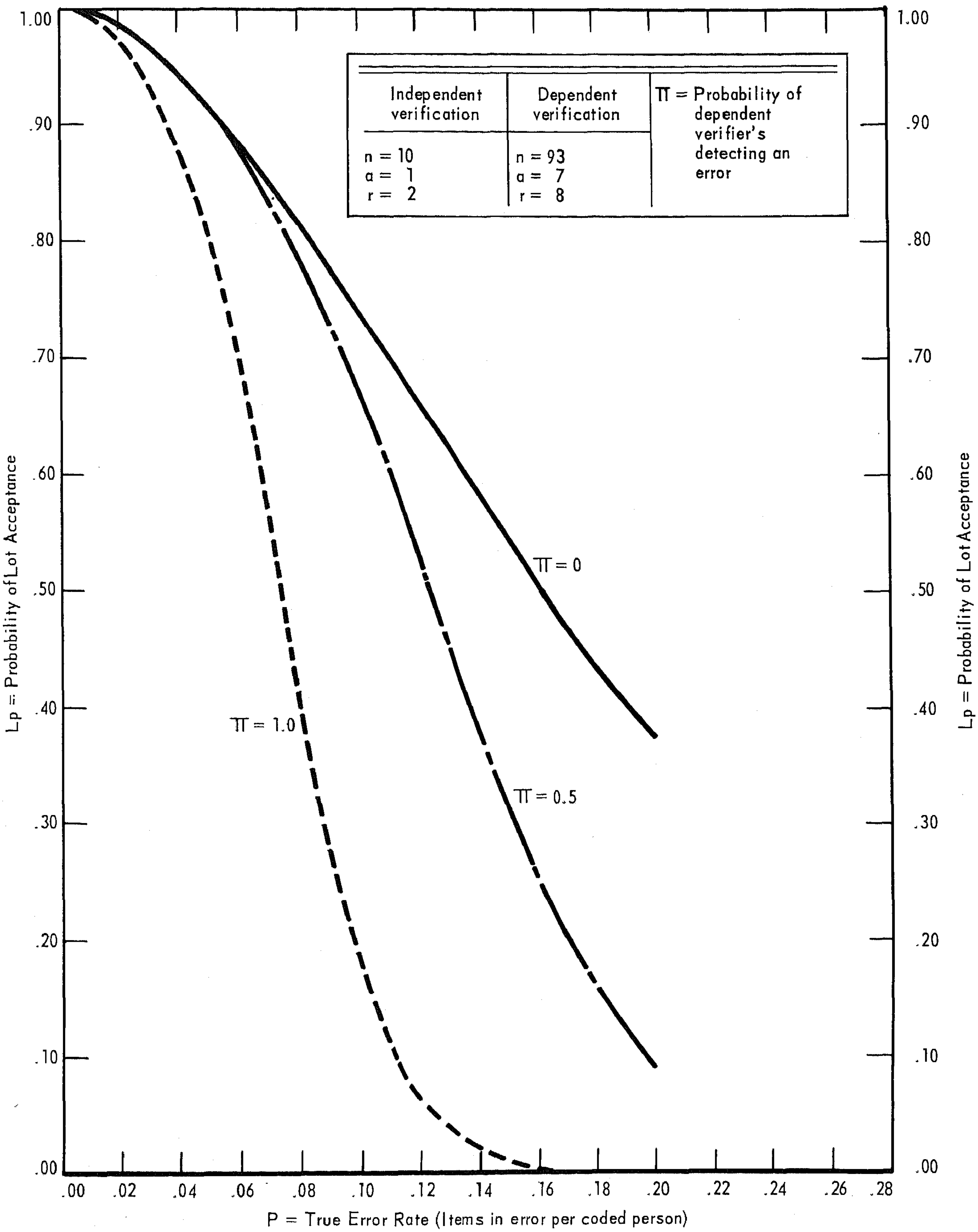


**Chart 14.—PROBABILITY OF A CODER'S QUALIFYING FOR POST-TRAINING INDUSTRY AND OCCUPATION CODING**

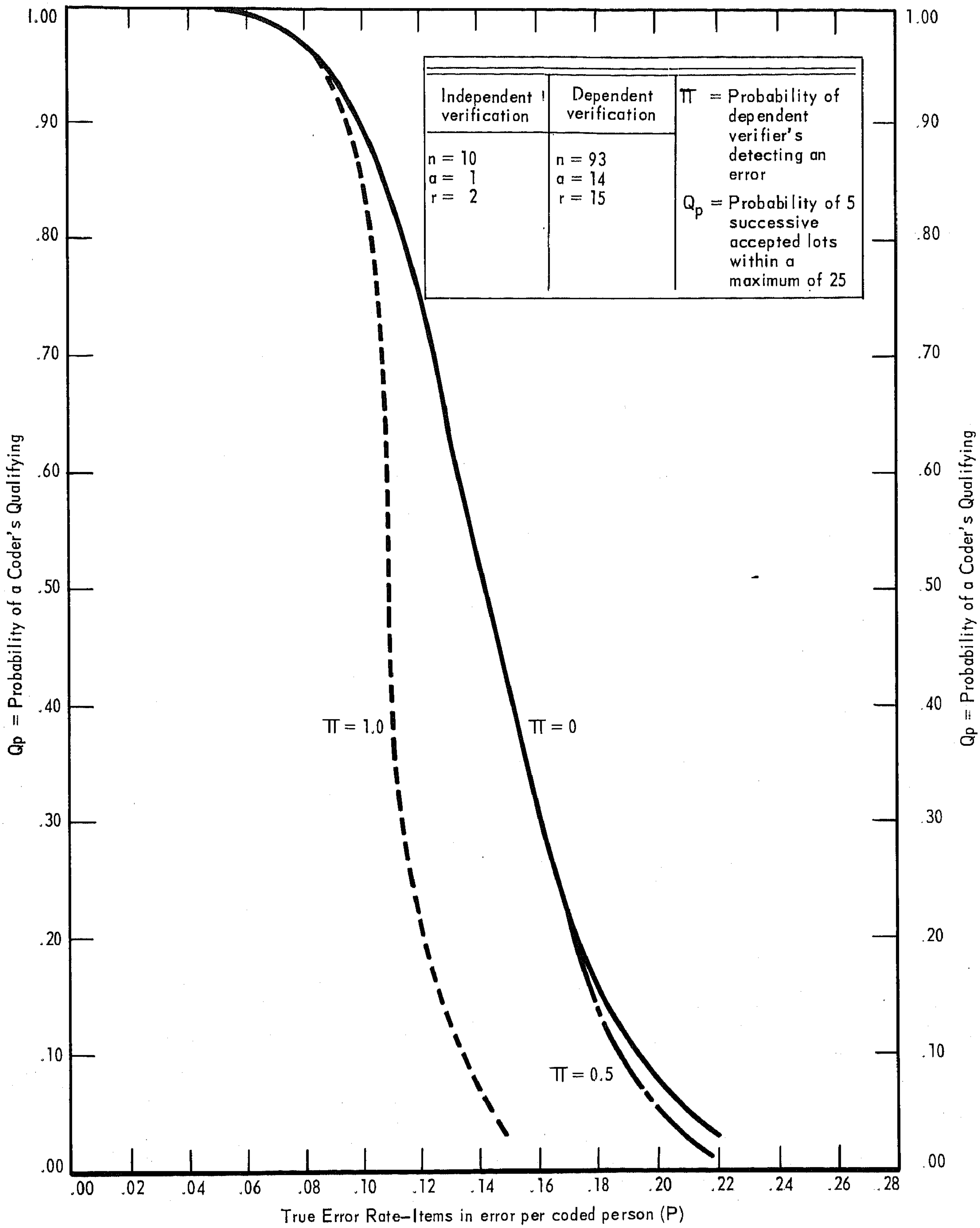


**Table 41.—SAMPLE SIZES AND ACCEPTANCE NUMBERS FOR SINGLE LOT DECISIONS FOR LOTS AND CODERS: INDUSTRY AND OCCUPATION CODING, TRAINING PERIOD**

| Independent verification (Pench-card system) Lots and coders | | Dependent verification | | | |
|---|---|---|---|---|---|
| | | Lots | | Coders | |
| Sample size[1] (coded persons) | Acceptance number[2] (items in error) | Sample size[1] (coded persons) | Acceptance number[2] (items in error) | Sample size[1] (coded persons) | Acceptance number[2] (items in error) |
| 8-10 | 1 | 64-73 | 5 | 64-77 | 12 |
| 11-16 | 2 | 74-83 | 6 | 78-87 | 13 |
| 17-20 | 3 | 84-103 | 7 | 88-93 | 14 |
| | | 104-117 | 8 | 94-103 | 15 |
| | | 118-137 | 9 | 104-113 | 16 |
| | | 138-147 | 10 | 114-117 | 17 |
| | | 148-153 | 11 | 118-127 | 18 |
| | | | | 128-133 | 19 |
| | | | | 134-143 | 20 |
| | | | | 144-147 | 21 |
| | | | | 148-153 | 23 |

[1]If the sample size was less than eight, the sample was cumulated with that of the succeeding lot.
[2]Rejection number was one greater than the acceptance number for each sample size.

cupation, or class of worker for about 12 percent of the coded persons. This method of calculating the error rate (average number of coded persons for whom one or more coded items were in error, per 100 coded persons) was essentially the basis for controlling the coder. However, if a person required one code, he required all three (industry, occupation, and class of worker). Since the average number of errors per person for whom there were one or more errors was 1.1 percent, the error rate per item coded by coders in training, therefore, was about 4 percent (see table 43).

Post-training period.—The industry and occupation coder, like his counterpart in general coding, was placed under the independent verification system once he qualified. This system operated by means of a point system with rules for accepting, rejecting, and removing a coder similar to those established for a general coder. The sampling plan provided for a sample size of 22 coded persons and an acceptance number of three. A coder who had three or fewer items in error in the sample of 22 coded persons received an "accept" decision and one credit. If a coder made more than three errors, he lost a credit.

The average number of errors per 100 coded persons is estimated to have been slightly more than eight. The average error rate per item is estimated at 2.7 percent.

### Verification of the Matching

The pench-card system of verification involved a comparison of the codes assigned by the three independent coders. The correct assignment of error rates depended upon an accurate matching of the codes in the pench cards with each other and those coded in the enumeration book. Had these codes been matched on a computer, there would have been a truly independent system of verification. However, the coding on the pench cards and in the enumeration books was manually matched; therefore, the matching operation was subject to error.

The pench card was designed to minimize error in this matching. If the codes in the two pench cards were not the same, the color of one pench card showed through the penched hole in the other card when the pench cards were placed one on top of the other. For the coded item on the schedule in the enumeration book to match the pench card, the darkened circle in the book had to appear through the hole in the pench card. The matcher was also asked to see that there were never two circles darkened in the same column of the code box on the FOSDIC schedule. This was a more objective system of verification than reading coded entries, but it was still subject to error. Consequently, a system of planting differences in a sample of pench cards was instituted to measure the degree to which matchers failed to detect differences among the pench cards and the coded schedule.

Errors were not planted in the coded entries on the FOSDIC schedules themselves because (1) changing them back would have necessitated erasures on the schedules which might cause poor reading by FOSDIC; (2) there was a possibility that a planted error would slip by and not be changed back; and (3) the flow of enumeration books from one operation to another would have been interrupted. Therefore, instead of changing the coded schedule, both pench cards were changed to the same code by preparing a false set of pench cards, or, less frequently, the code of only one of the two pench cards was changed.

Twice each day the first pencher selected a 1-in-25 sample of his pench cards from a table of random numbers and prepared duplicate first and second pench cards showing only identification information (State, enumeration district, page number, and person within household) for the sample cards. The error planter picked up these cards twice a day. The error planter was located in the second pench unit and planted his errors in the duplicate sets of cards after the second pench coding had been done for the relevant enumeration book.

Since there were three coded items (industry, occupation, class of worker) for a person in the labor force and all three were generally coded, the location of the item in which the error was to be planted in the industry and occupation operation was a simple choice according to one or three digits. There were, however, 10 items which could be coded for a person who was coded by a general coder. Consequently, a method to randomize

**Table 42.—PROBABILITY OF A CODER'S CONTINUANCE, BY ERROR RATE AND NUMBER OF ENUMERATION BOOKS CODED: INDUSTRY AND OCCUPTION CODING, POST-TRAINING PERIOD**

| Coder's error rate (P)[2] | Probability of coder's receiving a credit point per decision (Lp) | Number of enumeration books coded[1] | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 70 | 140 | 210 | 280 | 350 | 420 | 490 | 560 | 630 | 700 | 770 | 840 | 910 | 980 | 1050 | 1120 |
| .00 | 1.000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .01 | 1.000 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .02 | .999 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .03 | .996 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .04 | .989 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .05 | .978 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .06 | .960 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .07 | .936 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .08 | .906 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| .09 | .870 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | .99 | .99 | .99 | .99 | .99 | .98 | .98 | .98 | .98 | .98 |
| .10 | .828 | 1.00 | .99 | .99 | .98 | .98 | .98 | .97 | .96 | .96 | .95 | .95 | .94 | .94 | .93 | .92 | .92 |
| .11 | .782 | .98 | .96 | .94 | .92 | .90 | .89 | .87 | .85 | .83 | .82 | .80 | .79 | .77 | .75 | .74 | .72 |
| .12 | .733 | .96 | .92 | .89 | .85 | .82 | .78 | .75 | .72 | .69 | .67 | .64 | .61 | .59 | .57 | .54 | .52 |
| .13 | .681 | .94 | .88 | .83 | .78 | .73 | .69 | .64 | .61 | .57 | .54 | .51 | .48 | .45 | .42 | .40 | .37 |
| .14 | .628 | .87 | .76 | .66 | .57 | .50 | .43 | .38 | .33 | .29 | .25 | .22 | .19 | .16 | .14 | .12 | .11 |
| .15 | .575 | .80 | .64 | .51 | .41 | .33 | .26 | .21 | .17 | .13 | .11 | .09 | .07 | .06 | .04 | .04 | .03 |
| .16 | .523 | .70 | .49 | .34 | .24 | .17 | .12 | .08 | .06 | .04 | .03 | .02 | .01 | .01 | .01 | .01 | .00 |
| .17 | .471 | .59 | .35 | .21 | .12 | .07 | .04 | .03 | .02 | .01 | .01 | .00 | | | | | |
| .18 | .422 | .47 | .22 | .10 | .05 | .02 | .01 | .00 | | | | | | | | | |
| .19 | .376 | .37 | .14 | .05 | .02 | .01 | .00 | | | | | | | | | | |
| .20 | .332 | .28 | .08 | .02 | .01 | .00 | | | | | | | | | | | |

[1]There were 10 decisions for each successive 70 enumeration books. Each enumeration book contained entries for between 400 and 1,200 persons.
[2]*Items in error per coded person.*

**Table 43.—QUALITY OF CODER AND PENCHER PRODUCTION BY TIME PERIOD: INDUSTRY AND OCCUPATION CODING**

| Period | Percent of coded items in error in the period | | | | Cumulative number of persons in sample | | |
|---|---|---|---|---|---|---|---|
| | In-training coders | Trained coders | First penchers | Second penchers | In-training coders | Trained coders | Penchers |
| Total | 4.2 | 2.7 | 2.9 | 2.7 | - | - | - |
| 5/23/60-6/24/60 | 4.9 | - | 2.3 | 2.2 | 1,895 | 9 | 1,906 |
| 6/25/60-7/29/60 | 4.5 | 3.7 | 3.2 | 2.5 | 12,555 | 623 | 13,179 |
| 7/30/60-8/26/60 | 4.6 | 2.1 | 3.4 | 3.1 | 31,585 | 8,411 | 39,996 |
| 8/27/60-9/30/60 | 3.4 | 3.1 | 3.4 | 3.4 | 45,802 | 39,856 | 85,658 |
| 10/1/60-10/28/60 | 4.4 | 3.1 | 3.3 | 2.9 | 50,699 | 90,606 | 141,300 |
| 10/29/60-11/25/60 | 3.8 | 3.0 | 2.8 | 2.5 | 52,283 | 145,687 | 198,020 |
| 11/26/60-12/9/60 | 2.7 | 2.7 | 2.6 | 2.7 | 52,344 | 178,179 | 230,571 |
| 12/10/60-12/30/60 | - | 2.8 | 2.8 | 2.4 | - | 217,077 | 269,469 |
| 12/31/60-1/27/61 | - | 2.8 | 2.8 | 2.3 | - | 270,841 | 323,233 |
| 1/28/61-2/24/61 | - | 2.7 | 2.5 | 2.3 | - | 328,824 | 381,216 |
| 2/25/61-3/31/61 | - | 2.8 | 2.3 | 2.2 | - | 379,179 | 431,571 |
| 4/1/61-4/7/61 | - | 2.6 | 2.5 | 2.4 | - | 381,382 | 433,726 |

-Represents zero.

the items in which errors were to be planted was required since all items were seldom coded. The division algorithm[4] was utilized for this purpose. The number of items coded on the sample card to be replaced was counted. Then, a 2-digit random number (from a table of random numbers, 02-99) greater than the number of items coded was selected. The random number was divided by the number of items coded, and the remainder plus one determined in which coded item the error was to be planted. There were two exceptions: (1) If all 10 items were coded and the random digit signified that a code for an extra item was to be penched, a coded item was omitted instead, and the formula was used to determine which item to omit; and (2) if no items were coded, an extra item was penched and a random number (1 to 10 inclusive) was selected to identify the item in which the error would be penched.

The error cards were then interfiled with the regular cards for matching and the original cards were filed separately. After the pench cards had been matched, the error planter pulled the error cards from the file. He maintained records for each matcher showing the number of planted errors not found.

For making a decision to accept or reject a matcher, a single sampling plan with truncation when the matcher was rejected was used. Acceptance occurred when he had missed no more than 4 in 50 planted errors inspected. In the course of inspecting the 50 planted errors, whenever the cumulative number of errors missed reached 5, the matcher was rejected.

A matcher was removed from the matching operation whenever he failed sample verification twice in 10 or fewer successive decisions. Characteristics of the sampling plan are shown in table 44 and in charts 15 and 16.

Matching was expected to be a source of trouble in the 3-way independent verification scheme. It was expected that the matching operation would be similar to dependent verification in that matchers would fail to pick up differences among the three coders. Results of the matching operation indicated the fear was unfounded. The miss rate of matchers for errors planted in the general coding, was 3.6 percent. In the case of matchers in industry and occupation coding, it was 1.3 percent. Results are shown in table 45.

[4]The division algorithm: Given two integers R and N, with $N \neq 0$, then there exists a unique pair of integers Q and r such that $R = NQ + r$ where $0 \leq r \leq /N/$. This algorithm was modified to $R = NQ + r + 1$, so that zero would be excluded. R, the random number. N, the number of items coded. Q, the quotient determined by R/N.

**Table 44.—PROBABILITY OF MATCHER'S CONTINUANCE, BY ERROR RATE AND NUMBER OF DECISIONS**

| True matcher's error rate | One decision | | Number of decisions[2] | | | |
|---|---|---|---|---|---|---|
| | Probability of acceptance[1] | Expected sample size | 5 | 10 | 15 | 20 |
| .00 | 1.00 | 50 | 1.00 | 1.00 | 1.00 | 1.00 |
| .01 | 1.00 | 50 | 1.00 | 1.00 | 1.00 | 1.00 |
| .03 | .98 | 50 | 1.00 | 1.00 | .99 | .99 |
| .04 | .95 | 49 | .98 | .91 | .85 | .79 |
| .06 | .82 | 48 | .84 | .54 | .36 | .24 |
| .07 | .63 | .47 | .65 | .25 | .11 | .05 |
| .09 | .53 | 44 | .23 | .02 | .00 | .00 |
| .15 | .11 | 32 | .00 | .00 | ...... | ....... |
| .20 | .02 | 25 | ...... | ...... | ...... | ....... |

[1]Maximum number of planted errors to be inspected for a decision, 50; acceptance if number of planted errors missed was 4 or less; rejection if number was 5 or more.
[2]Matcher terminated when he failed sample verification twice in 10 or fewer decisions.

**Chart 15.—PROBABILITY OF A MATCHER'S CONTINUANCE AFTER NUMBER OF DECISIONS SHOWN**

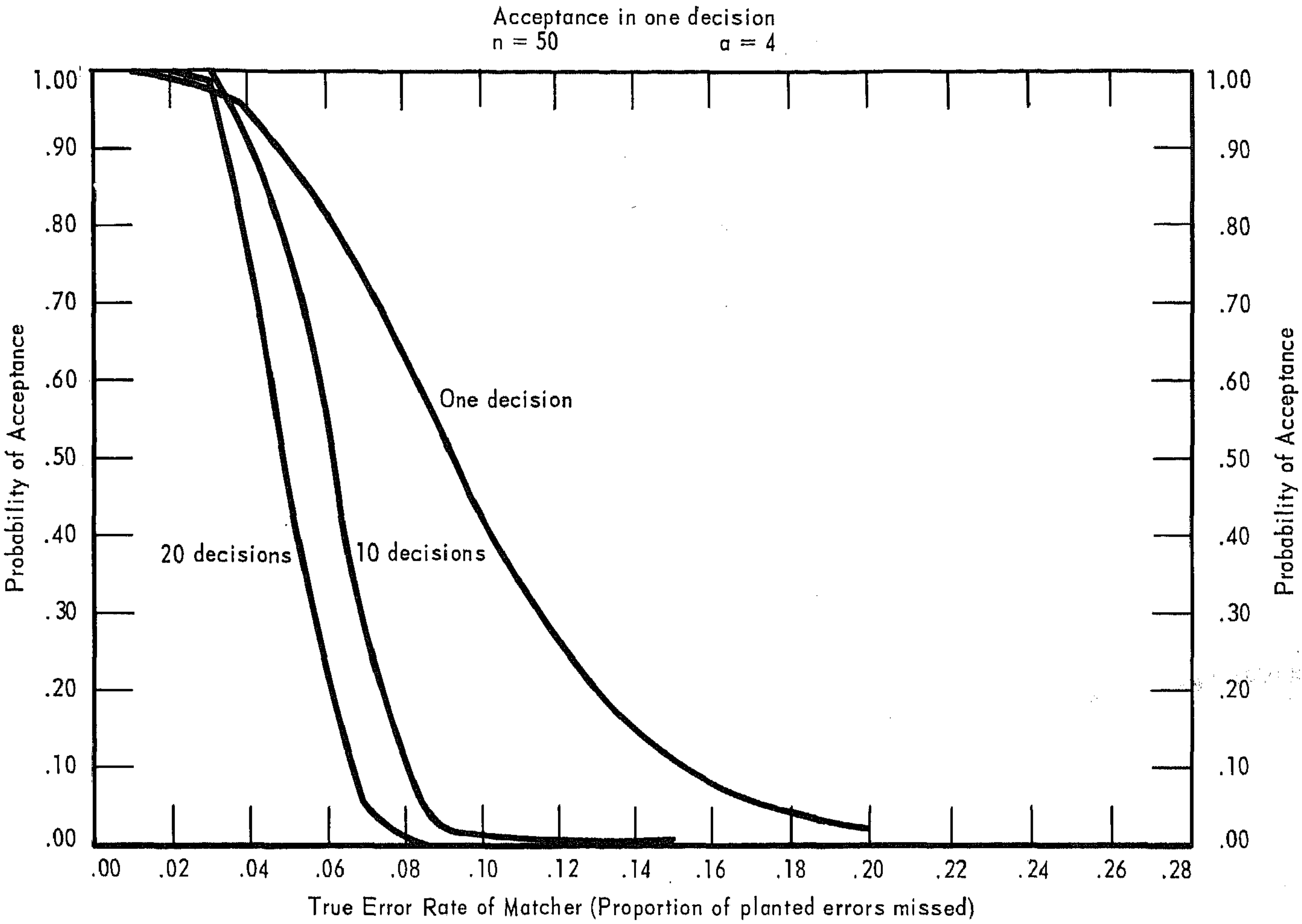



**Table 45.—QUALITY OF MATCHING OF INDEPENDENT VERIFICATION CODING BY TIME PERIOD**

| Period | General coding | | | Industry and occupation coding | | |
|---|---|---|---|---|---|---|
| | Number of planted errors | Number of errors missed | Matcher's error rate | Number of planted errors | Number of errors missed | Matcher's error rate |
| Total......... | 22,441 | 798 | 3.6 | 23,676 | 316 | 1.3 |
| 5/23/60-6/24/60.. | 432 | 19 | 4.4 | 173 | 6 | 3.5 |
| 6/25/60-7/29/60.. | 1,725 | 78 | 4.5 | 781 | 18 | 2.3 |
| 7/30/60-8/26/60.. | 3,076 | 151 | 4.9 | 1,347 | 40 | 3.0 |
| 8/27/60-9/30/60.. | 3,240 | 184 | 5.7 | 2,389 | 79 | 3.3 |
| 10/1/60-10/28/60. | 2,549 | 105 | 4.1 | 2,914 | 47 | 1.6 |
| 10/29/60-11/25/60 | 2,046 | 83 | 4.1 | 2,948 | 43 | 1.5 |
| 11/26/60-12/9/60. | 1,062 | 21 | 2.0 | 1,634 | 14 | 0.9 |
| 12/10/60-12/30/60 | 1,388 | 38 | 2.7 | 2,096 | 17 | 0.8 |
| 12/31/60-1/27/61. | 2,508 | 48 | 1.9 | 2,872 | 22 | 0.8 |
| 1/28/61-2/24/61.. | 2,458 | 47 | 1.9 | 3,329 | 13 | 0.4 |
| 2/25/61-3/31/61.. | 1,764 | 24 | 1.4 | 3,053 | 16 | 0.5 |
| 4/1/61-4/7/61.... | 193 | - | - | 140 | 1 | 0.7 |

- Represents zero.