# CHAPTER 5

# ANALYSIS AND RESULT

*5.1 Introduction*

*5.2 Differences in Yield By Tester*

*5.3 Differences in Yield By Day*

*5.4 Yield Performance At Each Insert*

## 5.1 Introduction

Product yield is important for cost, quality and service in the ICs industry. Despite advances in integrated circuits (IC) equipment and fabrication techniques, there still exist random fluctuation or statistical variation in any IC manufacturing facility, which can adversely affect the production yield. As noted in Chapter Four, the manufactured chips are subject to a number of tests. Chips that fail these tests are known as defects. The chips are tested at three test inserts. The product will undergo extensive testing at different temperature condition, i.e. TOS at -5°C, follow by TLO at -5°C for low temperature and THI set at +80°C for high temperature respectively. Both high and low temperature tests have a number of tests in itself. These include tests for voltage levels, open short, margin, current and etc. tests. At TOS and THI test insert, there are 4 testers been utilized, i.e. KLM53, KLM55, KLM57 and KLM58. Whereas for TLO test insert, only 3 testers were being utilized, i.e. KLM53, KLM57 and KLM58 only.

In this chapter, careful analyses will determine whether there are any significant differences in the average yield by tester and by day at TOS, TLO and THI test process. Yield can be measured in a variety of ways. For the purpose of this study, yield is expressed in percentage as the ratio of output quantity to input quantity (which is output quantity added to reject quantity). Then, according to the test and the type of defect, defective chips are placed in various bins, i.e. bin 5, bin 6, bin 7 and bin 8. We'll examine the yield across the various test inserts to identify the stage, which results in most defects, and then identify the bin with most defects.

## 5.2 Differences in Yield By Tester

As noted in the literature review, Francois Bergeret (1999) found that more than half of the problems related to yield are caused by process equipment. Here we examine yield by tester to see whether the equipment used has an impact on yield performance.

Analysis of Variance (ANOVA) is an efficient method of determining whether there is a statistically significant difference among the testers in the average yield. It is a methods that have been useful in improving yield by detecting problems in tester handler and in reducing defect density by identifying tester generate too many yield lost. For hypothesis testing, the model errors are assumed to be normally and independently distributed random variables with mean zero and variance $\sigma^2$.

Table 5.1 displayed mean or average yield by tester at each test insert.

In general, to test whether several groups all have the same population average, the null and alternative hypotheses would be stated as follows:

$H_0$ : $\mu_1 = \mu_2 = \mu_3 = .....\mu_C$

$H_1$ : Not all the means are equal.

However, prior to interpreting these results we should evaluate the validity of the assumptions of normality and homogeneity of variance by performing test of homogeneity of variances. This may obtained by using the computer software package, i.e. SPSS. Table 5.2 consists of Levene statistic and p-value for each test insert. From Table 5.2 we may observe that the computed p-value is exceed to the ignificance level $\alpha$=0.05 for TLO and THI test insert, thus we accept $H_0$ and conclude that the variance is constant for all levels of the factor. However, homogeneity-of-variance assumption is violated for TOS as the computed p-value s less than the significance level $\alpha$=0.05, thus we reject $H_0$.

The yield of each tester for each test insert is displayed in Table 5.1.

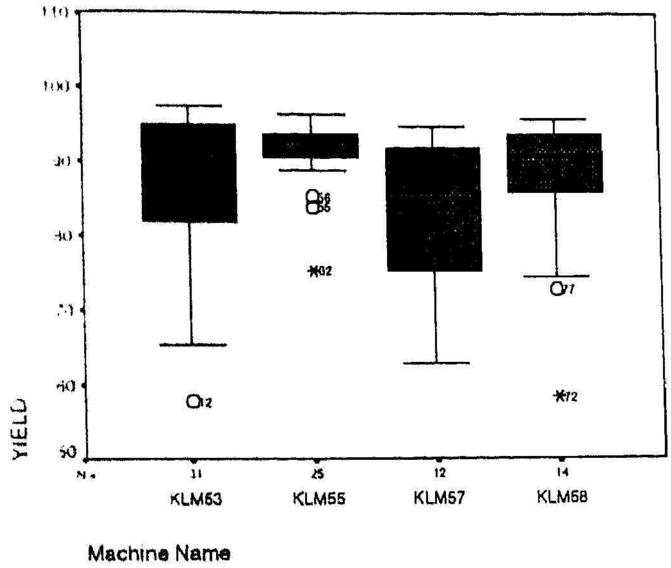
**Table 5.1 Average Yield of Each Tester for Each Test Insert (in percent)**

| | Tester Name | N | Mean |
|---|---|---|---|
| TOS YIELD | KLM53 | 31 | 86.63 |
| | KLM55 | 25 | 91.64 |
| | KLM57 | 12 | 82.89 |
| | KLM58 | 14 | 86.66 |
| TLO YIELD | KLM53 | 24 | 77 |
| | KLM57 | 9 | 62.43 |
| | KLM58 | 11 | 61.28 |
| THI YIELD | KLM53 | 20 | 85.14 |
| | KLM55 | 32 | 88.95 |
| | KLM57 | 18 | 89.47 |
| | KLM58 | 13 | 90.96 |

Test of Homogeneity of Variance at Each Test Insert (by tester)

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| TOS YIELD | 4.614 | 3 | 78 | 0.005 |
| TLO YIELD | 1.245 | 2 | 41 | 0.299 |
| THI YIELD | 2.054 | 3 | 79 | 0.113 |

In order to evaluate the validity of the assumption of normality, Box and Whisker Plots was applied through SPSS package. Figure 5.1, 5.2 and 5.3 consists of Box and Whisker Plots for each test insert by tester, we observe that there is different median for each tester at each test insert. Majority of the distribution is negatively skewed for TOS test insert. Some testers are having normal distribution, such as KLM57 at TLO test insert and KLM53, KLM58 at THI test insert.




igure 5.1 Box and Whisker Plots for TOS Test Insert

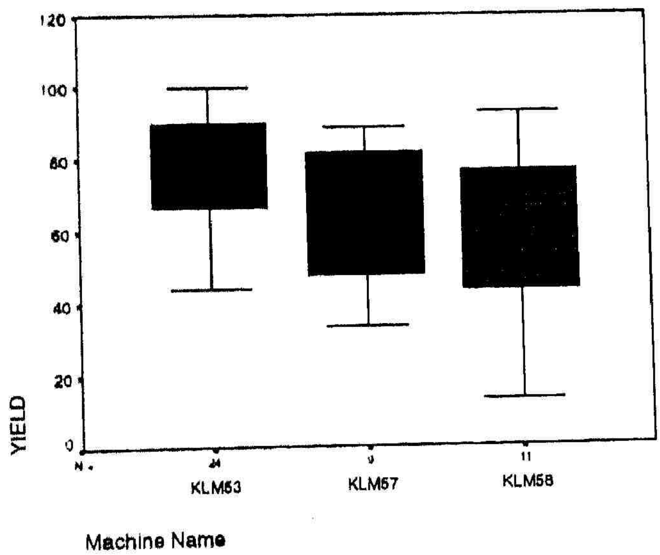
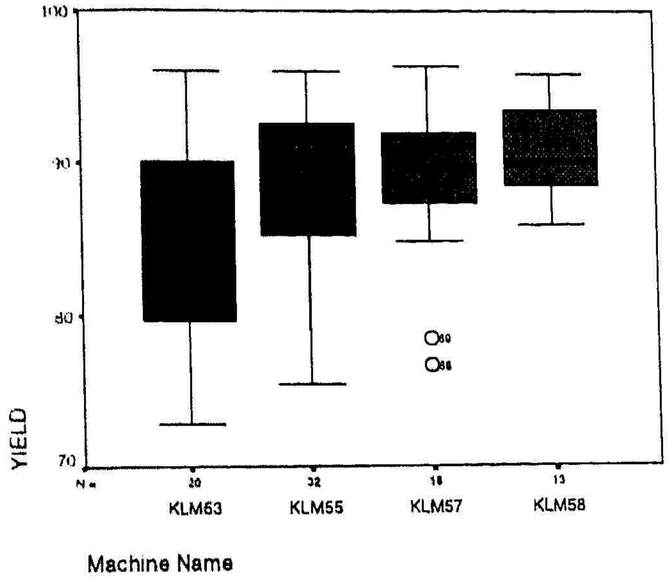



Figure 5.2 Box and Whisker Plots for TLO Test Insert




gure 5.3 **Box and Whisker Plots for THI Test Insert**

Since TLO and THI mean data is not violating assumptions in the analysis-
; variance, we will perform ANOVA. As for TOS test insert, both normality and
omogeneity assumptions are seriously violated even though an appropriate data
ansformation has been used to normalize the data and reduce the differences in
ariances. Hence, a non-parametric methods i.e. Kruskal-Wallis test will be
lternatives to the analysis-of variance F test.

i) **Kruskal-Wallis Test for TOS**

The Kruskal-Wallis procedure is used to test whether c independent sample groups have been drawn from populations possessing equal medians. That is

$H_0$ : $M_{53} = M_{55} = M_{57} = M_{58}$

$H_1$ : Not all $M_j$'s are equal (where j=1,2...c)

The test statistic simplifies to

$$H = \left[ \frac{12}{n(n+1)} \sum_{j=1}^{r} \frac{T_j^2}{n_j} \right] - 3(n+1)$$

The null hypothesis is rejected if H > $\chi^2_{\alpha,a-1}$, the p-value approach could also be used as shown in SPSS package.

**Table 5.3 Kruskal-Wallis Test for TOS Test Insert (by tester)**

**Ranks**

| | Machine Name | N | Mean Rank |
|---|---|---|---|
| YIELD | KLM53 | 31 | 39.77 |
| | KLM55 | 25 | 50.80 |
| | KLM57 | 12 | 28.33 |
| | KLM58 | 14 | 40.00 |
| | Total | 82 | |

**Test Statistics[a,b]**

| | YIELD |
|---|---|
| Chi-Square | 7.699 |
| df | 3 |
| Asymp. Sig. | .053 |

a. Kruskal Wallis Test

b. Grouping Variable: Machine Name

ice H =7.699 < $\chi^2_{0.05,3}$ =7.815 as shown in Table 5.3, we would accept the null pothesis and conclude that the median scores for the four testers are equal.

Under the null hypothesis the population means among the groups are esumed equal, a measure of the total variation (sum of squares between group ded to sum of squares within group) among the tester can be obtained by lculating the ANOVA.

**ANOVA for TLO Test Insert**

The null and alternative hypothesis would be stated as follows:

$H_0$ : $\mu_{53} = \mu_{57} = \mu_{58}$

$H_1$ : Not all the testers have equal means

Table 5.4 displayed ANOVA for TLO insert. Note that the between-:atment mean square (1264.678) is about 3 times larger than the within-treatment 84.553). This indicates that it is unlikely that the treatment means are equal. nce there are 2 degree of freedom in the numerator and 41 degrees of freedom in e denominator, the critical value of F at the 0.05 level of significance is 3.289. hus the decision rule would be to reject the null hypothesis if the calculated F ılue exceeds $F_{\alpha=0.05,2,41}$=3.22. Since $F_0$ = 3.289 > $F_{\alpha=0.05,2,41}$=3.22, we reject $H_0$ ıd conclude that there is a significance difference in the average yield performance n the three testers at TLO insert. However, the difference is marginal significance ue to $F_0$ is slightly higher than critical value.

**'able 5.4 Analysis of Variance for TLO Test Insert (by tester)**

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| YIELD | Between Groups | 2529.356 | 2 | 1264.678 | 3.289 | .047 |
| | Within Groups | 15766.690 | 41 | 384.553 | | |
| | Total | 18296.046 | 43 | | | |

**ANOVA for THI Test Insert**

The null and alternative hypothesis would be stated as follows:

$H_0$ : $\mu_{53} = \mu_{55} = \mu_{57} = \mu_{58}$

$H_1$ : Not all the testers have equal means

The analysis of variance is summarized in Table 5.5.

e 5.5 **Analysis of Variance for THI Test Insert (by tester)**

ANOVA

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| ELD | Between Groups | 327.887 | 3 | 109.296 | 3.733 | .015 |
| | Within Groups | 2313.105 | 79 | 29.280 | | |
| | Total | 2640.992 | 82 | | | |

As for THI test insert, Since $F_0 = 3.733 > F_{\alpha=0.05,4,81} = 2.50$, we reject $H_0$ :onclude that there is a significance difference in the average yield performance ıe four testers at THI insert.

Since differences in the average yield performance of each tester at each insert are found significant at TLO and THI test insert, it is important that we rmine which particular groups are different. Tukey's T method was used in r to determine which of the means are significantly different from each other. Tukey's T method enables us to simultaneously examine comparisons between airs of groups. The pairwise multiple comparisons can determine which means :r by using SPSS package, assume equal variances. Pairwise multiple ıparisons test the difference between each pair of means, and yield a matrix asterisks indicate significantly different group means at an alpha level of

Table 5.6 and 5.7 shown the multiple comparison output from SPSS am for test insert TLO and THI respectively. From this computer output, it l be concluded that there is no significant difference between each pair of s at TLO test insert. As for THI test insert, there is significance difference een tester KLM53 and KLM58, thus we can conclude that KLM58's yield rmance is the best.

**e 5.6 Multiple Comparisons: The Tukey T Method at TLO Test Insert**

**Multiple Comparisons**

ependent Variable: YIELD
key HSD

| achine ame | (J) Machine Name | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| LM53 | KLM57 | 14.5741 | 7.665 | .151 | -4.0644 | 33.2126 |
| | KLM58 | 15.7250 | 7.140 | .083 | -1.6375 | 33.0875 |
| LM57 | KLM53 | -14.5741 | 7.665 | .151 | -33.2126 | 4.0644 |
| | KLM58 | 1.1509 | 8.814 | .991 | -20.2818 | 22.5837 |
| LM58 | KLM53 | -15.7250 | 7.140 | .083 | -33.0875 | 1.6375 |
| | KLM57 | -1.1509 | 8.814 | .991 | -22.5837 | 20.2818 |

**Multiple Comparisons: The Tukey T Method at THI Test Insert**

**Multiple Comparisons**

ændent Variable: YIELD
ıy HSD

| hine ıe | (J) Machine Name | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| ı53 | KLM55 | -3.8112 | 1.542 | .072 | -7.8594 | .2369 |
| | KLM57 | -4.3269 | 1.758 | .074 | -8.9410 | .2872 |
| | KLM58 | -5.8234* | 1.928 | .018 | -10.8830 | -.7638 |
| ı55 | KLM53 | 3.8112 | 1.542 | .072 | -.2369 | 7.8594 |
| | KLM57 | -.5157 | 1.594 | .988 | -4.6999 | 3.6686 |
| | KLM58 | -2.0122 | 1.780 | .672 | -6.6831 | 2.6588 |
| ⁄157 | KLM53 | 4.3269 | 1.758 | .074 | -.2872 | 8.9410 |
| | KLM55 | .5157 | 1.594 | .988 | -3.6686 | 4.6999 |
| | KLM58 | -1.4965 | 1.970 | .872 | -6.6656 | 3.6726 |
| ⁄158 | KLM53 | 5.8234* | 1.928 | .018 | .7638 | 10.8830 |
| | KLM55 | 2.0122 | 1.780 | .672 | -2.6588 | 6.6831 |
| | KLM57 | 1.4965 | 1.970 | .872 | -3.6726 | 6.6656 |

'. The mean difference is significant at the .05 level.

## Differences in Yield by Day

Having discussed yield varies by tester, we may wanted to determine ıer there is evidence of a difference in yield performance by day at each test , i.e. TOS, TLO and THI. The null and alternative hypotheses set up as ving:

$H_0$ : $\mu_{mon} = \mu_{tue} = \mu_{wed} = \mu_{thur} = \mu_{fri} = \mu_{sat} = \mu_{sun}$

$H_1$ : Not all the means are equal.

**Yield of Each Day for Each Test Insert (in percent)**

| | Day | Mon | Tue | Wed | Thur | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|---|
| | N | 13 | 12 | 19 | 14 | 10 | 14 | 14 |
| ) | Mean | 88.04 | 82.7 | 89.6 | 91.08 | 83.51 | 90.17 | 88.17 |
| | N | 7 | 13 | 9 | 10 | 7 | 3 | 10 |
| ) | Mean | 81.03 | 65.96 | 60.28 | 69.67 | 66.43 | 72.5 | 77.81 |
| | N | 14 | 19 | 15 | 10 | 13 | 7 | 20 |
| ) | Mean | 87.3 | 88.2 | 88.93 | 87.5 | 87.79 | 90 | 87.22 |

Table 5.8 displayed mean or average yield by seven day in a week at each sert. However, prior to interpreting these results we should evaluate the / of the assumptions of normality and homogeneity of variance by ning test of homogeneity of variances. This may accomplished by using the packages. Table 5.9 consists of Levene statistic and p-value for each test

From Table 5.9 we may observe that the computed p-value is less than to ;nificance level $\alpha$=0.05 for TOS and TLO test insert, thus we reject $H_0$ and ıde that homogeneity-of-variance assumption is violated for both TOS and :est insert except THI.

9 Test of Homogeneity of Variances at Each Test Insert (by day)

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| TOS YIELD | 3.583 | 6 | 89 | 0.003 |
| TLO YIELD | 2.382 | 6 | 52 | 0.041 |
| THI YIELD | 1.263 | 6 | 91 | 0.282 |

We evaluated the validity of the assumption of normality by obtaining Box
isker Plots through SPSS package. Figure 5.4, 5.4 and 5.6 consists of Box
nisker Plots for each test insert, we observe that there is different median for
ay for each test insert. Majority of the distribution is negatively skewed for
est insert.

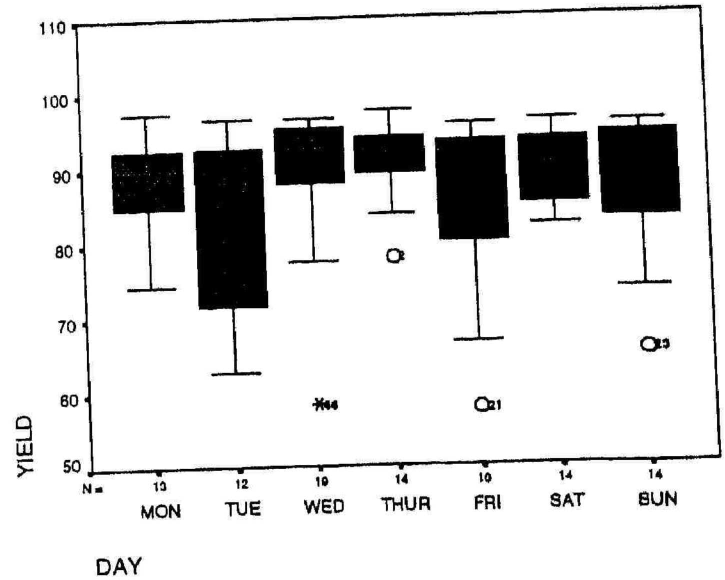
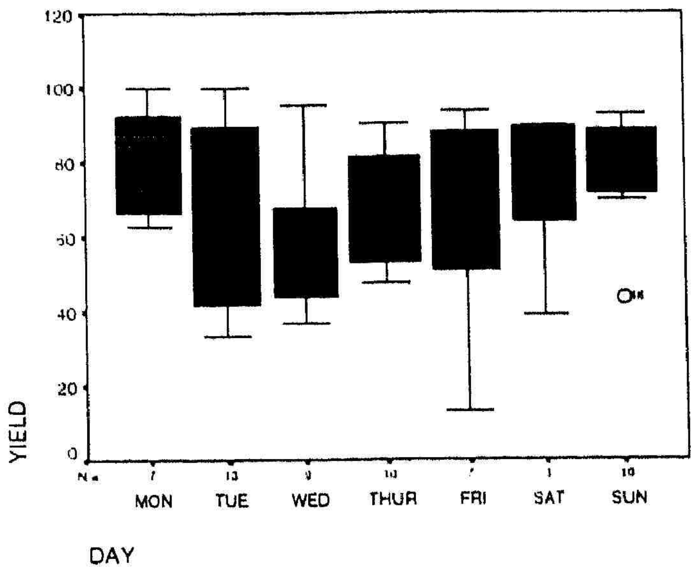
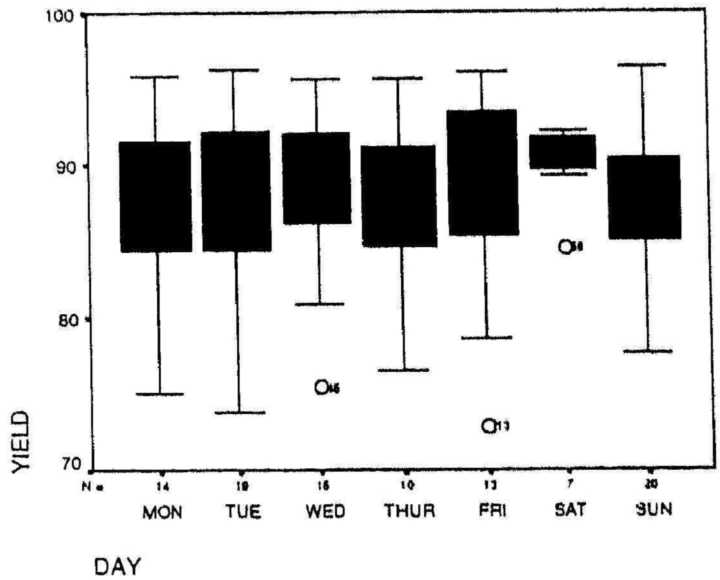



Figure 5.4 Box and Whisker Plots for TOS Test Insert




5.5 **Box and Whisker Plots for TLO Test Insert**




e 5.6 **Box and Whisker Plots for THI Test Insert** ince the normality and homogeneity assumption is seriously violated, an /e to the analysis-of variance F test is Kruskal-Wallis test, a nonparametric .e Kruskal-Wallis procedure is most often used to test whether c lent sample groups have been drawn from populations processing equal . The null hypothesis to be tested is that the median scores of yield for the ıys in a week are equal; the alternative is that not all the median score are

$H_0$ : $M_{mon} = M_{tue} = M_{wed} = M_{thur} = M_{fri} = M_{sat} = M_{sun}$

$H_1$ : Not all Mj's are equal (where j = 1,2...c).

ıskal-Wallis test statistic H may be computed from

$$H = \left[ \frac{12}{n(n+1)} \sum_{j=1}^{c} \frac{T_j^2}{n_j} \right] - 3(n+1)$$

ı is the total number of observations over the combined samples, i.e.,

$n = n_1 + n_2 + \dots + n_c$

$n_j$ is the number of observations in the $j_{th}$ sample; j = 1,2,....c

$T_j^2$ is the square of the sum of the ranks assigned to the $j_{th}$ sample

5.10 displayed the mean rank and computed H for each day in a week at est insert, the result was obtained from SPSS package. The critical $\chi^2$ value ; c - 1 = 6 degree of freedom and corresponding to a 0.05 level of cance is 12.592. Since the computed value of the test statistic H are 7.458, and 2.967 for TOS, TLO and THI respectively, is less than critical value, we a  1e null hypothesis and conclude that the yield were the same with respect

t(  n yield performance.

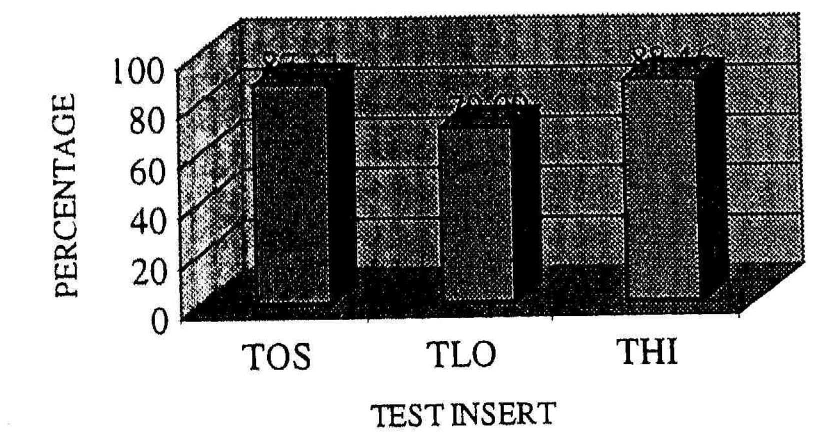
1  .10)  **Kruskal-Wallis Test for Each Day in A Week at Each Test Insert**

| | DAY | N | MEAN RANK | | |
|---|---|---|---|---|---|
| 3 | MON | 13 | 42.31 | | |
| LD | TUE | 12 | 35.50 | H | = 7.458 |
| | WED | 19 | 57.16 | | |
| | THUR | 14 | 55.00 | df | = 6 |
| | FRI | 10 | 38.60 | | |
| | SAT | 14 | 50.21 | | |
| | SUN | 14 | 52.50 | | |
| O | MON | 7 | 39.00 | | |
| :LD | TUE | 13 | 26.92 | H | = 4.968 |
| | WED | 9 | 22.56 | | |
| | THUR | 10 | 28.60 | df | = 6 |
| | FRI | 7 | 30.29 | | |
| | SAT | 3 | 32.33 | | |
| | SUN | 10 | 34.90 | | |
| II | MON | 14 | 45.00 | | |
| ΞLD | TUE | 19 | 52.58 | H | = 2.967 |
| | WED | 15 | 55.27 | | |
| | THUR | 10 | 43.90 | df | = 6 |
| | FRI | 13 | 51.77 | | |
| | SAT | 7 | 57.43 | | |
| | SUN | 20 | 43.95 | | |

### 'ield Performance At Each Insert

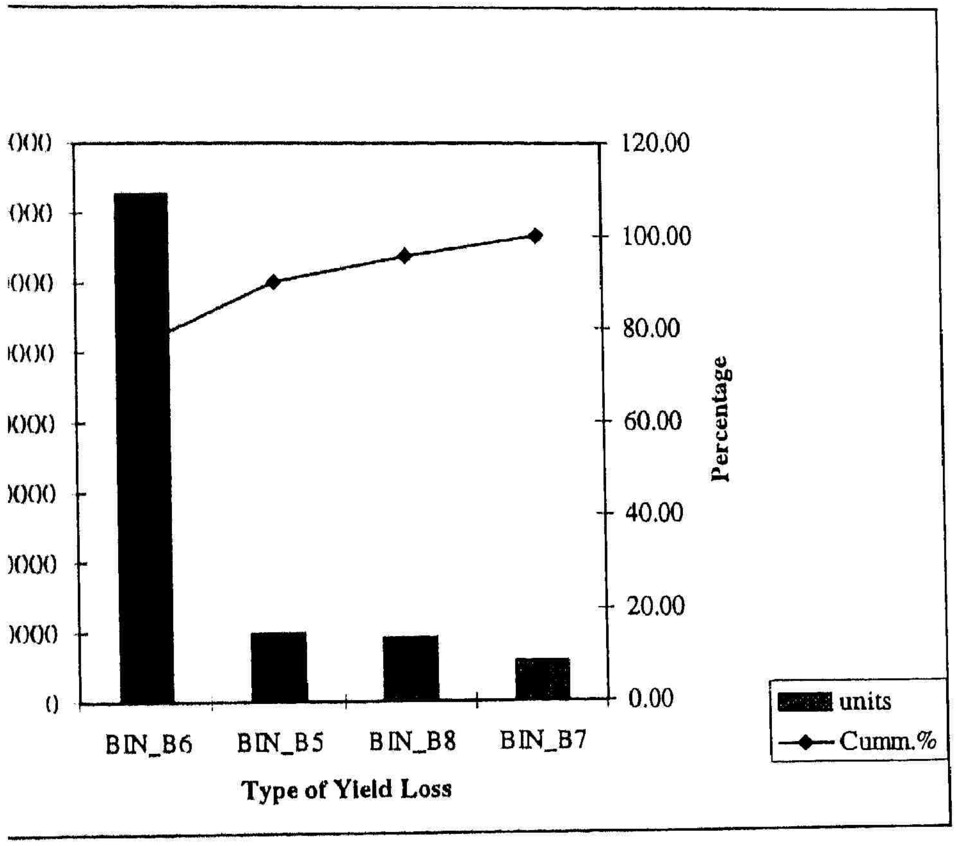
ı this, we examine the yield across the various test inserts to identify the ıt contributes to the greatest yield lost. We construct histogram of the yield performance by each test insert.

'rom the six month's data (July - Dec 1999) that had been collected, the TOS yields was 87.61%, TLO yields was 70.09% while THI yields at as illustrates in Figure 5.7. TLO insert is the lowest yield as compared to r two test inserts.




**: 5.7 Average Yield Performance at Each Test Insert**

ı order to identify the major defect type from TLO test insert, a Pareto
el sed to search for significant causes of problems and to focus efforts on the
pı ; that offer the greatest potential for improvement by showing their relative
fr y or size in a descending bar graph. From the Pareto chart as showed in
F 8, the main defect type for TLO was bin 6, about 79 percent of the defect
ty 'LO test insert result from bin 6.




I 5.8 **Pareto Chart: Defect Type by Bin at TLO Test Insert**

There are several process variables classifieds to be sorted under bin 6, such
ET, walk I/O, current, resistive, and etc. We will identify the process
:s that explain most of the observed variation in a chip, this will discuss in
etail in subsequent section.