# FOREWORD

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Reports for the various tasks listed below are being issued under separate covers:

| | |
|---|---|
| Equipment Evaluation by Design Techniques | WADD TR 60-760 |
| Circuit Classification and Evaluation | WADD TR 60-848 |
| Incipient Failure Detection | WADD TR 60-788 |
| Part Rejection Analysis | WADD TR 60-516 |
| Reliability of Modular Assemblies | WADD TR 60-515 |
| Collection, Analysis, and Reporting of Reliability Test Data | WADD TR 61-30 |

T. Andrews and F. Applegate of the Advanced Electronics Center of the General Electric Light Military Electronics Department, Ithaca, New York, are responsible for the material in this report on Part Rejection Analysis.

## ABSTRACT

Rejections of parts were studied at two incoming inspection operations of military equipment manufacturers. Data were analyzed in terms of vendor quality, part type quality, and the nature of the defects.

## PUBLICATION REVIEW

The publication of this report does not constitute approval by the Air Force of the findings or conclusions contained herein. It is published only for the exchange and stimulation of ideas.

FOR THE COMMANDER:

Harvey R. Shute

HARVEY R. SHUTE
Chief, Engineering Services Branch
Operational Support Engineering Division

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# I. INTRODUCTION

This study is concerned with an investigation of the quality of the parts received by manufacturers from vendors as determined by the manufacturers' incoming inspection operation. It is preliminary and intended as a pilot study for possible larger scale studies of military product incoming inspection operations.

The initial objective was to determine if there was a relationship between the quality of parts and the reliability of these parts when assembled in equipment. It was realized, however, following initiation of the effort that the available data from the incoming inspection operations and from reliability records were not suitable for such a comparison. Therefore, the study was limited to an investigation of the incoming inspection operations.

The data for the study were selected from two quality control operations, one a manufacturer producing a number of different airborne electronic equipments and the other a manufacturer producing a single missile guidance equipment. In the remainder of the report the former is referred to as the general operation and the latter as the specialized operation. The majority of the data analyzed was from 1959 operations.

A few of the questions posed at the beginning of the study were:

1) What is the quality level of component parts in these operations?

2) Is the quality of standard parts higher than the quality of nonstandard parts?

3) What are the types of defects observed?

4) Does the experience over a period of time with individual suppliers, with the accompanying feedback of quality control information, have an observable positive effect on incoming quality?

To answer these particular questions and to gain insight concerning incoming inspection operations, the data were analyzed in terms of vendor quality, part type quality, and the nature of the observed defects.

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## II. VENDOR QUALITY

The study approach was to collect and analyze from both of the operations described previously a sample of incoming inspection records, covering a three-month period. The same sample of records was also used to determine part type quality which will be discussed later.

In each operation parts of an electrical nature were inspected for both electrical and mechanical defects with few exceptions. Parts predominantly mechanical were inspected only for mechanical defects.

The general operation used a sampling plan for inspection based on an Acceptable Quality Level (AQL) of 0.65 percent for electrical defects and 1.0 percent for mechanical defects. However, critical parts and parts with a history of production problems were 100 percent inspected. Also due to the purchasing of small quantities of some parts, the sampling plan for these resulted in 100 percent inspection. In the specialized operation all parts were 100 percent inspected, because of the critical nature of the product.

The inspection data for both operations listed the percent defective in the samples for each part type and also the average percent defective in the samples of parts received from each vendor. The term "part type" as used in this report is a specific item which differs in some respect from another item and is identified by a drawing number, for example, 470-ohm, 0.5-watt, 5 percent carbon composition resistors. "Part type" also includes materials and assemblies but such items constitute only a small percentage of all items. Later the term "part class" will be used to refer to the broader collection of part types, for example carbon composition resistors, paper capacitors, vacuum tubes, etc. "Percent defective" is defined as the percentage of inspected parts in a sample which contains one or more defects. For the general operation, the number of samples inspected but not the number of parts received was tabulated. In the specialized operation, the number of parts received was accurately known. This latter point will be important since, as will be shown, the process average for the specialized operation could then be determined.

TABLE I

DISTRIBUTION OF QUALITY OF VENDORS

| Range of Percent Defective | Vendors (Percent) | | | |
|---|---|---|---|---|
| | Electrical Defects | | Mechanical Defects | |
| | General | Specialized | General | Specialized |
| $x = 0$ | 58.8 | 54.9 | 57.2 | 51.2 |
| $0 < x < 1$ | 12.0 | 6.5 | 3.2 | 0.77 |
| $1 \leq x < 2$ | 5.0 | 4.9 | 2.7 | 0.77 |
| $2 \leq x < 3$ | 3.7 | 4.6 | 2.0 | 0.93 |
| $3 \leq x < 4$ | 3.7 | 2.6 | 2.1 | 1.2 |
| $4 \leq x < 5$ | 1.4 | 1.1 | 1.6 | 1.1 |
| $5 \leq x < 10$ | 4.2 | 4.5 | 5.6 | 2.6 |
| $0 < x < 10$ | 30.3 | 24.3 | 17.3 | 7.4 |
| $10 \leq x < 20$ | 4.3 | 6.5 | 7.1 | 5.1 |
| $20 \leq x < 30$ | 1.6 | 2.3 | 4.9 | 4.2 |
| $30 \leq x < 40$ | 1.7 | 1.5 | 2.5 | 3.1 |
| $40 \leq x < 50$ | 0.3 | 1.5 | 1.8 | 2.3 |
| $50 \leq x < 60$ | 0.4 | 2.2 | 1.9 | 2.6 |
| $60 \leq x < 70$ | 0.6 | 0.76 | 1.4 | 1.7 |
| $70 \leq x < 80$ | 0.0 | 0.00 | 0.55 | 0.31 |
| $80 \leq x < 90$ | 0.1 | 0.00 | 0.58 | 1.7 |
| $90 \leq x < 100$ | 0.2 | 0.00 | 0.58 | 3.4 |
| $x = 100$ | 2.0 | 6.0 | 4.3 | 17.0 |
| Sample Size Number of Vendors | 993 | 264 | 2569 | 647 |

To show vendor quality, the distribution of vendor percent defective was obtained. This distribution is shown in Table I. This table shows the percentage of vendors within a specified range of quality (i.e., percent defective product). Zero percent defective and 100 percent defective are presented discretely since these quality values are important in a true representation of the data. The correct interpretation of the distribution is to imagine that a vendor is chosen at random from all of the vendors. If this is done a number of times, the proportion of vendors within a specified range of percent defective will be given by the tabulated percentage in the body of the table. For example, the percentage of vendors in the specialized operation with electrical defects in the range from 10 to 20 percent is 6.5 percent. Note that this representation of incoming inspection data disregards the amount of product supplied by a vendor. Thus a vendor who supplies 1000 parts total is given the same weight as a vendor who supplies only 10 parts.

The vendor quality distribution shows that a large number of the vendors supply a product containing no defects. The distribution also shows that the number of vendors decreases sharply as the percent defective increases toward 100 percent. Note especially that many vendors during the three-month period from which the data were collected supplied a 100-percent defective product. Further examination of the sample of data indicates that those vendors which had 100-percent defective products supplied a relatively small number of parts or a nonstandard part type.

In order to summarize the vendor quality data, the average vendor quality was calculated for each of the four subclassifications of vendor quality. These vendor quality averages are shown in Table II. It should be emphasized that since the parent distributions of these averages are highly skewed, the averages primarily reflect what happens at higher percent defective values.

TABLE II

VENDOR AVERAGE QUALITY

| | Percent Defective | |
|---|---|---|
| | General Operation | Specialized Operation |
| Electrical Defects | 5.3 | 11.2 |
| Mechanical Defects | 12.2 | 28.7 |

Since, as was previously mentioned, each vendor is weighted the same in the compilation of the distribution, neither the distribution nor the vendor average quality should be interpreted as the overall process quality of received parts. The vendor average quality is considerably lower (i.e., the percent defective is higher) in general than the process average.

The process average is defined as the number of parts (or items) found defective divided by the total number of parts received. This is a true measure of the quality of parts received. Process average in the sense used here applies to a population of all parts received. Generally the process average is applied to a more homogeneous set of objects, for example, to the population of a single part type received during some period of time.

Unfortunately the process average could be computed only for the specialized and not for the general operation. In the latter case, the number of parts received was not tabulated with the percentage defective and could not be obtained from other sources during the course of this effort. The process average for the specialized operation was computed from the same data as the distribution of vendor quality and is shown in Table III.

TABLE III

OVERALL PROCESS AVERAGE FOR SPECIALIZED OPERATION

| | Percent Defective | Sample Size Number of Parts |
|---|---|---|
| Electrical Defects | 1.1 | 78,496 |
| Mechanical Defects | 19 | 21,088 |

These process averages are lower than the vendor average quality levels. The differences are due to the greater number of parts or items received from vendors supplying higher quality parts. The major contribution to the lower vendor average quality is due to the large number of vendors with a 100-percent defective product. Mathematically different averaging methods have been applied to the same data. To be explicit concerning the methods, the average vendor quality was computed by the

$$\frac{1}{v} \sum_{j=1}^{v} \frac{\sum_{i=1}^{r_j} d_{ij}}{\sum_{i=1}^{r_j} n_{ij}}$$

(Average of vendor percent defective)

and the process average by

$$\frac{\sum_{j=1}^{v} \sum_{i=1}^{r_j} d_{ij}}{\sum_{j=1}^{v} \sum_{i=1}^{r_j} n_{ij}}$$

(Average percent defective)

where

$v$ = number of vendors

$r_j$ = number of part types produced by the $j^{th}$ vendor

$d_{ij}$ = number of defective parts of the $i^{th}$ part type from the $j^{th}$ vendor

$n_{ij}$ = number of received parts of the $i^{th}$ part type from the $j^{th}$ vendor

Further examination of the vendor data was made in an attempt to corroborate the beneficial effects of feedback from the quality control operation on average vendor quality. The data on vendors supplying the specialized operation were used.

The vendors were classified into groups which had supplied the operation for two preceding quarters, three preceding quarters, and four preceding quarters. The average quality (i.e., the average percent of electrical defects) of these groups was then plotted by succeeding quarters. This plot, which is shown in Figure 1, indicates that there is a decrease in vendor percent defective as the time over which the vendor supplies parts is increased. The percent defectives may be compared with the

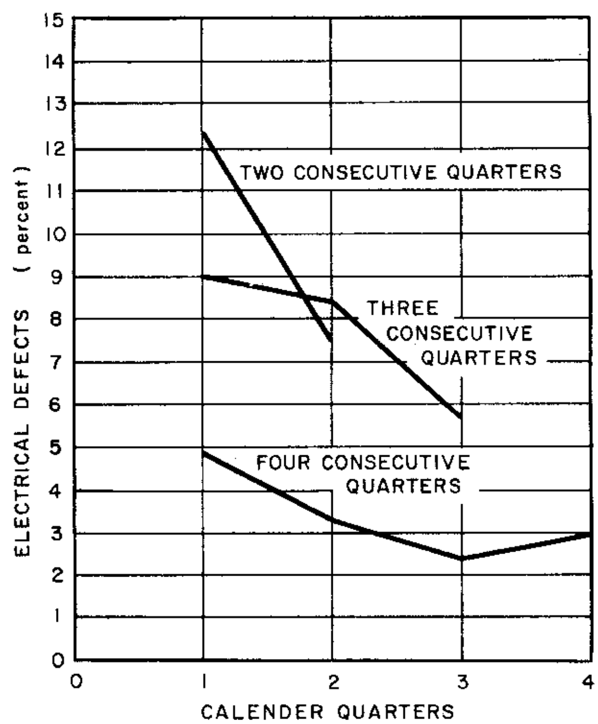


Figure 1. Vendor Percent Defective vs Number of Calendar Quarters the Vendor Supplied the Specialized Operation

11.2 percent value for vendor average percent defectives given in Table II. Statistically, the average quality of the group that supplied parts for four consecutive quarters is significantly better than the average quality of all other vendors. The data also show that in each group there is generally an increase in quality in succeeding quarters and this may be interpreted as supporting evidence of the positive effects of feedback from quality control to the vendor.

# III. PART TYPE QUALITY

An analysis similar to that made for vendor quality was made for part types. The data were from the same quarter as for the vendor analysis. The percent defective for a part type is a weighted average of the percent defective from each lot.

A distribution of part type quality is shown in Table V. This is to be interpreted in the same way as the vendor quality distribution of Table I. The part type average percent defective is presented in Table IV.

TABLE IV

PART TYPE AVERAGE QUALITY

| | Percent Defective | |
|---|---|---|
| | General Operation | Specialized Operation |
| Electrical Defects | 1.8 | 7.2 |
| Mechanical Defects | 9.0 | 17.0 |

Note in comparing Tables II, III, and IV that part type quality is closer to the process average than vendor quality. The differences between the two are due to the methods of averaging. Similar to the method used in obtaining the vendor average, where the number of parts supplied by each vendor is ignored, the part type average ignores the different numbers of parts of the various part types which are received.

In the previous section some discussion of the reasons for differences in quality between vendors was presented. Similar differences are evident among part types also. In order to better understand the reasons for the differences, two sets of additional data were analyzed.

TABLE V

DISTRIBUTION OF QUALITY OF PART TYPE

| Range of Percent Defective | Part Types (percent) | | | |
|---|---|---|---|---|
| | Electrical Defects | | Mechanical Defects | |
| | General | Specialized | General | Specialized |
| $x = 0$ | 90.1 | 81.8 | 84.0 | 79.0 |
| $0 < x < 1$ | 1.8 | 1.8 | 0.48 | 0.04 |
| $1 \leq x < 2$ | 0.80 | 1.6 | 0.33 | 0.13 |
| $2 \leq x < 3$ | 0.85 | 0.92 | 0.33 | 0.13 |
| $3 \leq x < 4$ | 0.53 | 0.92 | 0.24 | 0.09 |
| $4 \leq x < 5$ | 0.36 | 0.51 | 0.33 | 0.04 |
| $5 \leq x < 10$ | 1.5 | 2.1 | 1.32 | 0.63 |
| $0 < x < 10$ | 5.8 | 7.9 | 3.0 | 1.08 |
| $10 \leq x < 20$ | 1.2 | 1.6 | 1.5 | 0.81 |
| $20 \leq x < 30$ | 0.76 | 0.82 | 1.2 | 0.94 |
| $30 \leq x < 40$ | 0.67 | 0.31 | 1.1 | 0.90 |
| $40 \leq x < 50$ | 0.31 | 0.31 | 0.66 | 0.58 |
| $50 \leq x < 60$ | 0.27 | 1.0 | 1.2 | 0.72 |
| $60 \leq x < 70$ | 0.09 | 0.51 | 0.59 | 0.54 |
| $70 \leq x < 80$ | 0.04 | 0.10 | 0.22 | 0.40 |
| $80 \leq x < 90$ | 0.04 | 0.00 | 0.26 | 0.67 |
| $90 \leq x < 100$ | 0.00 | 0.10 | 0.15 | 0.09 |
| $x = 100$ | 0.62 | 5.0 | 6.1 | 14.3 |
| Sample Size No. of Part Types | 2242 | 977 | 4560 | 2223 |

TABLE VI

QUALITY OF STANDARD PART CLASSES (GENERAL OPERATION)

| Standard Part Classes* | | | Percent Defective Electrical Defects | Percent Defective Mechanical Defects |
|---|---|---|---|---|
| Resistor | Fixed | Composition | 0.00 | 0.00 |
| Resistor | Fixed | Deposited Film | 0.06 | 0.42 |
| Resistor | Fixed | Metal Film | 0.78 | 1.52 |
| Resistor | Fixed | Power Wirewound | 0.28 | 0.03 |
| Resistor | Fixed | Accurate Wirewound | 0.31 | 2.27 |
| Resistor | Variable | Composition | 0.00 | 0.00 |
| Resistor | Variable | Wirewound | 0.00 | 0.00 |
| Resistors | (average) | | 0.20 | 0.60 |
| Capacitor | Paper | 125 C | 0.00 | 0.00 |
| Capacitor | Paper | 85 C | 0.21 | 1.46 |
| Capacitor | Mica | | 0.01 | 0.00 |
| Capacitor | Tantalum | | 0.11 | 0.11 |
| Capacitor | Ceramic | | 0.00 | 0.00 |
| Capacitors | (average) | | 0.07 | 0.31 |
| Part Classes in General | | | | |
| Resistor | | | 1.6 | 7.1 |
| Capacitor | | | 0.5 | 10.5 |

*MIL-STD parts or company-accepted standard parts

TABLE VII

LOTS REJECTED IN THE SPECIALIZED OPERATION

| Month | Number of Lots Received | Number of Lots Rejected | Number of GSI Lots Rejected | Percent Lots Rejected | Percent GSI Lots Rejected |
|---|---|---|---|---|---|
| 1 | 262 | 79 | 25 | 30.1 | 9.5 |
| 2 | 204 | 80 | 20 | 39.2 | 9.8 |
| 3 | 235 | 90 | 17 | 38.3 | 7.2 |
| 4 | 187 | 53 | 19 | 28.3 | 10.2 |
| 5 | 204 | 56 | 17 | 27.4 | 8.3 |
| 6 | 305 | 82 | 13 | 26.9 | 4.3 |
| 7 | 297 | 48 | 18 | 16.2 | 6.1 |
| 8 | 188 | 34 | 9 | 19.0 | 4.8 |
| 9 | 255 | 60 | 11 | 23.5 | 4.3 |
| 10 | 279 | 99 | 17 | 35.5 | 6.1 |
| 11 | 207 | 55 | 19 | 26.6 | 9.2 |
| 12 | 95 | 35 | 8 | 37.0 | 8.4 |
| 13 | 76 | 27 | 3 | 35.6 | 11.1 |
| 14 | 116 | 52 | 11 | 51.0 | 21.0 |
| 15 | 121 | 50 | 5 | 41.2 | 10.0 |
| 16 | 118 | 37 | 6 | 31.4 | 16.4 |
| 17 | 122 | 49 | 0 | 40.2 | 0.0 |
| 18 | 108 | 22 | 3 | 20.3 | 13.6 |
| 19 | 106 | 28 | 1 | 26.2 | 3.6 |
| Total | 3485 | 1036 | 222 | 29.7 | 6.4 |

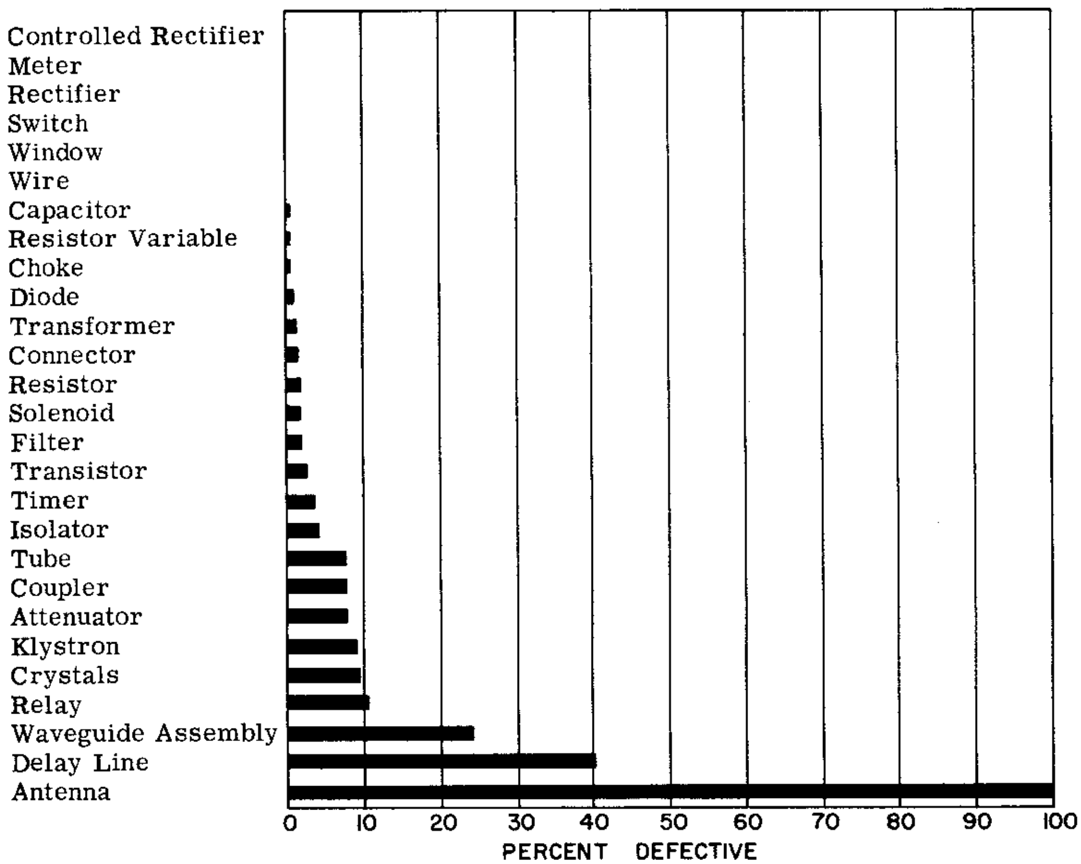


Figure 2. Percent Defective of Various Part Classes Inspected for Electrical Defects (Specialized Operation)

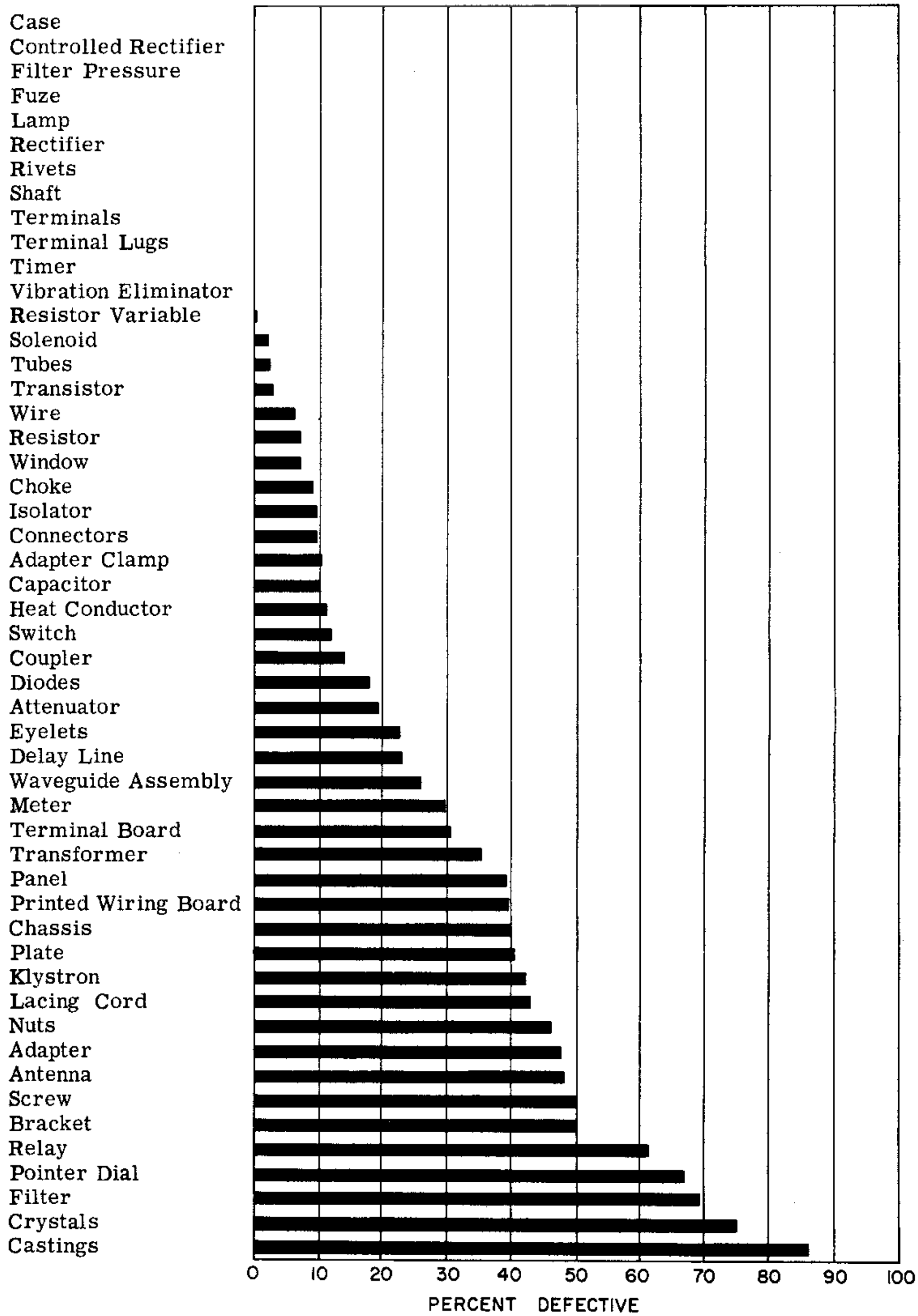


Figure 3. Percent Defective of Various Part Classes Inspected for Mechanical Defects (Specialized Operation)

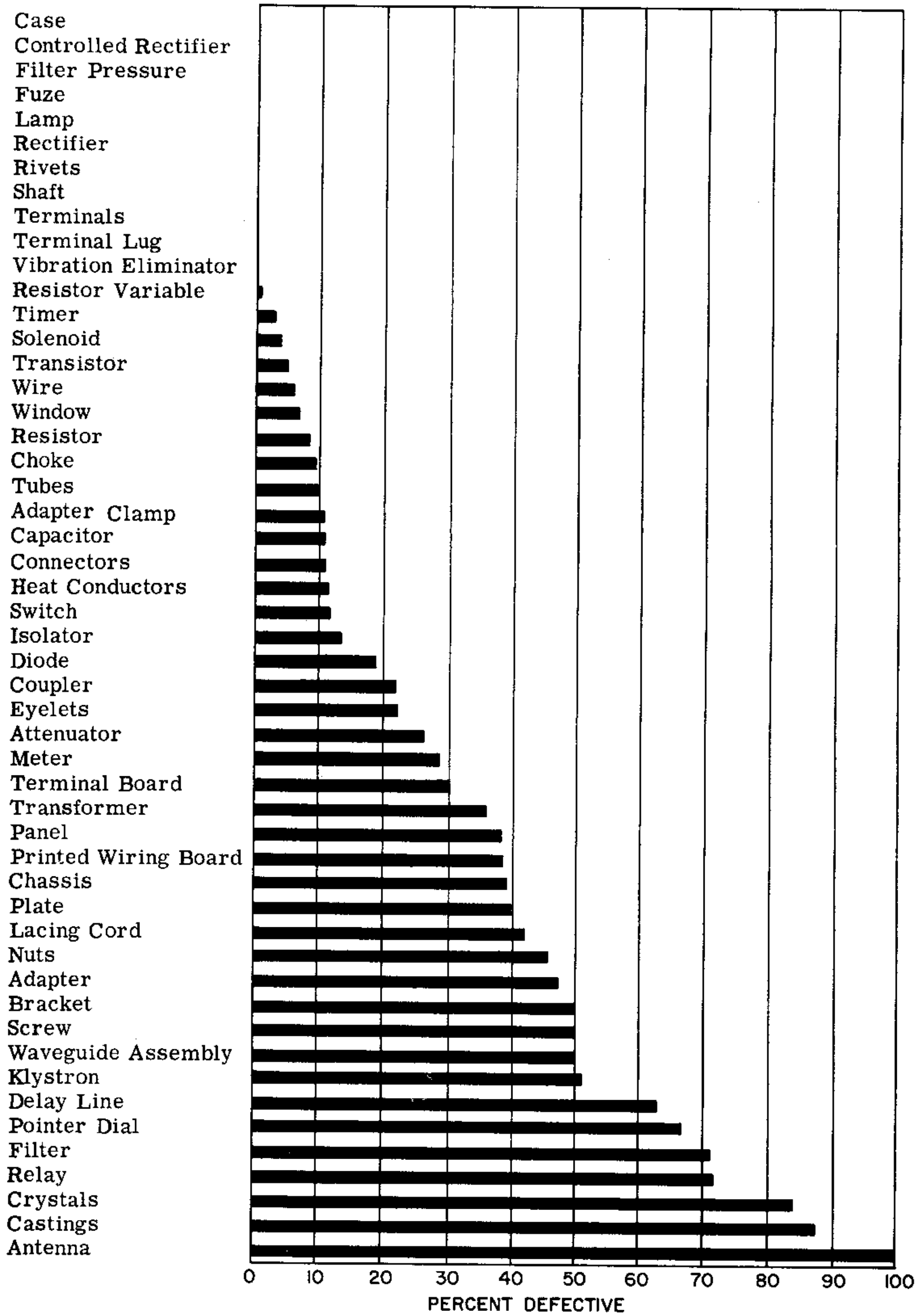


**Figure 4.** Percent Defective of Various Part Classes Inspected for Both Electrical and Mechanical Defects (Specialized Operation)

The first set was a sample collected from the general operation of part classes which were either MIL-Standard or considered as standard by the manufacturer. The results of the analysis of these data are shown in Table VI. Standard part classes exhibit a lower percent defective than the same part classes considered in general which include both standard and nonstandard parts.

The second set of data was collected from the specialized operation and included a much broader range of part classes. The objective in this case was to see whether or not any ordering of the percent defective of the classes reflected any a priori ideas concerning the complexity of parts. It was conjectured that the simple part classes (i.e., simple in terms of the difficulty and number of separate operations required to produce the part) would have a lower percentage defective. The collected data are shown in Figures 2, 3, and 4. Figure 2 includes electrical defects only, Figure 3 mechanical defects only, and Figure 4 includes the total mechanical and electrical defects. In each figure, the part classes are arranged according to percent defective. No obvious ordering is apparent although some tendencies are present. This yields the tentative conclusion that the differences between vendors and the differences between part types are not solely due to the part class manufactured.

An investigation was made to determine the effect of government source inspection (GSI). Answering this question conclusively was impossible but a sample of data from the specialized operation was collected which showed the lot rejection rates for a 19-month period. This sample is shown in Table VII where it can be noted that a large number of GSI lots were rejected.

## IV. NATURE OF DEFECTS

To determine the nature of defects, a sample was collected of the disposition records of rejected lots from the specialized operation over a 17-month period (see Table VIII). Twenty-five percent of the rejected lots can be used as they are. This high incidence of rejected lots which can be used as they are is presumed to be due to minor defects, i.e., those that do not materially reduce the usability of the item for its intended purpose. It indicates that minor defects should be classified into a separate group with a more liberal AQL assigned. On the other hand, 46 percent of all rejects have to be returned to the vendor or scrapped; this segment of rejects causes a great deal of wasted time and expense to a manufacturing operation. Six percent of the rejects are reworked, but not to the drawing.

TABLE VIII

DISPOSITIONS OF REJECTED LOTS

| Month | Number of Lots | Use as is | | Rework to Drawing | | Rework Not to Drawing | | Scrap | | Return to Vendor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number | Percent | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| 1 | 83 | 25 | 30.1 | 15 | 18.1 | 4 | 4.8 | 18 | 21.7 | 21 | 25.3 |
| 2 | 60 | 13 | 21.7 | 15 | 25.0 | 8 | 13.3 | 12 | 20.0 | 12 | 20.0 |
| 3 | 72 | 17 | 23.6 | 12 | 16.7 | 10 | 13.9 | 10 | 13.9 | 23 | 31.9 |
| 4 | 95 | 35 | 36.8 | 16 | 16.8 | 6 | 6.3 | 11 | 11.6 | 27 | 28.4 |
| 5 | 65 | 19 | 29.2 | 17 | 26.2 | 6 | 9.2 | 5 | 7.7 | 18 | 27.7 |
| 6 | 45 | 14 | 31.1 | 10 | 22.2 | 5 | 11.1 | 5 | 11.1 | 13 | 24.4 |
| 7 | 69 | 17 | 24.6 | 13 | 18.8 | 2 | 2.9 | 15 | 21.7 | 22 | 31.9 |
| 8 | 100 | 23 | 23.0 | 32 | 32.0 | 5 | 5.0 | 7 | 7.0 | 33 | 33.0 |
| 9 | 57 | 16 | 28.1 | 5 | 8.8 | 1 | 1.8 | 10 | 17.5 | 25 | 43.9 |
| 10 | 48 | 11 | 23.0 | 9 | 18.9 | 2 | 4.2 | 11 | 37.5 | 15 | 31.3 |
| 11 | 39 | 5 | 12.8 | 15 | 38.5 | 0 | | 10 | 25.7 | 9 | 23.0 |
| 12 | 34 | 13 | 38.5 | 7 | 20.9 | 1 | 2.9 | 3 | 7.9 | 10 | 29.8 |
| 13 | 35 | 4 | 11.4 | 8 | 22.8 | 3 | 8.6 | 2 | 5.7 | 18 | 51.5 |
| 14 | 55 | 8 | 14.5 | 24 | 43.6 | 2 | 3.6 | 5 | 9.1 | 16 | 29.2 |
| 15 | 40 | 7 | 17.5 | 11 | 27.5 | 2 | 5.0 | 6 | 15.0 | 14 | 35.0 |
| 16 | 36 | 3 | 8.3 | 6 | 16.6 | 0 | | 4 | 11.1 | 23 | 64.0 |
| 17 | 28 | 13 | 46.5 | 4 | 14.3 | 1 | 3.6 | 8 | 28.6 | 2 | 7.2 |
| Total | 961 | 243 | 25.3 | 219 | 22.8 | 58 | 6.0 | 141 | 14.8 | 301 | 31.3 |

TABLE IX

DISTRIBUTION OF DEFECTS

| Part | Number of Parts | | Percent Defective | | Types of Defects (Percent) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Electrical | Mechanical | Electrical | Mechanical | Electrical | | | Mechanical | | | | | | | | | Wrong Part |
| | | | | | Major | Minor | | Major | Minor | | Markings | | | Dimensions | | | |
| | | | | | | Repair | Use | | Repair | Use | Major | Minor | Use | Major | Minor | Use | |
| DC Power Supply | 14 | 14 | | 14.3 | | | | | 100.0 | | | | | | | | |
| RC Network | 19 | 19 | | 89.5 | | | | | | | | 100.0 | | | 58.8 | | |
| Pulse Forming Network | 16 | 16 | | | | | | | | | | | | | | | |
| Crystal Detector | 5 | 5 | | | | | | | | | | | | | | | |
| RF Detector | 2 | 2 | | 50.0 | | | | | | | | 100.0 | | | 100.0 | | |
| Detector | 12 | 12 | | 83.3 | | | | | | | | | | | | 100.0 | |
| Mixer | 44 | 44 | 18.2 | | 100.0 | | | | | | | | | | | | |
| Electrical Assemblies | 112 | 112 | 7.1 | 26.8 | 100.0 | | | | 6.7 | | | 60.0 | | | 36.7 | 33.3 | |
| Attenuator | 26 | 26 | 7.7 | 19.2 | 100.0 | | | 40.0 | 60.0 | | | | | | | | |
| Isolator | 173 | 203 | 4.0 | 9.4 | 14.3 | 42.9 | 42.9 | 26.3 | 10.5 | | | 26.3 | | | 5.3 | | 31.6 |
| Window | 42 | 42 | | 7.1 | | | | | | 33.3 | | 33.3 | | | | 33.3 | |
| Rectifier | 371 | 103 | | | | | | | | | | | | | | | |
| Transistor | 3119 | 712 | 2.3 | 2.9 | 100.0 | | | | | | | | | 19.0 | | 52.4 | 28.6 |
| Solenoid | 56 | 44 | 1.8 | 2.3 | 100.0 | | | | | | | | | | | 100.0 | |
| Timer | 28 | 28 | 3.6 | | 100.0 | | | | | | | | | | | | |
| Relay | 315 | 49 | 10.5 | 61.2 | 100.0 | | | | | | | 100.0 | | | | | |
| Crystals | 63 | 79 | 9.5 | 74.7 | 16.7 | 83.3 | | | | | | 66.1 | | | | 33.9 | |
| Controlled Rectifier | 20 | 20 | | | | | | | | | | | | | | | |
| Resistor Variable | 350 | 285 | 0.6 | 0.4 | 100.0 | | | | | | | | | | | | 100.0 |
| Resistor | 1583 | 689 | 1.6 | 7.1 | 100.0 | | | 2.0 | | | | | | | 6.1 | | 91.8 |
| Capacitor | 1362 | 419 | 0.5 | 10.5 | 100.0 | | | 2.3 | | | | 34.0 | | | 18.2 | 34.0 | 11.4 |
| Choke | 5093 | 949 | 0.6 | 9.1 | 100.0 | | | | 7.0 | | 67.4 | 32.6 | | | | | |
| Delay Line | 237 | 238 | 40.1 | 22.7 | 87.4 | | 12.6 | 18.5 | 37.0 | | 9.3 | 3.7 | 20.4 | 5.6 | 1.9 | 9.3 | |
| Klystron | 154 | 149 | 9.1 | 42.3 | 100.0 | | | 34.9 | 63.5 | | | | | | | | 1.6 |
| Tube | 355 | 286 | 7.6 | 2.4 | 100.0 | | | 100.0 | | | | | | | | | |
| Diodes | 29,086 | 4694 | 1.1 | 17.8 | 100.0 | | | 1.2 | | 78.9 | 1.2 | 10.2 | 8.6 | | 0.7 | | |
| Transformer | 651 | 306 | 1.4 | 35.0 | 100.0 | | | 1.9 | | 94.4 | | | 17.8 | | | | 0.9 |
| Filter | 390 | 378 | 2.1 | 69.0 | 50.0 | 50.0 | | 28.7 | 2.7 | 2.3 | | 53.6 | | | | 12.3 | 0.4 |
| Lamp | | 432 | | | | | | | | | | | | | | | |
| Electronic Parts | 43,474 | 10,127 | 1.5 | 16.3 | 95.9 | 1.8 | 2.3 | 8.1 | 4.7 | 46.6 | 4.5 | 20.9 | 6.2 | 0.4 | 1.2 | 5.2 | 4.0 |
| Fuse | | 45 | | | | | | | | | | | | | | | |
| Wire | 29 | 31 | | 6.5 | | | | | | | | | | | | | 100.0 |
| Cable Wire | | 1 | | 100.0 | | | | | | | | | | | | | 100.0 |
| Connectors | 61 | 373 | 1.6 | 9.4 | 100.0 | | | 14.3 | | | | 51.4 | | 28.6 | | | 5.7 |
| Coupler | 117 | 268 | 7.7 | 14.2 | 88.9 | 11.1 | | 18.4 | 31.6 | | | | 2.6 | 7.9 | 26.3 | 2.6 | 13.2 |
| Waveguide Assembly | 82 | 93 | 24.4 | 25.8 | 20.0 | 40.0 | 40.0 | 4.2 | 16.7 | 25.0 | | | 16.7 | | 37.5 | 16.7 | |
| Antenna | 1 | 52 | 100.0 | 48.1 | 100.0 | | | 4.0 | 4.0 | 28.0 | | 32.0 | | | 52.0 | 16.0 | |
| Meter | 3 | 17 | | 29.4 | | | | | | 100.0 | | | | | | | |
| Switch | 4 | 42 | | 11.9 | | | | 40.0 | | | | | | | | 60.0 | |
| Adapter | | 138 | | 47.8 | | | | 7.6 | | | | 81.8 | | 10.6 | | | |
| Adapter Clamp | | 143 | | 10.5 | | | | | | | | | | | | 100.0 | |
| Vibration Eliminator | | 20 | | | | | | | | | | | | | | | |
| Lacing Cord | | 70 | | 42.9 | | | | | | | 50.0 | 50.0 | | | | | |
| Pointer Dial | | 90 | | 66.7 | | | | | | | | | | 50.0 | | 50.0 | |
| Filter Pressure | | 40 | | | | | | | | | | | | | | | |
| Printed Wiring Board | | 698 | | 39.3 | | | | 39.8 | 57.3 | | | | 57.3 | | 1.5 | 1.5 | |
| Terminal Board | | 325 | | 30.8 | | | | 85.0 | | | 6.0 | 7.0 | | 4.0 | | | |
| Terminals | | 800 | | | | | | | | | | | | | | | |
| Rivets | | 2695 | | | | | | | | | | | | | | | |
| Nuts | | 465 | | 46.2 | | | | 23.3 | | | | | | | | | 76.7 |
| Eyelets | | 1350 | | 22.2 | | | | | | | | | | | | | 100.0 |
| Terminal Lug | | 725 | | | | | | | | | | | | | | | |
| Screw | | 30 | | 50.0 | | | | 100.0 | | | | | | | | | |
| Heat Conductor | | 265 | | 11.3 | | | | 50.0 | | | | | | | 50.0 | | |
| Shaft | | 4 | | | | | | | | | | | | | | | |
| Chassis | | 10 | | 40.0 | | | | | | | | | 100.0 | | | | |
| Panel | | 133 | | 39.1 | | | | 28.8 | 17.3 | | 26.9 | | 26.9 | | | | |
| Case | | 10 | | | | | | | | | | | | | | | |
| Bracket | | 38 | | 50.0 | | | | 26.3 | | 73.7 | | | | | | | |
| Plate | | 94 | | 40.4 | | | | 94.7 | | | | | | | | | 5.3 |
| Castings | | 28 | | 85.7 | | | | | 54.2 | 16.7 | | 8.3 | | | 29.2 | | |
| Mechanical Parts | 297 | 9093 | 10.4 | 15.1 | 45.2 | 29.0 | 25.8 | 25.5 | 14.2 | 2.3 | 1.5 | 8.6 | 12.4 | 4.9 | 4.2 | 4.4 | 34.6 |
| All Parts | 43,883 | 19,332 | 1.6 | 15.8 | 93.7 | 3.0 | 3.3 | 15.9 | 9.0 | 26.2 | 3.1 | 15.7 | 8.9 | 2.5 | 2.9 | 5.1 | 17.8 |
| (Percent of Parts) | | | | | 1.5 | 0.1 | 0.1 | 2.5 | 1.4 | 4.1 | 0.5 | 2.5 | 1.4 | 0.4 | 0.5 | 0.8 | 2.8 |

This latter category "rework not to drawing" indicates a type of defect in which the possibility of "reworking to drawing" does not exist. Of course rework either "to drawing" or "not to drawing" results in satisfactory parts. The fact that these two categories amount to nearly 29 percent of the rejection lots indicates that the categories are highly significant to the incoming inspection operation and therefore of considerable expense.

To obtain a more detailed analysis of the types of defects observed, a sample was sorted to show various defect types for each part class. These results are shown in Table IX. Major defects are defects which could result in failure of the item or materially reduce the usability of the item for its intended purpose; minor defects, as was mentioned previously, are ones that do not materially reduce the usability of the item for its intended purpose. Of electrical defects 93.7 percent are major and cannot be used or repaired, and only 3 percent can be used as they are. On the other hand, of the mechanical defects, only 39 percent are major (i.e., 15.9 percent major, 3.1 percent marking major, 2.5 percent dimension major and 17.8 percent wrong parts) and 40 percent can be used as they are. The high percentage of mechanical rejects that can be used as they are offers the possibility that some effort is being wasted during the incoming inspection looking for defects that are not important enough to class as rejects. A detailed investigation would be necessary before a conclusion could be made on this matter. The reason that the sum of the mechanical categories is over 100 percent is because a few parts have more than one defect.

Table IX also contains an estimate of the process average that independently corroborates the process average shown previously in Table III. This estimate of the process average appears at the bottom of the column labeled "percent defective" and in the row labeled "all parts." This shows 1.6 percent defective for electrical defects and 15.8 percent defective for mechanical defects. Although there is some difference between the two estimates of the process average, the difference is not statistically significant.

## V. CONCLUSIONS

Because of the more complete data from the specialized operation the conclusions are based primarily on the specialized operation. However, since the available data from the general operation are similar to the data in the specialized operation, the conclusions are expected to apply to both operations.

It was shown that the process average was approximately 19 percent for mechanical defects plus 1.1 percent for electrical defects. On the other hand, the vendor percentage defective was approximately 28.7 percent for mechanical defects and 11.2 percent for electrical defects. This can happen only if vendors supplying a small number of parts also supply parts with a greater percentage defective than the process average. Thus it seems that there is correlation between the number of parts received from a vendor and part quality. Moreover, there is strong indication that standard parts have better quality than nonstandard parts. This supports in part the previous statement.

The data obtained indicate that the incoming inspection operation is very complex. The high level of the percent defective process average is due to many different causes, not all of which are actually related to the quality of the parts, for example, rejections due to the wrong part received or to lack of uniform quality criteria by the manufacturer and the vendor. It is also true that some part types are difficult to manufacture with present day materials and processes and consequently a high rate of rejection may be expected. Other contributors to the percent defective are variations in the test equipment used by the manufacturer and vendor, and lack of specialized knowledge regarding test procedures. An important factor present in many of the above is the effectiveness of the communication between the manufacturer and the vendor.

It must be emphasized that this study has only analyzed some of the parameters of military product incoming inspection operations. Further studies are recommended to determine appropriate techniques which would contribute to more effective incoming inspection, higher part quality, and higher equipment reliability.



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