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# A CODE TO EVALUATE INSPECTION DATA BY PAIRED COMPARISON METHOD

## – NPT-JAPAN SYSTEM II, PART II –

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# A Code to Evaluate Inspection Data by Paired Comparison Method
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A sampling plan was investigated from the point of view of the counter-strategies to the diversion of an amount of nuclear material. Assuming that an inspection would be carried out based on such a plan, a method for evaluating inspection data obtained during and/or after the inspection was developed on the same basis as the plan, and was materialized as a computer code which is an element of the safeguards information treatment system of Japan. The code was successfully applied to the inventory verification of a fast critical assembly.

Key words : Safeguards, Inspection Planning, Inspection Evaluation, Paired Comparison, NPT-JAPAN System , Computer Code

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# 対比較法による査察データ評価用コード
# NPT－JAPAN System II, Part II

日本原子力研究所動力炉開発・安全性研究管理部
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核物質の転用に対する対抗戦略の観点からサンプリング計画を検討した。査察はそのような計画に基づいてなされるものであるとの仮定に立ち，査察中ないし査察後に得られた査察データを評価するための方法を開発し，これをコンピュータ・コードとして完成した。このコードは，わが国の国内保障措置情報処理システムの一部を成すものである。本コードを高速臨界実験装置の在庫検認に対して適用したところ，満足すべき結果を得ることが出来た。報告書には，その結果を適用例として示す。

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+ 企画室

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## 1. INTRODUCTION

One of the safeguards objectives is to verify that all source or special fissionable material in all peaceful nuclear activities is not diverted to nuclear weapons or other nuclear explosive devices or for purposes unknown.

Such verification activities should be planned, performed and evaluated on a logical and technological basis. Logically or mathematically speaking, the verification should be done by rejecting the alternative hypothesis that the diversion of nuclear material has occurred.

The diversion hypothesis requires studies of the diversion strategies, according to which the diversion might be performed, and their counter-strategies, by which the diversion could be detected. This is one of the main themes of the inspection planning.

According to the inspection planning, the inspection is carried out on site of a facility under the peaceful nuclear activities. Then, an inspection report is produced during and/or after the inspectors' visit to the facility.

This inspection report should be carefully analyzed in consistency with the philosophy applied to the inspection planning. The purpose of this paper is to try to give a practical and convenient solution to such a problem with the mathematical description and with the scope, functions and handling of the computer code which has been developed reflecting the results of the study.

The following sections of this paper discuss the inspection planning and the analysis method of paired comparison by critically reconstructing the works[1,2,3] on a same theoretical basis, give the input form to and sample output from the code, and analyze the output from a viewpoint of how to use the code. The code is a revised version of the one previously reported[4,5].

## 2. INSPECTION PLANNING

### 2.1 Material Balance

There are three kinds of material balances in an MBA on a material balance period, i.e. the true material balance, the operator's material balance which might be falsified, and the material balance estimated by inspector. These material balances are expressed as follows:

$$MUF_T = BI_T + R_T - S_T - W_T - EI_T ,$$
$$MUF_O = BI_O + R_O - S_O - W_O - EI_O ,$$
$$MUF_I = BI_I + R_I - S_I - W_I - EI_I ,$$

where BI is the beginning inventory, R is all receipts, S is all shipments, W is all waste disposals, EI is the ending inventory and MUF is the material unaccounted for. Suffixes T, O and I denote True, Operator and Inspector, respectively. Suppose that these variables are all defined exactly without any measurement errors and that any values estimated by inspector are not biased, then the following relations are obtained:

$$BI_T = BI_I ,$$
$$R_T = R_{SRD} + R_F + R_I ,$$
$$S_T = S_I - S_F - S_{SRD} ,$$
$$W_T = W_I - W_F - W_{(SRD)} ,$$
$$EI_T = EI_I ,$$

where $R_{SRD}$ is $R_T$-$R_O$, $R_F$ is $R_O$-$R_I$, $S_F$ is $S_I$-$S_O$, $S_{SRD}$ is $S_O$-$S_T$, $W_F$ is $W_I$-$W_O$, and $W_{(SRD)}$ is $W_O$-$W_T$. If the shipper to and the receiver from the MBA are all honest, $R_{SRD}$ and $S_{SRD}$ mean the real shipper-receiver differences even if the operator falsifies his values $R_O$ and $S_O$. $W_{(SRD)}$, however, does not have any so-called receivers. On the other hand, $R_F$, $S_F$ and $W_F$ represent the differences between the operator's and the inspector's values, and these values are not zero if the operator falsifies his values $R_O$, $S_O$ and $W_O$. Hence, $MUF_T$ is related with $MUF_I$ as follow:

$$MUF_T = MUF_I + R_{SRD} + R_F + S_F + S_{SRD} + W_F + W_{(SRD)} .$$

If the relations: $R_T$=$R_I$, $S_T$=$S_I$ and $W_T$=$W_I$ are attained, however, $MUF_T$ is represented like this:

$$MUF_T = MUF_I .$$

Requirements needed to attain these relationships are:

1) the seals should be detached from the received material under the inspector's observation so as to preserve $R_T$.

2) measurements should be done just after the seals are detached. The inspector should observe these measurements so as to reduce $R_{SRD}$ to zero.

3) just after the operator's measurements, the inspector should pick up a suitable number of samples and measure them not so as to permit the existence of non-zero $R_F$.

4) the inspector should observe the operator's measurements for shipments and/or waste disposals in order not to permit the falsification of an amount of $S_F$ and/or $W_F$ by the operator.

5) just after the measurements, the inspector should define $S_I$ and/or $W_I$ by his measurements and attach a seal to prevent the existence of $S_{SRD}$ and/or $W_{(SRD)}$.

These requirements are based on the fact that the inspector could not measure all the items so that he must rely on the operator's measurements to estimate his values. It should be noted that in the courses of 3) and 5) above a temporary seal might be used.

If these requirements could be attained, then $MUF_I$ (or $MUF_0-\hat{D}$) or $\hat{D}$ and $MUF_0$ evaluation approach is useful, where $\hat{D}$ represents the following relation:

$$\begin{aligned}\hat{D} &= MUF_0 - MUF_I \ , \\ &= (BI_0-BI_I) + (R_0-R_I) - (S_0-S_I) - (W_0-W_I) - (EI_0-EI_I) \ , \\ &= (BI_0-BI_I) + R_F + S_F + W_F - (EI_0-EI_I) \ .\end{aligned}$$

On the contrary, if these requirements could not be attained, a severer procedure of evaluation should be applied as follows:

1) the hypothesis: $(BI_0-BI_I)-(EI_0-EI_I)=0$ should not be rejected.
2) the hypothesis: $\hat{D}=0$ should not be rejected so as to guarantee the relation: $R_F+S_F+W_F=0$.
3) the hypotheses: $R_{SRD}=0$, $S_{SRD}=0$ and $W_{(SRD)}=0$ should not be rejected by analyzing the shipper-receiver differences or by using seals.
4) the hypothesis: $MUF_0=0$ (and/or $MUF_0-\hat{D}=0$) should not be rejected.

It is desirable that the hypotheses: $BI_0=BI_I$, $EI_0=EI_I$, $R_F=0$, $S_F=0$ and $W_F=0$ are not rejected at the same time.

## 2.2 Diversion of Nuclear Material

As to how to divert a quantity of nuclear material, there are two diversion strategies; one is to divert it by relatively large quantity within a relatively short time interval (abrupt diversion) and the other is to divert it by relatively small quantity within a relatively long time interval ( protracted diversion).

Counter-strategies to such diversion possibilities should be based on a philosophy of timely detection of diversion of significant amounts of nuclear material, i.e. the threshold amount, TA, of nuclear material needed to fabricate a nuclear explosive device should be detected within the critical time, CT, needed to convert the material to a weapon with the detection probability $1-\beta$ and misjudgement probability $\alpha$.

Against the abrupt diversion, an attribute testing is effective if it is done timely, i.e. periodically in the critical time interval or randomly with a mean time interval and a variance. On the other hand, a variable testing is useful against the protracted diversion if it is performed in a suitable time interval.

Then the inspection would be carried out like this:

1) All receipts, shipments and waste disposals should be verified by the variable testing so as to make it possible to verify the material balance or MUF at the end of the material balance period.
   At the same time the attribute testing for the purpose of 2) below might be used in parallel to make maximum use of inspection manpower by cutting the inspectors' travelling time.
2) Running inventory should be verified by the attribute testing in order to prove the running book inventory against the abrupt diversion in an appropriate time span.
3) At the end of the period, physical inventory should be verified by the variable testing. The data obtained by the inspector's measurement on the beginning inventory, all the receipts and shipments, and the ending inventory, and their corresponding source data recorded on book or measured by the operator make it possible to verify the over-all material balance against the protracted diversion.

The attribute measurement is able to detect with nearly 100 percent probability the defection of the nominal item quantity ranging from 100 percent to a smaller one depending on the relative standard deviation of the measurement error (for example: 100 - 4$\delta$). If the measurement has high accuracy and precision, the detectable defection range is widened to a much smaller percentage. As the result the range covered by the variable testing is narrowed and, hence, the material balance period could be extended longer because it requires much more time to accumulate the quantity TA by smaller removals. On the contrary, if the measurement accuracy and precision are poor, the material balance period must be shortened because of the possibility of easy accumulation of the quantity.

## 2.3 Attribute Testing

For the attribute testing, number of samples to be measured during inspection is calculated for each stratum of nuclear material using the formula:

$$n = N \left( 1 - \beta^{1/r} \right), \quad r = \frac{M}{\bar{x}}, \tag{1}$$

where n is the sampling size, N is the total number of items contained in the stratum, M is a goal quantity such as the threshold amount or less quantity than that, $\bar{x}$ is the average content of the item, and hence r is the number of defects needed to accomplish the diversion of an amount M. This formula is derived from the following exact equation based on the hypergeometric probability density function with some modifications which give a little greater sampling size than the rigorous one;

$$\beta = \frac{\binom{r}{0}\binom{N-r}{n}}{\binom{N}{n}}. \tag{2}$$

Such modifications make it possible to analyze the data obtained during the inspection by giving a sampling size of more than two even though the stratum contains a small content of nuclear material and/or a small number of items.

On site inspection it is important to judge the discrepancies between the operator's and inspector's measured data based on the reject limit (for example: 4$\delta$). In the evaluation stage, it should be tested whether the assigned measurement accuracy ($\delta$) has been attained during inspection. Reflecting the results of such analysis the discrepancies should be re-evaluated.

## 2.4 Variable Testing

The variable testing should cover the defection range below the lower limit of that of the attribute testing. Since it is considered that the accuracy of the variable testing is higher than that of the attribute testing, the range could be devided into two parts: one is the attribute mode detection range and the other is the bias detection range.

For the attribute mode detection, number of samples to be measured during or after the inspection is calculated for each stratum of nuclear material just like the attribute testing with an exception of introduction of $\gamma$ as follows:

$$n_{V1} = N\ (\ 1 - \beta^{1/r}\ ),\quad r = \frac{M}{\gamma\bar{x}}, \tag{3}$$

where $n_{V1}$ is the sampling size, N is the total number of items contained in the stratum, M is the goal quantity, $\bar{x}$ is the average content of the item, $\gamma$ is the lower limit of the defection rate detected in the attribute testing, and r is the number of defects needed to accomplish the diversion of the amount M. It should be noted that $\gamma$ is set to 1 if the attribute measurements work for the variable testing at the same time.

At the course of evaluation it should be judged whether the discrepancies between the operator's and inspector's measured data are significant or not based on the reject limit (for example: $4\sigma_d$).

For the bias detection, number of samples to be measured by the audit team is calculated using the following equation:

$$M = Z_{1-\alpha}\ \sigma_{\hat{D}|H_0} + Z_{1-\beta}\ \sigma_{\hat{D}|H_1}, \tag{4}$$

where

$$\sigma^2_{\hat{D}|H_0} = \sigma^2_{\hat{D}s} + \sigma^2_{\hat{D}r|H_0}, \tag{5}$$

$$\sigma^2_{\hat{D}|H_1} = \sigma^2_{\hat{D}s} + \sigma^2_{\hat{D}r|H_1}, \tag{6}$$

and Z is the cumulative normal distribution function, suffixes s and r denote systematic and random error components, respectively, and suffixes $H_0$ and $H_1$ denote the null hypothesis: $\hat{D}=0$ and the alternative hypothesis: $\hat{D}=M$, respectively.

The amount of $\sigma_{\hat{D}r|H_0}$ is related to the sample size n for the whole material balance using the minimum variance propagation method:

$$\sigma^2_{\hat{D}r|H_0} = \frac{(\Sigma N_i \sigma_{dri})^2}{n} \tag{7}$$

where $N_i$ is the number of items of the i-th stratum and $\sigma_{dri}$ is the random component of the standard deviation of the difference between the operator's and inspector's measured values for an individual item in the i-th stratum. And the sample size for the i-th stratum is as follows:

$$n_{V2i} = n\left(\frac{N_i \sigma_{dri}}{\Sigma N_i \sigma_{dri}}\right). \tag{8}$$

Therefore if $\sigma_{\hat{D}|H_0}$ is obtained by solving Eq. (4), the sample size is fixed. In order to solve Eq. (4), the following relation is assumed:

$$\sigma_{\hat{D}r|H_1} = 2\sigma_{\hat{D}r|H_0} \, . \tag{9}$$

As to the propagation of measurement errors for each stratum, the following relations are assumed:

$$\sigma^2_{dr} = \bar{x}^2(\delta^2_{Orw}+\delta^2_{Irw}+\delta^2_{Ore}+\delta^2_{Ire}+\delta^2_{Orf}+\delta^2_{Irf}) \tag{10}$$

$$\sigma^2_{ds} = \bar{x}^2(\delta^2_{Osw}+\delta^2_{Isw}+\delta^2_{Ose}+\delta^2_{Ise}+\delta^2_{Osf}+\delta^2_{Isf}) \tag{11}$$

where $\sigma_{ds}$ is the systematic error standard deviation of the difference between the operator's and inspector's measured values for an individual item, $\delta$ denotes the relative standard deviation, and suffixes O, I, r, s, w, e, and f denote operator, inspector, random error, systematic error, weighing, element factor, and fissile factor, respectively. In this model the sampling error and the effect of the number of measurements to give an average value to each item are contained in each error component.

The systematic and random error variances of $\hat{D}$ are described as follows:

$$\sigma^2_{Ds} = \sum_i (N_i \sigma_{dsi})^2 \tag{12}$$

$$\sigma^2_{Dr|H_0} = \sum_i (N_i \sigma_{dri})^2 / n_i \tag{13}$$

In Eq.(13), if $n_i$ is fixed so as to minimize the variance, Eq.s (7) and (8) are easily concluded. Eq.(12) means that the systematic error for an individual item is constant over items in the same stratum and that it has a different value for a different stratum and it has the expected mean value of zero in the case of the same measurement technique (method and instrument) being used without the so-called long term systematic error.

In order to deal with the long term systematic error correctly, the measurement techniques should be identified and allocated to each stratum. In our computer code system, this procedure can be applied but the real function has not yet been built in.

After the preparation mentioned above, Eq.(4) can be solved. Sometimes, however, Eq.(5) does not give a suitable value for $\sigma_{\hat{D}r|H_0}$ because of a large quantity of $\sigma_{\hat{D}s}$. In such a case, in principle, the material balance period should be shortened so as to reduce the value of $\sigma_{\hat{D}s}$. The alternative methods contain re-evaluating the systematic errors and their propagation formula, deviding the material balance area into two or more small material balance areas, fully utilizing the containment/surveillance devices and drastically improving the measurement techniques.

At the stage of verification, the attained goal quantity is expressed as follows:

$$M' = Z_{1-\alpha}\sigma_{\hat{D}|H_0} + Z_{1-\beta}S_{\hat{D}} \tag{14}$$

where $S_{\hat{D}}$ is the observed error standard deviation. If $M \geqq M'$, it is concluded that the sampling size is adequate. On the contrary if $M'>M$, it should be concluded that the sampling plan is unreasonable.

In order to check the design value of the random error standard deviation, the following hypothesis testing should be performed:

The null hypothesis $H_0$: $S_{\hat{D}r} = \sigma_{\hat{D}r|H_0}$, against the alternative hypothesis $H_1$: $S_{\hat{D}r} = 2\sigma_{\hat{D}r|H_0}$.

where $S_{\hat{D}r}$ is the observed random error standard deviation.
For this testing, sample size ($n_{V3}$) of more than 12 is required for the whole strata. If it is necessary to check the hypothesis stratum-wise, this number $n_{V3}$ should be adopted for each stratum as its sample size.

Whether or not the hypothesis $H_0$ is rejected, the hypothesis $\hat{D}=0$ should be verified by using the value of $\sigma_{\hat{D}|H_0}$ based on the design information as the standard deviation of $\hat{D}$ because the actual standard deviation could be contaminated by the diversion. In the case of $S_{\hat{D}r}<\sigma_{\hat{D}r|H_0}$, however, $\sigma_{\hat{D}|H_0}$ should be replaced by $S_{\hat{D}}$ because the high accuracy of measurements and/or concentrated inspection efforts make it possible to evaluate more severely the hypothesis $\hat{D}=0$ resulting in the attained goal quantity as follows:

$$M' = Z_{1-\alpha}S_{\hat{D}} + Z_{1-\beta}S_{\hat{D}} \ . \qquad (15)$$

For the variable testing the sample size finally results in the maximum value of $n_{V1}$ and $n_{V2}$, and $n_{V3}$ if the variance test is applied to each stratum.

## 3. PAIRED COMPARISON METHOD

### 3.1 Single Stratum

Under the situation of no diversion, the operator's and inspector's measured values of item i in a stratum are expressed as follows:

$$x_{0i} = \mu_i + s_0 + r_{0i} \tag{16}$$

$$x_{Ii} = \mu_i + s_I + r_{Ii} \tag{17}$$

where $x_{0i}$ is the operator's value of the item, $x_{Ii}$ is the inspector's value, $\mu_i$ is the true value, $s_0$ and $s_I$ are the systematic errors for the operator and inspector, respectively, and $r_{0i}$ and $r_{Ii}$ are the corresponding random errors.

Since the sample variance and covariance are given by:

$$S_x^2 = \frac{\Sigma x_i^2 - (\Sigma x_i)^2/n}{n-1} \tag{18}$$

$$S_{xy} = \frac{\Sigma x_i y_i - (\Sigma x_i \Sigma y_i)/n}{n-1}, \tag{19}$$

the following relations are obtained from Eqs.(16) and (17) if the covariance terms between $\mu_i$ and $r_{0i}$, $\mu_i$ and $r_{Ii}$, and $r_{0i}$ and $r_{Ii}$, are equal to zeros:

$$S_0^2 = S_\mu^2 + S_{r0}^2 \tag{20}$$

$$S_I^2 = S_\mu^2 + S_{rI}^2 \tag{21}$$

$$S_{0I} = S_\mu^2 \tag{22}$$

Since the values of $S_\mu^2$, $S_{r0}^2$ and $S_{rI}^2$ estimate $\sigma_\mu^2$, $\sigma_{r0}^2$ and $\sigma_{rI}^2$, respectively, the following hypothesis testings can be made:

1) The null hypothesis $H_{01}$: $\sigma_{r0}^2 = \sigma_{rI}^2$ against the alternative hypothesis $H_{11}$: $\sigma_{r0}^2 \neq \sigma_{rI}^2$
2) The null hypothesis $H_{02}$: $(\sigma_{r0}^2+\sigma_{rI}^2) = \sigma_{rm}^2$ against the alternative hypothesis $H_{12}$: $(\sigma_{r0}^2+\sigma_{rI}^2) \neq \sigma_{rm}^2$
3) The null hypothesis $H_{03}$: $\sigma_{r0}^2 = \sigma_{\varepsilon 0}^2$ and $\sigma_{rI}^2 = \sigma_{\varepsilon I}^2$ against the

alternative hypothesis $H_{13}$: $\sigma_{r0}^2 \neq \sigma_{\varepsilon 0}^2$ or $\sigma_{rI}^2 \neq \sigma_{\varepsilon I}^2$, or both.

4) The null hypothesis $H_{04}$: $\sigma_{rI}^2 = \sigma_{\varepsilon I}^2$ (or $\sigma_{r0}^2 = \sigma_{\varepsilon 0}^2$) against the alternative hypothesis $H_{14}$: $\sigma_{rI}^2 \neq \sigma_{\varepsilon I}^2$ (or $\sigma_{r0}^2 \neq \sigma_{\varepsilon 0}^2$),

where $\sigma_{rm}^2$, $\sigma_{\varepsilon 0}^2$ and $\sigma_{\varepsilon I}^2$ are the given (or design) values for the corresponding valiances.

According to the reference 1), the following calculations are made:

1) For the $H_{01}$ testing,

$$t = r\sqrt{(n-1)/(1-r^2)}, \quad r = \frac{S_0^2 - S_I^2}{(S_0^2+S_I^2)^2-4S_{0I}^2}, \tag{23}$$

$H_{01}$ is rejected if $|t| > t_{1-(\alpha/2)}(n-2)$, where $t_{1-(\alpha/2)}(n-2)$ is the critical value of Student's t distribution with (n-2) degrees of freedom at the significance level of $\alpha$.

2) For the $H_{02}$ testing,

$$R = (n-1)(S_0^2+S_I^2-2S_{0I})/\sigma_{rm}^2 \tag{24}$$

$H_{02}$ is rejected if $R < \chi_{\alpha/2}^2(n-1)$, resulting in $\sigma_{r0}^2+\sigma_{rI}^2 < \sigma_{rm}^2$, or if $R > \chi_{1-(\alpha/2)}^2(n-1)$, resulting in $\sigma_{r0}^2+\sigma_{rI}^2 > \sigma_{rm}^2$, where $\chi_{\alpha/2}^2(n-1)$ and $\chi_{1-(\alpha/2)}^2(n-1)$ are the lower and upper critical values of chi-square distribution with (n-1) degrees of freedom at the $\alpha$ significance level.

3) For the $H_{03}$ testing,

$$\lambda_3 = 2[\ln L(\hat{\Omega}) - \ln L(\hat{\omega}_3)] \tag{25}$$

where

$$\ln L(\hat{\Omega}) = -n-0.5n \ln(S_0^2 S_I^2 - S_{0I}^2) \tag{26}$$

$$\ln L(\hat{\omega}_3) = 0.5n \ln(\hat{\sigma}_\mu^2\sigma_{\varepsilon 0}^2 + \hat{\sigma}_\mu^2\sigma_{\varepsilon I}^2 + \sigma_{\varepsilon 0}^2\sigma_{\varepsilon I}^2)$$
$$-n\left[\frac{(\hat{\sigma}_\mu^2+\sigma_{\varepsilon I}^2)S_0^2-2\hat{\sigma}_\mu^2 S_{0I}+(\hat{\sigma}_\mu^2+\sigma_{\varepsilon 0}^2)S_I^2}{2(\hat{\sigma}_\mu^2\sigma_{\varepsilon 0}^2+\hat{\sigma}_\mu^2\sigma_{\varepsilon I}^2+\sigma_{\varepsilon 0}^2\sigma_{\varepsilon I}^2)}\right] \tag{27}$$

and

$$\hat{\sigma}_\mu^2 = \frac{S^2\sigma_{\varepsilon I}^4 + 2S_{0I}\sigma_{\varepsilon 0}^2\sigma_{\varepsilon I}^2 + S_I^2\sigma_{\varepsilon 0}^4}{(\sigma_{\varepsilon 0}^2 + \sigma_{\varepsilon I}^2)^2} - \frac{\sigma_{\varepsilon 0}^2\sigma_{\varepsilon I}^2}{\sigma_{\varepsilon 0}^2 + \sigma_{\varepsilon I}^2} \tag{28}$$

$H_{03}$ is rejected if $\lambda_3 > \chi^2_{1-\alpha}(2)$.

4) For the $H_{04}$ testing,

$$\lambda_4 = 2[\ln L(\hat{\Omega}) - \ln L(\hat{\omega}_4)] \tag{29}$$

where $\ln L(\hat{\omega}_4)$ is calculated using Eq.(27) with the value of $\hat{\sigma}_{\varepsilon 0}^2$ from Eq.(31) replacing $\sigma_{\varepsilon 0}^2$. $\sigma_\mu^2$ and $\sigma_{\varepsilon 0}^2$ are obtained by solving the following equations with the iteration method:

$$\hat{\sigma}_\mu^2 = \frac{S_0^2\sigma_{\varepsilon I}^4 + 2S_{0I}\hat{\sigma}_{\varepsilon 0}^2\sigma_{\varepsilon I}^2 + S_I^2\hat{\sigma}_{\varepsilon 0}^4}{(\hat{\sigma}_{\varepsilon 0}^2 + \sigma_{\varepsilon I}^2)^2} - \frac{\hat{\sigma}_{\varepsilon 0}^2\sigma_{\varepsilon I}^2}{\hat{\sigma}_{\varepsilon 0}^2 + \sigma_{\varepsilon I}^2} \tag{30}$$

$$\hat{\sigma}_{\varepsilon 0}^2 = \frac{S_I^2\hat{\sigma}_\mu^4 - 2S_{0I}\hat{\sigma}_\mu^2(\hat{\sigma}_\mu^2 + \sigma_{\varepsilon I}^2) + S_0^2(\hat{\sigma}_\mu^2 + \sigma_{\varepsilon I}^2)^2}{(\sigma_{\varepsilon I}^2 + \hat{\sigma}_\mu^2)^2} - \frac{\sigma_{\varepsilon I}^2\hat{\sigma}_\mu^2}{\sigma_{\varepsilon I}^2 + \hat{\sigma}_\mu^2} \tag{31}$$

$H_{04}$ is rejected if $\lambda_4 > \chi^2_{1-\alpha}(1)$.

In our computer program, these hypotheses are automatically tested if the values of $\sigma_{rm}$, $\sigma_{\varepsilon 0}$ and/or $\sigma_{\varepsilon I}$ are given by the input. If one of these values is not given, the relevant hypothesis is not tested. If the relative standard deviation $\delta$ is given instead of the standard deviation $\sigma$, $\sigma$ is replaced by $\bar{x}_0\delta$ in the calculation formulas mentioned above. However, the output given by the program is converted to $\delta$ in such a case.

The best estimated random error standard deviations for the operator's and inspector's measurements are given as follows:

A) If $H_{01}$ is rejected and if the other hypotheses are not tested, then

$$\sigma_{r0}^2 = S_0^2 - S_{0I}$$

$$\sigma_{rI}^2 = S_I^2 - S_{0I}$$

If $\sigma_{r0}^2 < 0$ (or $\sigma_{rI}^2 < 0$),

$$\sigma_{r0}^2 = 0 \text{ (or } \sigma_{rI}^2 = 0)$$

$$\sigma_{rI}^2 = S_0^2 + S_I^2 - 2S_{0I} \text{ (or } \sigma_{r0}^2 = S_0^2 + S_I^2 - 2S_{0I})$$

If $S_{0I} < 0$,

$$\sigma_{r0}^2 = S_0^2$$

$$\sigma_{rI}^2 = S_I^2$$

In the case of negative $S_{0I}$, this term is set to zero in the $H_{01}$ testing, i.e. in Eq.(23).

B) If $H_{01}$ is not rejected and if the other hypotheses are not tested, then

$$\sigma_{r0}^2 = \sigma_{rI}^2 = (S_0^2 + S_I^2 - 2S_{0I})/2$$

If $S_{0I} < 0$,

$$\sigma_{r0}^2 = \sigma_{rI}^2 = (S_0^2 + S_I^2)/2$$

C) If $H_{01}$ and $H_{02}$ are both rejected and if $H_{03}$ and $H_{04}$ are not tested, the result is the same as A). In the $H_{02}$ testing, $S_{0I}$ is set to 0 if it is negative.

D) If $H_{01}$ is rejected and $H_{02}$ is not rejected and if $H_{03}$ and $H_{04}$ are not tested,

$$\sigma_{r0}^2 = \sigma_{rm}^2 \frac{S_0^2 - S_{0I}}{S_0^2 + S_I^2 - 2S_{0I}}$$

$$\sigma_{rI}^2 = \sigma_{rm}^2 \frac{S_I^2 - S_{0I}}{S_0^2 + S_I^2 - 2S_{0I}}$$

If $S_0^2 < S_{0I}$, $S_0^2 - S_{0I}$ is replaced by 0 and $S_I^2 - S_{0I}$ is replaced by $S_0^2 + S_I^2 - 2S_{0I}$ just like A). If $S_I^2 < S_{0I}$, then $S_I^2 - S_{0I}$ and $S_0^2 - S_{0I}$ are replaced by 0 and $S_0^2 + S_I^2 - 2S_{0I}$, respectively. If $S_{0I} < 0$, $S_{0I}$ is set to 0 in these equations and in the $H_{02}$ testing, i.e. in Eq.(24).

E) If $H_{01}$ is not rejected and $H_{02}$ is rejected and if $H_{03}$ and $H_{04}$ are not tested, the result is the same as B).

F) If $H_{01}$ and $H_{02}$ are not rejected and if $H_{03}$ and $H_{04}$ are not tested, then

$$\sigma_{r0}^2 = \sigma_{rI}^2 = \sigma_{rm}^2/2$$

G) If $H_{04}$ is rejected and if $H_{03}$ is not tested, the result is one of the estimations from A) to F) reflecting the results of the hypothesis testings. In the $H_{04}$ testing, $\hat{\sigma}_\mu^2$ is set to 0 if it is negative and $\hat{\sigma}_{\varepsilon 0}^2$ is re-calculated from Eq.(31), and $\hat{\sigma}_{\varepsilon 0}^2$ is set to 0 if it is negative and $\hat{\sigma}_\mu^2$ is re-calculated from Eq.(30).

H) If $H_{04}$ is not rejected and if $H_{03}$ is not tested, then

$$\sigma_{rI}^2 = \sigma_{\varepsilon I}^2 \quad (\text{or } \sigma_{r0}^2 = \sigma_{\varepsilon 0}^2)$$

$$\sigma_{r0}^2 = \hat{\sigma}_{\varepsilon 0}^2$$

where $\hat{\sigma}_{\varepsilon 0}$ is from Eq.(31). If this value is zero, again the results of the hypothesis testings are taken into account for this term.

I) If $H_{03}$ is rejected,

$$R_0 = \ell n\left(\frac{S_0^2 - S_{0I}}{\sigma_{\varepsilon 0}^2}\right)$$

and $$R_I = \ell n\left(\frac{S_I^2 - S_{0I}}{\sigma_{\varepsilon I}^2}\right)$$

are calculated. If $S_0^2 < S_{0I}$ or if $|R_I| < |R_0|$, the testing of $H_{04}$: $\sigma_{rI}^2 = \sigma_{\varepsilon I}^2$ is performed. If $S_I^2 < S_{0I}$ or if $|R_I| > |R_0|$, the testing of $H_{04}$:

$\sigma^2_{r0}=\sigma^2_{\varepsilon 0}$ is performed. Therefore the result is G) or H).
In the $H_{03}$ testing, $\hat{\sigma}^2_{\mu}$ is set to zero if it is negative.

J) If $H_{03}$ is not rejected,

$$\sigma^2_{r0} = \sigma^2_{\varepsilon 0}$$

$$\sigma^2_{rI} = \sigma^2_{\varepsilon I}$$

After the evaluation of the random error variances, a hypothesis testing of the difference between the operator's and inspector's mean values can be made by using these random error variances and the systematic error variances given by the input:
The null hypothesis $H_{05}$: $\mu_0 = \mu_I$ against the alternative hypothesis $H_{15}$: $\mu_0 \neq \mu_I$

In order to test this hypothesis, the statistic z is calculated as follows:

$$z = \frac{(\bar{x}_0 - \bar{x}_I)}{\sigma_d} \tag{32}$$

where

$$\sigma^2_d = \sigma^2_{s0} + \sigma^2_{sI} + \frac{\sigma^2_{r0} + \sigma^2_{rI}}{n} \tag{33}$$

and n is the number of items with paired measurements.
$H_{05}$ is rejected if $|z| > z_{1-(\alpha/2)}$, where $z_{1-(\alpha/2)}$ is the critical value of the cumulative normal distribution at the $\alpha$ level of significance.

The estimate of the true mean is

$$\hat{\mu} = \frac{w_0\bar{x}_0 + w_I\bar{x}_I}{w_0 + w_I} \tag{34}$$

where

$$w_0 = \left( \sigma^2_{s0} + \frac{\sigma^2_{r0}}{n} \right)^{-1} \tag{35}$$

and

$$w_I = \left( \sigma^2_{sI} + \frac{\sigma^2_{rI}}{n} \right)^{-1} \tag{36}$$

The variance of $\hat{\mu}$ is $(w_0+w_I)^{-1}$.

Estimation of the systematic error variances based on the paired measurements is poor if there is only one stratum on the material and if the same measurement technique is applied to the stratum. However, a hypothesis testing can be made:
The null hypothesis $H_{06}$: $\sigma_{s0}^2 + \sigma_{sI}^2 = \sigma_{sm}^2$ against the alternative hypothesis $H_{16}$: $\sigma_{s0}^2 + \sigma_{sI}^2 \neq \sigma_{sm}^2$, where $\sigma_{sm}^2$ is a variance given by input or by the sum of design values of the operator's and inspector's systematic error variances.

Assuming that the mean value of d is zero,

$$S_d^2 = d^2$$
$$= (\bar{x}_0 - \bar{x}_I)^2 \qquad (37)$$

An estimate of the combined systematic error variance is

$$\sigma_{s0}^2 + \sigma_{sI}^2 = S_d^2 - \frac{\sigma_{r0}^2 + \sigma_{rI}^2}{n} \qquad (38)$$

It is expected that the ratio

$$R = \frac{\sigma_{s0}^2 + \sigma_{sI}^2}{\sigma_{sm}^2} \qquad (39)$$

has the chi-square distribution with 1 degree of freedom, so that $H_{06}$ is rejected if $R < \chi_{\alpha/2}^2(1)$ or if $R > \chi_{1-(\alpha/2)}^2(1)$.

### 3.2 Several Strata

If the same measurement technique is used over several strata, it is expected that the random error standard deviation is constant over the entire strata and that the value of the systematic error is distributed as the normal distribution with a suitable standard deviation around a mean value of zero. Here, it is assumed that the long term systematic error does not exist. The mathematical model of measured values is again expressed by Eqs. (16) and (17). The hypothesis testings can be made except for the $H_{03}$ testing and, if it is convenient, a hypothesis testing is broken down into two parts.

1) The null hypothesis $H_{01,1}$: $\sigma_{r0}^2 \leqq \sigma_{rI}^2$ against the one-sided alternative hypothesis $H_{11,1}$: $\sigma_{r0}^2 > \sigma_{rI}^2$

For this testing, a statistic P is calculated as follows:

$$P = -2 \sum_{i=1}^{m} \ell n\ p_i \tag{40}$$

where m is the number of strata, and $p_i$ is calculated from

$$t_i = t_{1-p_i}(n_i-2) \tag{41}$$

Here $t_i$ is from Eq.(23) for each stratum. $H_{01,1}$ is rejected if $P>\chi^2_{1-\alpha}(2m)$, where $\chi^2_{1-\alpha}(2m)$ is the critical value of chi-square distribution with 2m degrees of freedom at the $\alpha$ level of significance.

2) The null hypothesis $H_{01,2}$: $\sigma_{r0}^2 \geqq \sigma_{rI}^2$ against the one-sided alternative hypothesis $H_{11,2}$: $\sigma_{r0}^2 < \sigma_{rI}^2$

For this testing, $p_i$ is replaced by $(1-p_i)$ in 1) above and $H_{01,2}$ is rejected if $P > \chi^2_{1-\alpha}$ (2m). The combined conclusion from 1) and 2) is that $\sigma_{r0}^2 = \sigma_{rI}^2$ if both null hypotheses are not rejected, $\sigma_{r0}^2 < \sigma_{rI}^2$ if $H_{01,2}$ is rejected, and $\sigma_{r0}^2 > \sigma_{rI}^2$ if $H_{01,1}$ is rejected.

3) The null hypothesis $H_{02,1}$: $\sigma_{r0}^2 + \sigma_{rI}^2 \leqq \sigma_{rm}^2$ against the one-sided alternative hypothesis $H_{12,1}$: $\sigma_{r0}^2 + \sigma_{rI}^2 > \sigma_{rm}^2$

A statistic is calculated as follows:

$$R = \sum_{i=1}^{m} R_i \tag{42}$$

where $R_i$ is from Eq.(24) for each stratum. $H_{02,1}$ is rejected if $R > \chi^2_{1-\alpha}(df)$, where df is the degrees of freedom which is obtained by summing $(n_i-1)$ over strata.

4) The null hypothesis $H_{02,2}$: $\sigma_{r0}^2 + \sigma_{rI}^2 \geqq \sigma_{rm}^2$ against the one-sided alternative hypothesis $H_{12,2}$: $\sigma_{r0}^2 + \sigma_{rI}^2 < \sigma_{rm}^2$

For this testing, the same statistic as 3) is used. In this case, however, $H_{02,2}$ is rejected if $R < \chi^2_{\alpha}(df)$. The combined conclusion from 3) and 4) is that $\sigma_{r0}^2 + \sigma_{rI}^2 = \sigma_{rm}^2$ if both null hypotheses are not rejected,

$\sigma_{r0}^2 + \sigma_{rI}^2 < \sigma_{rm}^2$ if $H_{02,2}$ is rejected, and $\sigma_{r0}^2 + \sigma_{rI}^2 > \sigma_{rm}^2$ if $H_{02,1}$ is rejected.

5) The null hypothesis $H_{04,1}$: $\sigma_{r0}^2 = \sigma_{\varepsilon 0}^2$ against the one-sided alternative hypothesis $H_{14,1}$: $\sigma_{r0}^2 > \sigma_{\varepsilon 0}^2$ or $\sigma_{r0}^2 < \sigma_{\varepsilon 0}^2$

A statistic is calculated as follows:

$$\lambda_4 = \sum_{i=1}^{m} \lambda_{4i} \tag{43}$$

where $\lambda_{4i}$ is from Eq.(29) for each stratum. $H_{04,1}$ is rejected if $\lambda_4 > \chi^2_{1-\alpha}(m)$.

6) The null hypothesis $H_{04,2}$: $\sigma_{rI}^2 = \sigma_{\varepsilon I}^2$ against the one-sided alternative hypothesis $H_{14,2}$: $\sigma_{rI}^2 > \sigma_{\varepsilon I}^2$ or $\sigma_{rI}^2 < \sigma_{\varepsilon I}^2$

For this testing, the same statistic as 5) is used. In this case, however, the roles of $\sigma_{r0}^2$ and $\sigma_{rI}^2$ are reversed in the calculations for Eq.(29). $H_{04,2}$ is rejected if $\lambda_4 > \chi^2_{1-\alpha}(m)$.

In our computer code system for analysis of paired data, these hypotheses are tested automatically if the values of $\sigma_{rm}$, $\sigma_{\varepsilon 0}$ and/or $\sigma_{\varepsilon I}$ are given by input. If one of these values is not given, the relevant hypothesis is not tested. If the relative standard deviation $\delta$ is given instead of the standard deviation $\sigma$, $\sigma$ is replaced by $\bar{x}_0\delta$ in the calculation formulas mentioned above. However, the output from the system is converted to $\delta$ in this case.

The best estimated random error standard deviations for the operator's and inspector's measurements are given for each stratum just like the case of single stratum. After that estimation, an average variance is calculated over all strata as follows:

$$V_0 = \frac{2\sigma_{r0}^4 + ( \sigma_\mu^2\sigma_{r0}^2 + \sigma_\mu^2\sigma_{rI}^2 + \sigma_{r0}^2\sigma_{rI}^2 )}{n-1} \tag{44}$$

where $\sigma_{r0}$ and $\sigma_{rI}$ are the values estimated above, and $\sigma_\mu$ is from Eq.(30) if $H_{04,1}$ is not rejected, from the equation with the roles of $\sigma_{r0}^2$ and $\sigma_{rI}^2$ reversed in Eq.(30) if $H_{04,2}$ is not rejected, from the mean value of these if both hypotheses are not rejected, or from $S_{0I}$ with a negative fix-up to zero if these hypotheses are not tested. In the case of $\sigma_{r0} = \sigma_{rI}$ in the $H_{01}$ testing, Eq.(44) is simply reduced as follows:

$$V_0 = \frac{C}{n-1} \qquad (44)'$$

where C is a constant (set to 1).
Over the m strata,

$$\sigma_{r0}^2 = \frac{\sum_{i=1}^{m} V_{0i}^{-1}\, \sigma_{r0i}^2}{\sum_{i=1}^{m} V_{0i}^{-1}} \qquad (45)$$

If the relative standard deviation is the case,

$$\delta_{r0}^2 = \frac{\sum_{i=1}^{m} V_{0i}^{-1}\, \bar{x}_{0i}^{2}\, \delta_{r0i}^2}{\sum_{i=1}^{m} V_{0i}^{-1}\, \bar{x}_{0i}^{2}} \qquad (46)$$

Estimation of $\sigma_{rI}^2$ is carried out like $\sigma_{r0}^2$ reversing the roles of $\sigma_{r0}^2$ and $\sigma_{rI}^2$ in Eqs.(44), (45) and (46).

At the same time, another estimation of random error variances is carried out as follows assuming that the prior knowledge about these variances is not available or is poor even if available:
Instead of $V_0$ in Eq.(44),

$$V_0 = \frac{S_0^2\,(\,2S_0^2 - 4S_{0I} + S_I^2\,) + S_{0I}^2}{n-1} \qquad (47)$$

$\sigma_{r0i}^2$ in Eq.(45) ( or $\delta_{r0i}^2$ in Eq.(46) ) is replaced by $S_0^2 - S_{0I}$ ( or $(S_0^2 - S_{0I})/\bar{x}_0^2$ ) if $H_{01,1}$ or $H_{01,2}$ is rejected, and by $(S_0^2+S_I^2-2S_{0I})/2$ ( or $(S_0^2+S_I^2-2S_{0I})/(2\bar{x}_0^2)$ ) if $H_{01,1}$ and $H_{01,2}$ are not rejected. For estimation of $\sigma_{rI}^2$, the roles of $\sigma_{r0}^2$ and $\sigma_{rI}^2$ are reversed in Eq.(47) and so forth. If the value of $\sigma_{r0}^2$ or $\sigma_{rI}^2$ is negative, it is set to zero.

As for the estimation of systematic error variances, Eq.(37) is replaced by Eq.(48) under the same assumption that the mean of d is zero:

$$S_d^2 = \sum_{i=1}^{m} \frac{d_i^2}{m}$$

$$= \sum_{i=1}^{m} \frac{(\bar{x}_{0i} - \bar{x}_{Ii})^2}{m} \tag{48}$$

Eq.(38) is replaced by:

$$\sigma_{s0}^2 + \sigma_{sI}^2 = S_d^2 - \frac{\sigma_{r0}^2 + \sigma_{rI}^2}{m} \sum_{i=1}^{m} \frac{1}{n_i} \tag{49}$$

where $\sigma_{r0}$ and $\sigma_{rI}$ are given for each estimation of random error variances, i.e. two kinds of evaluation of systematic error variances are carried out.

The hypothesis testing $H_{06}$ is divided into two hypotheses:

1) The null hypothesis $H_{06,1}$: $\sigma_{s0}^2 + \sigma_{sI}^2 \leqq \sigma_{sm}^2$ against the one-sided alternative hypothesis $H_{16,1}$: $\sigma_{s0}^2 + \sigma_{sI}^2 > \sigma_{sm}^2$

For this testing, the ratio R is calculated instead of Eq.(39):

$$R = \frac{m\ (\sigma_{s0}^2 + \sigma_{sI}^2)}{\sigma_{sm}^2} \tag{50}$$

It is expected that the ratio has the chi-square distribution with m degrees of freedom, so that $H_{06,1}$ is rejected if $R > \chi_{1-\alpha}^2(m)$.

2) The null hypothesis $H_{06,2}$: $\sigma_{s0}^2 + \sigma_{sI}^2 \geqq \sigma_{sm}^2$ against the one-sided alternative hypothesis $H_{16,2}$: $\sigma_{s0}^2 + \sigma_{sI}^2 < \sigma_{sm}^2$

For this testing, the same statistic as 1) above is used. $H_{06,2}$, however, is rejected if $R < \chi_{\alpha}^2(m)$. The combined conclusion from 1) and 2) is that $\sigma_{s0}^2 + \sigma_{sI}^2 = \sigma_{sm}^2$ if both null hypotheses are not rejected, $\sigma_{s0}^2+\sigma_{sI}^2<\sigma_{sm}^2$ if $H_{06,2}$ is rejected, and $\sigma_{s0}^2 + \sigma_{sI}^2 > \sigma_{sm}^2$ if $H_{06,1}$ is rejected.

In the case of multi-strata, the hypothesis testing of the mean differences is carried out for each stratum, too. The procedure of testing is the same as the case of single stratum, i.e. Eq.(32) is calculated for each stratum under the condition of Eq.(33) and the hypothesis $H_{05}$ is judged stratum-wise so as to be rejected if $|z| > z_{1-(\alpha/2)}$.

In Eq.(33), however, two possibilities to the variances are taken into account: one is that the systematic and random error variances are all from the estimated values and the other is that they are all from the design values given by input. For each case, the hypothesis testing is carried out. It should be noted that in our system these testings are repeated for the alternative estimation of random and systematic error variances.

### 3.3 Special cases: Falsification, Average value

Falsification

Falsification of data might be attempted by the potential divertor in order to conceal the diversion of an amount M of nuclear material. Hence, it should be kept in mind that the data given by the operator might be contaminated by falsification. In such a case the paired data are expressed in general as follows:

$$x_{0i} = \mu_i + s_0 + r_{0i} + \Delta + \eta_i \tag{51}$$

$$x_{Ii} = \mu_i + s_I + r_{Ii} \tag{52}$$

where $x_{0i}$ is the operator's value of the item i, $x_{Ii}$ is the inspector's value, $\mu_i$ is the true value, $s_0$ and $s_I$ are the systematic errors for the operator and inspector, respectively, $r_{0i}$ and $r_{Ii}$ are the corresponding random errors, and $\Delta$ and $\eta_i$ are the constant bias and the variable bias due to falsification, respectively. $\Delta + \eta_i$ is either an amount of diversion or only a falsified value, or a mixed value of these.

If any covariances between the terms at the right hand side of Eqs.(51) and (52) are negligibly small, the following equations are derived easily:

$$S_0^2 = S_\mu^2 + S_{r0}^2 + S_\eta^2 \tag{53}$$

$$S_I^2 = S_\mu^2 + S_{rI}^2 \tag{54}$$

$$S_{0I} = S_\mu^2 \tag{55}$$

Eq.(53) shows in comparison with Eq.(20) that the operator's random error variance is inflated by the variable bias variance $S_\eta^2$ when the paired data analysis is carried out.

The situation, however, would be changed if the potential divertor uses a sophisticated technique, or only if $\Delta+\eta_i$ is the case of diversion. It is possible to correlate $\eta_i$ with $\mu_i$ strongly, because the variance of $\mu_i$ is in general greater than that of $r_{0i}$, or only because $\mu_i+\Delta+\eta_i$ is the true value which the operator has measured before the diversion of $\Delta+\eta_i$.
In the extreme case of the former or in the latter case, $\mu_i$ can be replaced by $y_i$, which is the sum of $\mu_i$, $\Delta$ and $\eta_i$, resulting in no correlation occurring between the terms. In this case, Eqs.(51) and (52) are replaced by:

$$x_{0i} = y_i + s_0 + r_{0i} \quad (56)$$

$$x_{Ii} = y_i + s_I + r_{Ii} - \Delta - \eta_i \quad (57)$$

Eqs.(53), (54) and (55) are replaced by:

$$S_0^2 = S_y^2 + S_{r0}^2 \quad (58)$$

$$S_I^2 = S_y^2 + S_{rI}^2 + S_\eta^2 \quad (59)$$

$$S_{0I} = S_y^2 \quad (60)$$

Eq.(59) shows that the estimation of the inspector's random error variance is heavily contaminated by the variable bias variance if the paired data are analyzed under the usual procedure. Since the variance of $\mu_i$ is not a suitable parameter for safeguards in general, it is meaningless to analyze $S_\mu^2$ and/or $S_y^2$ relying on them. So the effect of the variable bias variance should be analyzed.

It is considered that the real situation is between the state expressed by Eqs.(53), (54) and (55), and the state expressed by Eqs.(58), (59) and (60). Therefore, the analysis of the combined random error variance is most important, i.e. the results of the hypothesis testing of $H_{02}$ in the case of single stratum or $H_{02,1}$ and $H_{02,2}$ in the case of multi-strata should be carefully analyzed.

In this respect, our computer code provides a factor $\rho^2$ and a critical value $R_1$ as follows:

$$\rho^2 = \frac{\sigma_{r0}^2 + \sigma_{rI}^2,\ \text{actual}}{\sigma_{r0}^2 + \sigma_{rI}^2,\ \text{design}}$$

$$= \frac{\chi_{1-\alpha}^2(df)}{\chi_{\alpha}^2\ (df)} \tag{61}$$

$$R_1 = \rho^2\ \chi_{1-\alpha}^2(df) \tag{62}$$

where df is the degrees of freedom. The factor $\rho^2$ gives a real target value to the hypothesis testing of the combined random error variance. On the other hand, the critical value $R_1$ can be used for judging whether the alternative hypothesis is true or not when the null hypothesis is rejected, i.e. it is considered that the alternative hypothesis is not true if $R > R_1$ , where R is from Eq.(24) or Eq.(42).

The constant bias, which is assumed to be constant in a stratum and may have a different value in a different stratum with a non-zero mean value, gives a great deal of effect to the estimation of the combined systematic error variance. The variance is heavily inflated by the variance of the constant biases and their non-zero mean value itself. Again it is important to analyze the results of the hypothesis $H_{06}$ or $H_{06,1}$ and $H_{06,2}$. For this purpose, the parameters $\rho^2$ and $R_1$ are provided by the code. This time, however, $\rho^2$ means that:

$$\rho^2 = \frac{\sigma_{s0}^2 + \sigma_{sI}^2,\ \text{actual}}{\sigma_{s0}^2 + \sigma_{sI}^2,\ \text{design}} \tag{63}$$

It should be noted that the discussion in this section can be applied to the case of sampling errors, too. Hence, a big value of the combined random error variance or the combined systematic error variance may occur due to an unanticipated bigger value of sampling error.

<u>Average value</u>

The operator sometimes gives an average value or a nominal value to the parameter of an item. In such a case, $x_{0i}$ in Eq.(16) is a constant value, and $S_0^2$ and $S_{0I}$ in Eqs.(20) and (22) are both zero. Apparently the estimate of $\sigma_{rI}^2$ contains the sample variance. As for the hypothesis testings, $H_{01}$ can not be tested because $r^2$ gives 1 in Eq.(23), $H_{02}$ testing has a possibility for us to lead to a wrong conclusion because of $S_I^2$ in Eq.(24) containing the sample variance, $H_{03}$ and $H_{04}$ can not be tested because the argument of $\ell n$ in Eq.(26) becomes zero, and the results of $H_{05}$ and $H_{06}$ testings are not guaranteed because of incorrect estimation of the random error variance.

Considering these points, the strata in which the average value is given are neglected during the course of estimation of random error variances. Since it is considered that there is a case having a really small sample variance, however, the hypothesis testings of $H_{02}$, $H_{05}$ and $H_{06}$ are carried out in such strata as the second case. The results of these testings should be carefully analyzed because the estimated random error variance may contain the variance of variable biases if the average value is falsified at the same time.

### 3.4 $\hat{D}$ statistics

The statistic $\hat{D}$ which has been introduced in Section 2.1 is the algebraic sum of the differences between the operator's and inspector's values on the beginning inventory, all the receipts, shipments and waste disposals, and the ending inventory. A component of $\hat{D}$, for example the ending inventory, is expressed as follows:

$$EI_0 - EI_I = \sum_{i=1}^{m} N_i \, d_i \tag{64}$$

where m is the number of the strata which belong to the ending inventory, $N_i$ is the number of items in the i-th stratum, and $d_i$ is the mean difference between the operator's and inspector's values of the items. $d_i$ has the following form.

$$d_i = \frac{\sum_{j=1}^{n_i} ( x_{0ij} - x_{Iij} )}{n_i} \tag{65}$$

where $n_i$ is the number of paired measurements in this stratum, and $x_{0ij}$

and $x_{Iij}$ are the operator's and inspector's values of the j-th item in the i-th stratum, respectively. These values are expressed as follows:

$$x_0 = w_0\, e_0\, f_0 \tag{66}$$

$$x_I = w_I\, e_I\, f_I \tag{67}$$

where w, e and f are weight, element factor and fissile isotope factor, respectively, and these parameters are separately analyzed for the estimation of their error variances. The expression of Eqs.(66) and (67) to the quantities of nuclear material is one of possibilities which we call Method 1. Other possibilities including Method 1 are:

$$\begin{aligned}
&\text{Method 1}: x = wef\\
&\text{Method 2}: x = we\bar{f}\\
&\text{Method 3}: x = w\bar{e}f\\
&\text{Method 4}: x = \bar{w}ef\\
&\text{Method 5}: x = w\bar{e}\bar{f}\\
&\text{Method 6}: x = \bar{w}e\bar{f}\\
&\text{Method 7}: x = \bar{w}\bar{e}f\\
&\text{Method 8}: x = \bar{w}\bar{e}\bar{f}
\end{aligned} \tag{68}$$

where $\bar{w}$, $\bar{e}$ and $\bar{f}$ mean the average values of w, e and f, respectively. If no datum is given on a parameter in Eq.(68), such a parameter is automatically set to one. In the sampling plan described before in this paper, it was assumed that the method 1 was applied to the inspection. Here, however, more general description is given in order to correspond with any inspection situations.

The variance of $\hat{D}$ is expressed as follows:

$$\sigma^2_{\hat{D}} = \sigma^2_{\hat{D}s} + \sigma^2_{\hat{D}r} \tag{69}$$

where

$$\sigma^2_{\hat{D}s} = \sum_i N_i^2\, \bar{x}_i^2\, (\delta^2_{Oswi}+\delta^2_{Iswi}+\delta^2_{Osei}+\delta^2_{Isei}+\delta^2_{Osfi}+\delta^2_{Isfi}) \tag{70}$$

and

$$\sigma^2_{\hat{D}r} = \sum_i N_i^2 \bar{x}_i^2 (\delta^2_{Orwi}/n_{Orwi}+\delta^2_{Irwi}/n_{Irwi}+\delta^2_{Orei}/n_{Orei}+\delta^2_{Irei}/n_{Irei} +\delta^2_{Orfi}/n_{Orfi}+\delta^2_{Irfi}/n_{Irfi}) \quad (71)$$

In the above expressions, N means the number of items, n means the number of paired data, $\bar{x}$ means the mean value of nuclear material of the items, $\delta$ means the relative standard deviation, and fuffixes i, O, I, s, r, w, e and f denote stratum, operator, inspector, systematic error, random error, weight, element factor and fissile isotope factor, respectively. If the standard deviation is given instead of the relative standard deviation, it is replaced by $\bar{x}\delta$.

Each of the relative standard deviations is given as the design value or as the estimated value. Therefore, there are two kinds of $\sigma^2_{\hat{D}}$, i.e. $\sigma^2_{\hat{D},design}$ and $\sigma^2_{\hat{D},actual}$. However, the paired data cannot give an accurate value to the systematic error variance because of a small number of data sets. On top of that, it is assumed in the inspection planning that the variances are not inflated due to diversion. Then, the systematic error variances are always from the design values. Noting this point and using the smaller value of these two, the following hypothesis testing is carried out:

The null hypothesis $H_0$: $\hat{D} = 0$ against the two-sided alternative hypothesis $H_1$: $\hat{D} \neq 0$

A statistic $D^*$ is calculated:

$$D^* = \frac{|\hat{D}|}{\sigma_{\hat{D}}} \quad (72)$$

$H_0$ is rejected if $D^* > z_{1-(\alpha/2)}$, where $z_{1-(\alpha/2)}$ is the cumulative normal distribution at the $\alpha$ level of significance.

Our computer code is still under development so that at present the $\hat{D}$ statistics can be applied only to the component of $\hat{D}$, e.g. receipts, shipments or the ending inventory. In the stage of the real $\hat{D}$ statistics, however, the following hypothesis should be tested rather than the hypothesis $H_0$ which is more suitable for applying to the component of $\hat{D}$, because it is important to detect the amount M under the design accuracy of the measurements and its actual one and under the given significance

levels of $\alpha$ and $\beta$:
The null hypothesis $H_0'$ : $-\hat{D} \leqq 0$ against the one-sided alternative hypothesis $H_1'$ : $-\hat{D} > 0$.

For this testing, Eq.(72) is replaced by:

$$D^* = \frac{-\hat{D}}{\sigma_{\hat{D}}} \tag{73}$$

And $H_0'$ is rejected if $D^* > z_{1-\alpha}$.

At the same time, Eq.(14) or (15) should be calculated in order to check whether the goal quantity M is attained or not. At present, our code can not give this value M' to $\hat{D}$ but to the component of $\hat{D}$ with a critical value $M_1$ for the alternative hypothesis:

$$M_1 = M' + z_{1-\beta} S_{\hat{D}} \tag{74}$$

where $S_{\hat{D}}$ is the actual standard deviation of $\hat{D}$. If $\hat{D} > M_1$, it should be concluded that statistically $\hat{D} > M'$.

## 4. INPUT FORM

The inspection gives us many kinds of information, such as the results of examination of records, comparison between records and reports, verification of inventory changes, updating of book inventory, verification of inventory, installation and servicing of containment and surveillance (C/S) devices and/or verification of C/S measures, verification of quality and functioning of operator's measurement system on site, and activities and observations in respect of MUF, SRDs and accidental losses on site. The treament of all these data is out of this report. It is restricted only to the data needed to analyze the paired measurements in this report.

The input forms should be completed according to the following instructions whereby P.xx ($1 \leq xx \leq 80$) refers to the position of the information within the 80 character record.

The input cards begin with the program request card followed by the special information required by each program and the inspection information if the INS program is called, and again followed by the program request card and so on until the end card appears. The programs called by the input should be INS, INFR and INVR in this order.

Program Request Card

P. 1 - P.60 : Title of the job, character type input (A60)
P.61 - P.64 : Selection of the program, (A4)
  ='INS' for the inspection information treatment
  ='INFR' for the evaluation of measurement error variances
  ='INVR' for the flow/inventory verification
  ='blank' for the end of job
P.65 - P.80 : not used, blank (16X)

Special information required by the INS program

P. 1 - P. 6 : Number of inspection reports, integer number input (I6)

Special information required by the INFR program

First card

P. 1 - P. 4 : Control of data plotting, character type input (A4)
  ='PLOT' for the plotting only
  ='PASS' for the evaluation only

='FULL' for the evaluation after the plotting
P. 5 - P.80 : not used, blank (76X)

Second card
P. 1 - P.12 : not used, blank (12X)
P.13 - P.18 : Plotting option, integer type input (I6)
= 0 for the direct difference expression
= 1 for the relative percent difference expression
P.19 - P.80 : not used, blank (62X)

Third card
P. 1 - P.60 : Significance levels of $\alpha$ for each hypothesis testing, real type input (5E12.5), given as follows:
P. 1 - P.12 : for $H_{01}$
P.13 - P.24 : for $H_{02}$ and $H_{06}$
P.25 - P.36 : for $H_{03}$
P.37 - P.48 : for $H_{04}$
P.49 - P.60 : for $H_{05}$

Special information required by the INVR program
First card
P. 1 - P. 6 : Selection of subroutines, integer type input (I6).
Only one option is available at present.
= 3
P. 7 - P.80 : not used, blank (74X)

Second card
P. 1 - P.12 : Significance level of $\alpha$, real type input (E12.5)
P.13 - P.24 : Significance level of $\beta$, (E12.5).
If no datum is given, then $\beta$ is set to $\alpha$.

Third card
P. 1 - P.80 : Blank data for returning from the INVR program to the main program

Inspection Information
There are four kinds of data which are treated in our code, i.e.(1) MBA data for the identification of a set of data -Form MI- which are punched

in one card, (2) measurement error data given as the design values -Form EI- which may need several cards repeatedly for each of the measurements, (3) stratum data which specify the number of samples, measurement methods, quantities of nuclear material, etc. in the stratum -Form SI- for which a set of three cards is repeated for each stratum, and (4) paired data for the analysis described in the previous sections -Form PI- which may need several cards for each of the measurements.

Completion of Form MI

P. 1 - P. 4 : Organization code, character type (A4)
P. 5 - P. 8 : Facility code, (A4)
P. 9 - P.12 : MBA code, (A4)
P.13 - P.18 : Date of the report, integer number (I6), e.g. 781127 is the input for November 27, 1978.
P.19 - P.22 : Report No., (I4)
P.23 - P.25 : Number of strata, (I3)
P.26 : Type of the paired data, (A1)
='I' for inventory
='R' for receipt
='S' for shipment
='W' for waste disposal
P.27 : Stratification, (A1), for future use
P.28 - P.57 : Numbers of measurement techniques (instruments and/or methods) for the following kinds of measurements (10I3)
P.28 - P.30 : weighing by operator
P.31 - P.33 : weighing by inspector
P.34 - P.36 : volume measurement by operator
P.37 - P.39 : volume measurement by inspector
P.40 - P.42 : density measurement by operator
P.43 - P.45 : density measurement by inspector
P.46 - P.48 : element factor by operator
P.49 - P.51 : element factor by inspector
P.52 - P.54 : fissile isotope factor by operator
P.55 - P.57 : fissile isotope factor by inspector
P.58 : Type of the measurement errors given in the form EI, (I1)
= 1 for standard deviation
= 2 for coefficient of variation (relative standard deviation)
P.59 - P.63 : not used, blank (5X)

P.64 - P.78 : Name of the reporter, (A15)

P.79 - P.80 : Type of the input form, (A2)
='MI'

Completion of Form EI

P. 1 - P. 4 : Report No., integer number (I4)

P. 5 - P. 8 : Entry No., (I4), in sequential

P. 9 - P.11 : not used, blank (3X)

P.12 - P.15 : MBA code, character type (A4)

P.16 - P.17 : not used, (2X)

P.18 - P.77 : Standard deviations, or coefficients of variation, of measurement errors for the measurement techniques used for each kind of measurements, real numbers (6E10.0), given as follows, and repeated in the same format if more than three measurement techniques are used:

P.18 - P.27 : random error component of the first measurement technique

P.28 - P.37 : systematic error component of the first measurement technique

P.38 - P.47 : random error component of the second measurement technique

P.48 - P.57 : systematic error component of the second measurement technique

P.58 - P.67 : random error component of the third measurement technique

P.68 - P.77 : systematic error component of the third measurement technique

P.78 : Type of the measurement, (A1)
='1' for weighing by operator
='2' for weighing by inspector
='3' for volume measurement by operator
='4' for volume measurement by inspector
='5' for density measurement by operator
='6' for density measurement by inspector
='7' for element factor by operator
='8' for element factor by inspector
='9' for fissile isotope factor by operator
='0' for fissile isotope factor by inspector

P.79 - P.80 : Type of the input form, (A2)
='EI'

Completion of Form SI-1

P. 1 - P. 4 : Report No., integer number (I4)
P. 5 - P. 7 : Stratum No., (I3)
P. 8 - P.11 : MBA code, character type (A4)
P.12 : KMP code, (A1)
P.13 - P.16 : Material description, (A4)
P.17 - P.24 : Name of stratum, (A8)
P.25 - P.30 : Number of items in the stratum, (I6)
P.31 - P.32 : Method for defining the quantities of nuclear material, (I2). If no datum is given on a parameter such as weighing, element factor or fissile isotope factor, that parameter is automatically set to one.

= 1 for wef, where w, e and f denote weight, element factor and fissile isotope factor, respectively.
=2 for $we\bar{f}$, where $\bar{f}$ means the mean value of f.
= 3 for $w\bar{e}f$
= 4 for $\bar{w}ef$
= 5 for $w\bar{e}\bar{f}$
= 6 for $\bar{w}e\bar{f}$
= 7 for $\bar{w}\bar{e}f$
= 8 for $\bar{w}\bar{e}\bar{f}$

P.33 - P.72 : Numbers of samples taken for the measurements by operator and inspector, (10I4), given for each measurement as follows:

P.33 - P.36 : weighing by operator
P.37 - P.40 : weighing by inspector
P.41 - P.44 : volume measurement by operator
P.45 - P.48 : volume measurement by inspector
P.49 - P.52 : density measurement by operator
P.53 - P.56 : density measurement by inspector
P.57 - P.60 : element factor by operator
P.61 - P.64 : element factor by inspector
P.65 - P.68 : fissile isotope factor by operator
P.69 - P.72 : fissile isotope factor by inspector
P.73 - P.77 : not used, blank (5X)

P.78 : Stratum data No., (A1)

='1'

P.79 - P.80 : Type of the input form, (A2)
='SI'

Completion of Form SI-2

P. 1 - P. 4 : Report No., integer number (I4)

P. 5 - P. 7 : Stratum No., (I3)

P. 8 - P.11 : MBA code, charactor type (A4)

P.12 - P.41 : Number of the measurement technique used in the stratum, (10I3), given for each measurement as follows. If the value is given, the corresponding measurement errors are taken into account in the $\hat{D}$ statistics whether the paired data are given or not.

P.12 - P.14 : weighing by operator
P.15 - P.17 : weighing by inspector
P.18 - P.20 : volume measurement by operator
P.21 - P.23 : volume measurement by inspector
P.24 - P.26 : density measurement by operator
P.27 - P.29 : density measurement by inspector
P.30 - P.32 : element factor by operator
P.33 - P.35 : element factor by inspector
P.36 - P.38 : fissile isotope factor by operator
P.39 - P.41 : fissile isotope factor by inspector

P.42 - P.76 : Combined random error variances of the measurements by the operator and inspector, real number (5E7.0), given for the following measurements:

P.42 - P.48 : weighing
P.49 - P.55 : volume measurement
P.56 - P.62 : density measurement
P.63 - P.69 : element factor
P.70 - P.76 : fissile isotope factor

P.77 : not used, blank (1X)

P.78 : Stratum data No., (A1)
='2'

P.79 - P.80 : Type of the input form, (A2)
='SI'

Completion of Form SI-3

P. 1 - P. 4 : Report No., integer number (I4)

P. 5 - P. 7 : Stratum No., (I3)

P. 8 - P.11 : MBA code, character type (A4)

P.12 : not used, blank (1X)

P.13 - P.24 : Total weight of nuclear material in the stratum. If no datum is given on the weighing as the paired data, the value given here is used for the $\hat{D}$ statistics.

P.25 - P.36 : Total volume of nuclear material in the stratum

P.37 - P.48 : Average density over the stratum

P.49 - P.60 : Average element factor over the stratum. If no datum is given on the element factor as the paired data, the value given here is used for the $\hat{D}$ statistics.

P.61 - P.72 : Average fissile isotope factor over the stratum. If no datum is given on the fissile isotope factor, the value given here is used for the $\hat{D}$ statistics.

P.73 - P.77 : not used, blank (5X)

P.78 : Stratum data No., (A1)
='3'

P.79 - P.80 : Type of the input form, (A2)
='SI'

Completion of Form PI

P. 1 - P. 4 : Report No., integer number (I4)

P. 5 - P. 8 : Entry No., (I4)

P. 9 - P.11 : Stratum No., (I3)

P.12 - P.15 : MBAcode, character type (A4)

P.16 : Continuation code, (A1), for future use

P.17 : Element code, (A1)
='D' for depleted uranium
='N' for natural uranium
='E' for enriched uranium
='P' for plutonium
='T' for thorium

P.18 - P.77 : Paired data for each of the measurements, real number (6E10.0), given as follows, and repeated in the same format if more than six items are measured:
P.18 - P.27 : amount of weight, volume, density, element

factor or fissile isotope factor by operator
or by inspector for the first item

P.28 - P.37 : amount for the second item
P.38 - P.47 : amount for the third item
P.48 - P.57 : amount for the fourth item
P.58 - P.67 : amount for the fifth item
P.68 - P.77 : amount for the sixth item

P.78 : Type of the measurement, (A1)
='1' for weighing by operator
='2' for weighing by inspector
='3' for volume measurement by operator
='4' for volume measurement by inspector
='5' for density measurement by operator
='6' for density measurement by inspector
='7' for element factor by operator
='8' for element factor by inspector
='9' for fissile isotope factor by operator
='0' for fissile isotope factor by inspector

P.79 - P.80 : Type of the input form, (A2)
='PI'

## 5. SAMPLE INPUT AND OUTPUT

Table 1 shows the sample data which were obtained in the course of the verification activities on the physical inventory at the Fast Critical Assembly (FCA) of JAERI. The measurements on the side of the audit team consist of the weighing of nuclear material by a scale and the non-destructive measurement by a high resolution gamma ray spectrometry for the determination of fissile isotope content. The element factor was not measured, but it is assumed that the factor is one without any measurement errors. The variable measurement data in Table 1 are analyzed here.

The input data to the system run by a FACOM 230-75 computer are given in Table 2.

Table 3 shows the sample output from the system after the input has been processed.

The first line of the output is the input title to the INS program. Following the line, input data are printed out without any modifications to the data, so that this output is convenient to the user to check his input data.

Following the output from the INS program, the output from the INFR program is given. The first line is also the input title to the program. In the next line, PROBLEM NO. corresponds to the material chategory number, so that the analysis on each material begins from this line. The analysis is carried out on the measurement of weight, measurement of element factor and measurement of isotope factor in this order, so that the next line is MEASUREMENT OF WEIGHT. Following the line, MBA code and KMP code are given for identification of the job. TOTAL NUMBER OF PAIRED DATA SETS corresponds to that of the stratum.
INFERENCE ABOUT MEAN DIFFERENCE is now indifferent option.
LEVEL OF SIGNIFICANCE (ALPHA) APPLIED FOR HYPOTHESIS TEST H01, H02, H03, H04 AND H05 are given by input. For the $H_{06}$ test, $\alpha$ for $H_{02}$ is used.
RANDOM AND SYSTEMATIC ERROR VARIANCES ASSIGNED BY SHIPPER (or Operator) AND RECEIVER (or Inspector) are given by input for each group which correspods to each stratum. Here, SUM is a given value or the sum of the shipper's and receiver's error variances unless a special value for SUM is given in input.

LIST OF MEASUREMENT INSTRUMENT NUMBERS is given by input for each stratum. SHIPPER AND RECEIVER DATA are the paired data given by input. Here, DIFFERENCE is a simple difference (S-R) or a % difference ((S-R)/S*100) according to the input option.

The message of INPUT DATA SHOULD BE ANALYZED WITHOUT THEIR RE-ARRANGEMENT is now indifferent because such test as judging the order of the paired data is not performed in this system and because always this statement appears.

NUMBER OF GROUPS means the number of strata in the material.

BOUNDARY NUMBER means the upper boundary number of each groups or strata.

In the NUMBER OF DATA INCLUDED IN EACH GROUP, the first line is the group number and the second one is the number of paired data included in each group.

In the SHIPPER AND RECEIVER DATA AFTER RE-ARRANGEMENT, the paired data are re-arranged in increasing order of the receiver's values.

The PLOTTING OF SHIPPER-RECEIVER DIFFERENCES gives a bird's eye view over the differences between paired data.

The first diagram gives the shipper-receiver differences (S-R or (S-R)/S* 100 according to the input option) versus each paired datum in the order of input data by dividing the differences into 20 groups from the maximum positive difference to the maximum negative difference. The figures on the left side show the group number in which the group of zero-differences is adjusted to 0. The figures on the right side column show the center value of each group. In the second diagram, the receiver's values are divided into 100 groups from the maximum value to the minimum value.

The shipper-receiver differences are plotted versus these groups. In the diagram, * denotes one point, 2, 3 and 4 denote two-, three-, and four-fold multiple points, respectively, and x denotes more than four-fold multiple points. From these two diagrams, it is easily found out how big the differences are, how the distribution of these differences is and how about the distribution of the receiver's values.

According to the number of strata which belong to the same material chategory, statistical inferences of random and systematic error variances are made as a single group or multi-groups. Both treatments are similar, so that we give some explanations to the case of multi-groups according to the sample output.

STATISTICAL INFERENCES ON PAIRED DATA SETS WITH MULTI-GROUP is the begin-

ning statement on the inferences. The paired data are printed out for each stratum, and sample averages, variances and covariances are calculated and printed out for each stratum. Here, AVS and AVR are the shipper's and the receiver's sample average, respectively, and SS2 and SR2 are the shipper's and the receiver's variances, respectively.
On hypothesis testings, descriptions are given in Section 3. However, it should be noted that VRSE, VRRE, VRXE, VSSE and VSRE correspond to $\sigma_{r0}^2$, $\sigma_{rI}^2$, $\sigma_{\mu}^2$, $\sigma_{s0}^2$ and $\sigma_{sI}^2$, respectively, and VRS, VRR, VRM and VSM correspond to $\sigma_{\varepsilon 0}^2$, $\sigma_{\varepsilon I}^2$, $\sigma_{rm}^2$ and $\sigma_{sm}^2$, respectively.
In the $H_{05}$ testing, SIG-D, AL, NOTR and RJCT denote $\sigma_d$, $\alpha$, NOT REJECTED and REJECTED, respectively.
Finally, estimates of the random error variances for each measurement method are printed out. Here, WEI is given 1, 2 or 3 according to whether the measurement is for weight, element factor or fissile isotope factor, respectively.

The similar output described above is obtained for the measurement of element factor and for the measurement of fissile isotope factor. If the measurement is not performed, only the title is printed out.
These outputs are repeatedly printed out for each material chategory.

The output from the program INVR is started from the input title to this program. VARIABLES PAIRED COMPARISONS is one of the titles of the sub-functions of the program, but it always appears in this system because the other sub-functions are not used. ALPHA and BETA are given by input. CASE NO. corresponds to the number of the material chategory. ORG. CODE, FAC. CODE, MBA CODE, DATE OF INS. REPORT and INS. REPORT NO. are all given by input. INVENTORY VERIFICATION DATA is a title always printed out. STRATA, SCALES, ANAL.S and NDAS refer to numbers of strata, scales, analysis methods and NDAs, respectively. MEASUREMENT-ERROR COEFFICIENTS OF VERIFICATION denotes whether the kind of measurement error is coefficients of variation or standard deviations depending on input data. SYSTEMATIC means the systematic errors which are given by input. RANDOM,DESIGN and RANDOM, ESTIMATE mean the random errors given by input and the random errors estimated in the INFR program, respectively. MATERIAL CODE is given by input. In SAMPLE SIZE, numbers of samples to be measured in each stratum are given for weight, element factor and fissile isotope factor for operator and for inspector. In MEASUREMENT, scale numbers, analysis method numbers and NDA numbers to be used in each stratum are given for operator and for inspector. In this column, STRATUM refers to the stratum number, MATERIAL refers to the MBA code, KMP code and material description in this order, ITEM refers to the number of items, and METHOD refers to the method number. In the next column, OP. WEIGHT and INS. WEIGHT refer to the weights measured by operator and by inspector, respectively. OP. E FACTOR and INS. E FACTOR refer to the element factors measured by operator and by inspector, respectively. OP. I FACTOR and INS. I FACTOR refer to the fissile isotope factors of operator and of inspector, respectively. These values are average values over each stratum and give the DIFFERENCE according to the method number. RESULTS OF CALCULATIONS gives values to the parameters described in Section 3.4.

Finally the decision whether $\hat{D}$ is equal to zero or not is statistically given and the attained goal quantity is printed out with the critical value which gives a rejection criterion of the $\hat{D}$ being the quantity when $\hat{D}$ is not equal to zero.

The output is repeated for each material chategory.

## 6. ANALYSIS OF SAMPLE OUTPUT

Sample input was prepared from the data obtained in the course of the physical inventory taking at the Fast Critical Assembly of JAERI. The operator's data are based on the shipper's values. On the other hand, the inspector's data are based on measurements made by inspectors during the inspection. All nuclear materials have plate type fixed shapes with several types of quantities which were manufactured under a high quality control. Number of samples was decided based on the sampling plan in which a stratification was made for each type of plates, the goal quantity was set to 8 Kg Pu, $\alpha$ and $\beta$ were both set to 5 %, the maximum defection rate for variable testing was set to 30 %, and the design values were used to the random and systematic errors. The samples were rondomly picked up and were measured by scales for deciding sample weights and by a high resolution gamma ray spectrometry for deciding quantities of their fissile isotopes.

On the measurement of sample weights, the plotting of operator-inspector differences given in Table 3 shows a good result of consistency except for one point in which 0.3 % discrepancy is found. This discrepancy, however, is not significant because it does not exceed the critical value of $4\sigma_d$ (4x0.2 %) which was obtained based on the design value.
The result of the hypothesis testings shows that the random and systematic error variances observed are less than those given as design values. This means that the measurement on weighing was satisfactorily made by both operator and inspector independently, and that any falsification on measurement errors is not found out.

Measurement of element factors was not performed and it was only assumed that the factors would be unit. However, it is considered that the quantity of Pu would be deduced from the measurement of fissile isotopes which was made by comparing the intensity of gamma ray emitted by fissile isotopes of the sample to that of a standard sample, if the sample thickness is within a suitable range. Therefore, the measurement of fissile isotope factors is important.

On the measurement of fissile isotope factors, the maximum difference between operator's and inspector's values is 2 %. This discrepancy is not significant because it is within the critical value of $4\sigma_d$ (4x1 %) which

was obtained based on the design value.
The result of the hypothesis testings shows that the average random error variance of inspector is slightly greater than that designated. This happens because nominal or average values appear in the operator's data and then because the variance of the true fissile isotope factors of the samples is added to the inspector's random error variance. However, since the combined random error variance is smaller, it is concluded that the measurement on fissile isotope factors was satisfactorily made by both side and that any falsification on measurement errors does not exist.

The difference between operator's and inspector's inventories estimated is about 0.5 Kg fissile Pu. This value is statistically judged as being zero, that is the operator's inventory record has been verified. The attained goal quantity is 4.9 Kg fissile Pu. The value obtained by converting this value to Kg Pu unit is less than the target goal quantity of 8 Kg Pu, so that the inspection intensity was sufficient to verify the physical inventory of the FCA.

## 7. CONCLUSION

A comprehensive subsystem for safeguards information treatment has been developed. In this system, inventory/flow data of an operator can be verified based on the paired comparison method by testing measurement errors and by analyzing the statistic $\hat{D}$.

Implementation of safeguards requires special procedures to the safeguards information system reflecting the actual situation on the site of a facility. Our system described in the preceding sections has a few special features. For example, nominal values or average values are acceptable as the paired data as well as measured data. One or two kinds of measurements, e.g. weighing only, is also acceptable to the $\hat{D}$ statistics analysis. The system, however, should be improved on a run by run basis in order to correspond with the actual situation.

Another feature of our system is that the consistency between the inspection planning and the inspection verification is maintained from the point of view of the safeguards concept. That is, a procedure for inspection planning is beforehand defined and the verification is carried out on that thoughts on which the inspection planning is based.

We have established a total system of safeguards information treatment named NPT-JAPAN[4,5]. This system, however, cooperates with an ideal situation, so that it is often difficult to treat with actual cases. We are now improving the system on a subsystem by subsystem basis. After these works, we will re-construct the system with more efficiency and with more perfectness.

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TABLE 1 LISTING OF THE DATA MEASURED DURING THE FCA PIT AND THE CORRESPONDING BOOK VALUES

| MATE RIAL | STRATUM | ITEM NO. | WEIGHT BOOK | WEIGHT AUDIT ATT./VAR. | FISSILE ISOTOPE FACTOR BOOK | FISSILE ISOTOPE FACTOR AUDIT ATT. | FISSILE ISOTOPE FACTOR AUDIT VAR. |
|---|---|---|---|---|---|---|---|
| PU92 | 2-4-1/16 | 1 | 92,129 | 92,131 | 0,91968 | 0,91891 | 0,91348 |
| PU92 | 2-4-1/16 | 2 | 91,879 | 91,882 | 0,91790 | 0,91413 | 0,92041 |
| PU92 | 2-4-1/16 | 3 | 91,959 | 91,962 | 0,91886 | 0,91385 | 0,92346 |
| PU92 | 2-4-1/16 | 4 | 92,393 | 92,397 | 0,91889 | 0,93279 | 0,92020 |
| PU92 | 2-4-1/16 | 5 | 91,360 | 91,363 | 0,92000 | 0,91643 | 0,92225 |
| PU92 | 2-4-1/16 | 6 | 92,400 | 92,401 | 0,91706 | 0,91762 | 0,91744 |
| PU92 | 2-4-1/16 | 7 | 92,452 | 92,453 | 0,91790 | 0,92543 | 0,91602 |
| PU92 | 2-4-1/16 | 8 | 92,467 | 92,431 | 0,91768 | 0,92727 | 0,92438 |
| PU92 | 2-4-1/16 | 9 | 92,146 | 92,164 | 0,91834 | 0,92543 | 0,92116 |
| PU92 | 2-4-1/16 | 10 | 91,690 | 91,694 | 0,92000 | 0,92268 | 0,91928 |
| PU92 | 2-4-1/16 | 11 | 91,510 | 91,516 | 0,92000 | 0,91441 | 0,92206 |
| PU92 | 2-4-1/16 | 12 | 92,062 | 92,064 | 0,91855 | 0,91542 | 0,92585 |
| PU92 | 2-4-1/16 | 13 | 92,341 | 92,362 | 0,91847 | 0,91918 | 0,92412 |
| PU92 | 2-4-1/16 | 14 | 91,350 | 91,353 | 0,92000 | 0,90834 | 0,91762 |
| PU92 | 2-4-1/16 | 15 | 91,547 | 91,548 | 0,91887 | 0,90365 | 0,91294 |
| PU92 | 2-4-1/16 | 16 | 91,130 | 91,131 | 0,92000 | 0,90044 | 0,0 |
| PU92 | 2-4-1/16 | 17 | 92,235 | 92,233 | 0,91887 | 0,93159 | 0,0 |
| PU92 | 2-4-1/16 | 18 | 92,106 | 92,108 | 0,91875 | 0,92268 | 0,0 |
| PU92 | 2-4-1/16 | 19 | 92,174 | 92,174 | 0,91855 | 0,91376 | 0,0 |
| PU92 | 2-4-1/16 | 20 | 92,151 | 92,151 | 0,91859 | 0,92608 | 0,0 |
| PU92 | 2-4-1/16 | 21 | 91,330 | 91,334 | 0,92000 | 0,91303 | 0,0 |
| PU92 | 2-4-1/16 | 22 | 91,330 | 91,327 | 0,92000 | 0,90623 | 0,0 |
| PU92 | 2-4-1/16 | 23 | 92,262 | 92,277 | 0,91724 | 0,91505 | 0,0 |
| PU92 | 2-4-1/16 | 24 | 91,790 | 91,797 | 0,92000 | 0,90531 | 0,0 |
| PU92 | 2-4-1/16 | 25 | 92,125 | 92,128 | 0,91734 | 0,92240 | 0,0 |
| PU92 | 2-2-1/16 | 1 | 46,140 | 46,136 | 0,91930 | 0,91579 | 0,91274 |
| PU92 | 2-2-1/16 | 2 | 45,890 | 45,890 | 0,91930 | 0,91441 | 0,91524 |
| PU92 | 2-2-1/16 | 3 | 46,300 | 46,299 | 0,91930 | 0,91790 | 0,90554 |
| PU92 | 2-2-1/16 | 4 | 46,260 | 46,258 | 0,92000 | 0,92056 | 0,92430 |
| PU92 | 2-2-1/16 | 5 | 46,140 | 46,004 | 0,91930 | 0,92249 | 0,90920 |
| PU92 | 2-2-1/16 | 6 | 46,010 | 46,015 | 0,91930 | 0,91689 | 0,91370 |
| PU92 | 2-2-1/16 | 7 | 46,220 | 46,217 | 0,91930 | 0,92460 | 0,92610 |
| PU92 | 2-2-1/16 | 8 | 46,280 | 46,285 | 0,92000 | 0,92726 | 0,91787 |
| PU92 | 2-2-1/16 | 9 | 46,170 | 46,172 | 0,91930 | 0,92148 | 0,91369 |
| PU92 | 2-2-1/16 | 10 | 45,960 | 45,953 | 0,91930 | 0,91597 | 0,91331 |
| PU92 | 2-2-1/16 | 11 | 45,930 | 45,929 | 0,91930 | 0,92120 | 0,91194 |
| PU92 | 2-2-1/16 | 12 | 46,010 | 46,011 | 0,92000 | 0,87357 | 0,0 |
| PU92 | 2-2-1/16 | 13 | 45,800 | 45,795 | 0,91930 | 0,89312 | 0,0 |
| PU92 | 2-2-1/16 | 14 | 46,060 | 46,059 | 0,91930 | 0,89477 | 0,0 |
| PU92 | 2-2-1/16 | 15 | 46,370 | 46,367 | 0,91930 | 0,89348 | 0,0 |
| PU92 | 2-2-1/16 | 16 | 46,000 | 45,999 | 0,92000 | 0,87136 | 0,0 |
| PU92 | 2-2-1/16 | 17 | 45,930 | 45,930 | 0,91930 | 0,88091 | 0,0 |
| PU92 | 2-2-1/16 | 18 | 46,310 | 46,308 | 0,91930 | 0,89817 | 0,0 |
| PU92 | 2-2-1/16 | 19 | 45,810 | 45,811 | 0,91930 | 0,88036 | 0,0 |

| MATE RIAL | STRATUM | ITEM NO. | WEIGHT BOOK | WEIGHT AUDIT ATT./VAR. | FISSILE ISOTOPE FACTOR BOOK | FISSILE ISOTOPE FACTOR AUDIT ATT. | FISSILE ISOTOPE FACTOR AUDIT VAR. |
|---|---|---|---|---|---|---|---|
| PU92 | 2-4-1/16 | 26 | 91,600 | 91,605 | 0,92000 | 0,91238 | 0,0 |
| PU92 | 2-4-1/16 | 27 | 91,420 | 91,424 | 0,92000 | 0,90880 | 0,0 |
| PU92 | 2-4-1/16 | 28 | 92,010 | 92,012 | 0,91862 | 0,92911 | 0,0 |
| PU92 | 2-4-1/16 | 29 | 91,500 | 91,503 | 0,92000 | 0,90209 | 0,0 |
| PU92 | 2-4-1/16 | 30 | 91,040 | 91,044 | 0,92000 | 0,91100 | 0,0 |
| PU92 | 2-4-1/16 | 31 | 91,390 | 91,395 | 0,92000 | 0,91413 | 0,0 |
| PU92 | 2-4-1/16 | 32 | 92,260 | 92,261 | 0,91687 | 0,90613 | 0,0 |
| PU92 | 2-4-1/16 | 33 | 92,400 | 92,402 | 0,91862 | 0,92350 | 0,0 |
| PU92 | 2-4-1/16 | 34 | 91,500 | 91,497 | 0,92000 | 0,90852 | 0,0 |
| PU92 | 2-4-1/16 | 35 | 92,312 | 92,328 | 0,91864 | 0,92065 | 0,0 |
| PU92 | 2-4-1/16 | 36 | 92,132 | 92,134 | 0,91935 | 0,91624 | 0,0 |
| PU92 | 2-4-1/16 | 37 | 91,778 | 91,780 | 0,91913 | 0,90191 | 0,0 |
| PU92 | 2-4-1/16 | 38 | 92,565 | 92,568 | 0,91875 | 0,92571 | 0,0 |
| PU92 | 2-4-1/16 | 39 | 92,049 | 92,053 | 0,91790 | 0,89740 | 0,0 |
| PU92 | 2-4-1/16 | 40 | 91,490 | 91,494 | 0,92000 | 0,92479 | 0,0 |
| PU92 | 2-4-1/16 | 41 | 91,610 | 91,615 | 0,92000 | 0,91395 | 0,0 |
| PU92 | 2-4-1/16 | 42 | 91,320 | 91,322 | 0,92000 | 0,91229 | 0,0 |
| PU92 | 2-4-1/16 | 43 | 91,490 | 91,494 | 0,92000 | 0,91845 | 0,0 |
| PU92 | 2-4-1/16 | 44 | 91,690 | 91,691 | 0,92000 | 0,91303 | 0,0 |
| PU92 | 2-4-1/16 | 45 | 91,540 | 91,547 | 0,92000 | 0,89915 | 0,0 |
| PU92 | 2-4-1/16 | 46 | 91,830 | 91,806 | 0,92000 | 0,91744 | 0,0 |
| PU92 | 2-4-1/16 | 47 | 92,001 | 92,000 | 0,91859 | 0,91753 | 0,0 |
| PU92 | 2-4-1/16 | 48 | 91,690 | 91,695 | 0,92000 | 0,90705 | 0,0 |
| PU92 | 2-4-1/16 | 49 | 91,530 | 91,527 | 0,92000 | 0,90099 | 0,0 |
| PU92 | 2-2-1/16 | 20 | 45,860 | 45,854 | 0,91930 | 0,87430 | 0,0 |
| PU92 | 2-2-1/16 | 21 | 46,280 | 46,284 | 0,92000 | 0,87063 | 0,0 |
| PU92 | 2-2-1/16 | 22 | 46,280 | 46,284 | 0,91930 | 0,87742 | 0,0 |
| PU92 | 2-2-1/16 | 23 | 46,095 | 46,100 | 0,91930 | 0,86925 | 0,0 |
| PU92 | 2-2-1/16 | 24 | 46,130 | 46,128 | 0,92000 | 0,88614 | 0,0 |
| PU92 | 2-2-1/16 | 25 | 45,900 | 45,904 | 0,91930 | 0,86898 | 0,0 |
| PU92 | 2-2-1/16 | 26 | 45,980 | 45,980 | 0,91930 | 0,86879 | 0,0 |
| PU92 | 2-2-1/16 | 27 | 45,950 | 45,947 | 0,91930 | 0,87614 | 0,0 |
| PU92 | 2-2-1/16 | 28 | 45,960 | 45,948 | 0,91930 | 0,88073 | 0,0 |
| PU92 | 2-2-1/16 | 29 | 46,140 | 46,136 | 0,91930 | 0,85034 | 0,0 |
| PU92 | 2-2-1/16 | 30 | 46,210 | 46,208 | 0,92000 | 0,86264 | 0,0 |
| PU92 | 2-2-1/16 | 31 | 46,350 | 46,350 | 0,91930 | 0,91542 | 0,0 |
| PU92 | 2-2-1/16 | 32 | 46,190 | 46,187 | 0,91930 | 0,88173 | 0,0 |
| PU92 | 2-2-1/16 | 33 | 45,880 | 45,884 | 0,91930 | 0,89899 | 0,0 |
| PU92 | 2-2-1/16 | 34 | 45,950 | 45,946 | 0,91930 | 0,87953 | 0,0 |
| PU92 | 2-2-1/16 | 35 | 45,960 | 45,950 | 0,91930 | 0,87678 | 0,0 |
| PU92 | 2-2-1/16 | 36 | 45,880 | 45,880 | 0,91920 | 0,88412 | 0,0 |
| PU92 | 2-2-1/16 | 37 | 46,330 | 46,328 | 0,91930 | 0,90560 | 0,0 |
| PU92 | 2-2-1/16 | 38 | 46,146 | 46,152 | 0,91970 | 0,86769 | 0,0 |

TABLE 1 LISTING OF THE DATA MEASURED DURING THE FCA PIT AND THE CORRESPONDING BOOK VALUES

| MATE RIAL | STRATUM | ITEM NO. | WEIGHT BOOK | WEIGHT AUDIT ATT./VAR. | FISSILE ISOTOPE FACTOR BOOK | AUDIT ATT. | AUDIT VAR. |
|---|---|---|---|---|---|---|---|
| PU92 | 2-1-1/16 | 1 | 22.365 | 22.371 | 0.91788 | 0.93818 | 0.91845 |
| PU92 | 2-1-1/16 | 2 | 22.351 | 22.354 | 0.91760 | 0.93441 | 0.91298 |
| PU92 | EX221/16 | 1 | 39.381 | 39.395 | 0.91996 | 0.91996 | 0.92403 |
| PU92 | EX221/16 | 2 | 39.554 | 39.566 | 0.91822 | 0.92382 | 0.92107 |
| PU81 | 2-2-1/16 | 1 | 51.690 | 51.693 | 0.81300 | 0.81300 | 0.80807 |
| PU81 | 2-2-1/16 | 2 | 51.530 | 51.530 | 0.81300 | 0.81235 | 0.82080 |
| PU81 | 2-2-1/16 | 3 | 51.360 | 51.361 | 0.81300 | 0.81032 | 0.80192 |
| PU81 | 2-2-1/16 | 4 | 51.540 | 51.542 | 0.81330 | 0.81633 | 0.0 |
| PU81 | 2-2-1/16 | 5 | 51.420 | 51.421 | 0.81300 | 0.81292 | 0.0 |
| PU81 | 2-2-1/16 | 6 | 51.760 | 51.760 | 0.81300 | 0.82755 | 0.0 |
| PU81 | 2-1-1/16 | 1 | 26.340 | 26.339 | 0.81300 | 0.81300 | 0.82325 |
| PU81 | 2-1-1/16 | 2 | 26.470 | 26.465 | 0.81300 | 0.81178 | 0.80702 |
| PU75 | 2-2-1/16 | 1 | 54.470 | 54.471 | 0.75690 | 0.75682 | 0.75305 |
| PU75 | 2-2-1/16 | 2 | 54.560 | 54.570 | 0.75690 | 0.75962 | 0.74843 |
| PU75 | 2-2-1/16 | 3 | 54.770 | 54.774 | 0.75690 | 0.75910 | 0.77064 |
| PU75 | 2-2-1/16 | 4 | 54.320 | 54.321 | 0.75690 | 0.75675 | 0.0 |
| PU75 | 2-2-1/16 | 5 | 54.500 | 54.507 | 0.75690 | 0.76462 | 0.0 |
| PU75 | 2-2-1/16 | 6 | 54.540 | 54.540 | 0.75690 | 0.75970 | 0.0 |

| MATE RIAL | STRATUM | ITEM NO. | WEIGHT BOOK | WEIGHT AUDIT ATT./VAR. | FISSILE ISOTOPE FACTOR BOOK | AUDIT ATT. | AUDIT VAR. |
|---|---|---|---|---|---|---|---|
| PU92 | 2-1-1/16 | 3 | 22.396 | 22.401 | 0.91834 | 0.91834 | 0.92277 |
| PU92 | EX221/16 | 3 | 39.379 | 39.391 | 0.91996 | 0.91812 | 0.91669 |
| PU81 | 2-2-1/16 | 7 | 51.600 | 51.599 | 0.81300 | 0.81641 | 0.0 |
| PU81 | 2-2-1/16 | 8 | 51.610 | 51.613 | 0.81300 | 0.80251 | 0.0 |
| PU81 | 2-2-1/16 | 9 | 51.690 | 51.693 | 0.81300 | 0.82723 | 0.0 |
| PU81 | 2-2-1/16 | 10 | 51.710 | 51.716 | 0.81300 | 0.78544 | 0.0 |
| PU81 | 2-2-1/16 | 11 | 51.480 | 51.484 | 0.81300 | 0.81202 | 0.0 |
| PU81 | 2-1-1/16 | 3 | 26.350 | 26.354 | 0.81300 | 0.81170 | 0.79745 |
| PU75 | 2-2-1/16 | 7 | 54.490 | 54.495 | 0.75690 | 0.77688 | 0.0 |
| PU75 | 2-2-1/16 | 8 | 54.320 | 54.320 | 0.75690 | 0.75826 | 0.0 |
| PU75 | 2-2-1/16 | 9 | 54.570 | 54.575 | 0.75690 | 0.76825 | 0.0 |
| PU75 | 2-2-1/16 | 10 | 54.590 | 54.589 | 0.75690 | 0.77257 | 0.0 |
| PU75 | 2-2-1/16 | 11 | 54.500 | 54.502 | 0.75690 | 0.75455 | 0.0 |

Table 2 Sample Input for FACOM 230-75 except for $NO, $GJOB and $JEND cards

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

                                                                     T,2/TIME  1M
                                                                     C,2/CORE 128
                                                                     W,2/PAGE 160
                                                                     P,0/PCH    0
¥DLIEDRUN  RFNAME=J2417,NPTJ2
¥DISK     F25
¥DISK     F26
¥DISK     F30
¥DATA
FCA PIT EVALUATION, 1978-09-28 H,NISHIMURA                      INS
    1
JAERFCA FCA 780925   1   7I    1  1                     1  12     H,NISHIMURA    MI
   1   1    FCA   0,001      0,001                                               1EI
   1   2    FCA   0,001      0,001                                               2EI
   1   3    FCA   0,005      0,005                                               9EI
   1   4    FCA   0,005      0,005                                               0EI
   1   1FCA VPU922-4-1/16       1   15  15                          15  15       1SI
   1   1FCA   1  1                       1  1                                    2SI
   1   1FCA                                                     0,919065         3SI
   1   1   1FCA   P92,129    91,879    91,959    92,393    91,360    92,400      1PI
   1   2   1FCA   P92,452    92,467    92,146    91,690    91,510    92,062      1PI
   1   3   1FCA   P92,341    91,350    91,547    91,130    92,235    92,106      1PI
   1   10  1FCA   P92,131    91,882    91,962    92,397    91,363    92,401      2PI
   1   11  1FCA   P92,453    92,431    92,164    91,694    91,516    92,064      2PI
   1   12  1FCA   P92,362    91,353    91,548    91,131    92,233    92,108      2PI
   1   19  1FCA   P,91968    ,91790    ,91886    ,91889    ,92000    ,91706      9PI
   1   20  1FCA   P,91790    ,91768    ,91834    ,92000    ,92000    ,91855      9PI
   1   21  1FCA   P,91847    ,92000    ,91887    ,92000    ,91887    ,91875      9PI
   1   28  1FCA   P,9134760  ,9204053  ,9234643  ,9201966  ,9222490  ,9174424    0PI
   1   29  1FCA   P,9160187  ,9243826  ,9211609  ,9192842  ,9220565  ,9258536    0PI
   1   30  1FCA   P,9241209  ,9176248  ,9129363  ,90044    ,93159    ,92268      0PI
   1   2FCA VPU922-2-1/16       1   11  11                          11  11       1SI
   1   2FCA   1  1                       1  1                                    2SI
   1   2FCA                                                     0,919276         3SI
   1   1   2FCA   P46,14     45,89     46,30     46,26     46,14     46,01       1PI
   1   2   2FCA   P46,22     46,28     46,17     45,96     45,93     46,01       1PI
   1   8   2FCA   P46,136    45,890    46,299    46,258    46,004    46,015      2PI
   1   9   2FCA   P46,217    46,285    46,172    45,953    45,929    46,011      2PI
   1   15  2FCA   P,9193     ,9193     ,9193     ,9200     ,9193     ,9193       9PI
   1   16  2FCA   P,9193     ,9200     ,9193     ,9193     ,9193     ,9200       9PI
   1   22  2FCA   P,9127403  ,9152388  ,9055415  ,9243034  ,9092007  ,9137022    0PI
   1   23  2FCA   P,9261045  ,9178689  ,9136857  ,9133125  ,9119421  ,87357      0PI
   1   3FCA VPU922-1-1/16       1   3   3                           3   3        1SI
   1   3FCA   1  1                       1  1                                    2SI
   1   3FCA                                                     0,918180         3SI
   1   1   3FCA   P22,365    22,351    22,396                                    1PI
   1   2   3FCA   P22,371    22,354    22,401                                    2PI
   1   3   3FCA   P,91788    ,91760    ,91834                                    9PI
   1   4   3FCA   P,9184465  ,9129824  ,9227683                                  0PI
```

Table 2  Sample Input for FACOM 230-75 (continued)

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

   1  4FCA VPU92EX221/16        1   3   3                         3   3     1SI
   1  4FCA   1  1                       1  1                                2SI
   1  4FCA                                                  0,918585        3SI
   1   1  4FCA  P39,381     39,554     39,379                               1PI
   1   2  4FCA  P39,395     39,566     39,391                               2PI
   1   3  4FCA  P,91996     ,91822     ,91996                               9PI
   1   4  4FCA  P,9240254   ,9210650   ,9166867                             0PI
   1  5FCA VPU812-2-1/16        1   3   3                         3   3     1SI
   1  5FCA   1  1                       1  1                                2SI
   1  5FCA                                                  0,813052        3SI
   1   1  5FCA  P51,69      51,53      51,36      51,42      51,76     51,61     1PI
   1   3  5FCA  P51,693     51,530     51,361     51,421     51,760    51,613    2PI
   1   5  5FCA  P,8130      ,8130      ,8130      ,8133      ,8130     ,8130     9PI
   1   7  5FCA  P,8080739   ,8207983   ,8019171   ,81292     ,82755    ,80251    0PI
   1  6FCA VPU812-1-1/16        1   3   3                         3   3     1SI
   1  6FCA   1  1                       1  1                                2SI
   1  6FCA                                                  0,813117        3SI
   1   1  6FCA  P26,34      26,47      26,35                                1PI
   1   2  6FCA  P26,339     26,465     26,354                               2PI
   1   3  6FCA  P,8130      ,8130      ,8130                                9PI
   1   4  6FCA  P,8232547   ,8070166   ,7974462                             0PI
   1  7FCA VPU752-2-1/16        1   3   3                         3   3     1SI
   1  7FCA   1  1                       1  1                                2SI
   1  7FCA                                                  0,756924        3SI
   1   1  7FCA  P54,47      54,56      54,77      54,32      54,50     54,54     1PI
   1   3  7FCA  P54,471     54,570     54,774     54,321     54,507    54,540    2PI
   1   5  7FCA  P,7569      ,7569      ,7569      ,7569      ,7569     ,7569     9PI
   1   7  7FCA  P,7530507   ,7484269   ,7706416   ,75675     ,76462    ,75970    0PI
FCA PIT EVALUATION, 1978-09-28 H,NISHIMURA                   INFR
FULL
                 1
0,05        0,05        0,05        0,05        0,05
FCA PIT EVALUATION, 1978-09-28 H,NISHIMURA                   INVR
    3     1
0,05
```

Table 3 Sample Output from the NPT-JAPAN System II Part II

```
                    FCA PII EVALUATION, 1978-09-28 H.NISHIMURA                      INS

JAERFCA FCA 780925   1  71   1  1  0  0  0  0  0  0  1  12     H.NISHIMURA      MI
 1   1  OFCA    1.00000E-03 1.00000E-03 0.0          0.0         0.0          0.0         1EI
 1   2  OFCA    1.00000E-03 1.00000E-03 0.0          0.0         0.0          0.0         2EI
 1   3  OFCA    5.00000E-03 5.00000E-03 0.0          0.0         0.0          0.0         9EI
 1   4  OFCA    5.00000E-03 5.00000E-03 0.0          0.0         0.0          0.0         0EI
 1  1FCA VPU922-4-1/16        1  15  15   0   0   0   0   0   0  15  15      1SI
 1  1FCA   1  1  0  0  0  0  0  0  1  1 0.0          0.0         0.0          0.0          0.0          2SI
 1  1FCA              0.0         0.0         0.0        9.19065E-01      3SI
 1   1  1FCA  P 9.21290E+01 9.18790E+01 9.19590E+01 9.23930E+01 9.13600E+01 9.24000E+011PI
 1   2  1FCA  P 9.24520E+01 9.24670E+01 9.21460E+01 9.16900E+01 9.15100E+01 9.20620E+011PI
 1   3  1FCA  P 9.23410E+01 9.13500E+01 9.15470E+01 9.11300E+01 9.22350E+01 9.21060E+011PI
 1  10  1FCA  P 9.21310E+01 9.18820E+01 9.19620E+01 9.23970E+01 9.13630E+01 9.24010E+012PI
 1  11  1FCA  P 9.24530E+01 9.24310E+01 9.21640E+01 9.16940E+01 9.15160E+01 9.20640E+012PI
 1  12  1FCA  P 9.23620E+01 9.13530E+01 9.15430E+01 9.11310E+01 9.22330E+01 9.21080E+012PI
 1  19  1FCA  P 9.19680E-01 9.17900E-01 9.18860E-01 9.18890E-01 9.20000E-01 9.17060E-019PI
 1  20  1FCA  P 9.17900E-01 9.17680E-01 9.18340E-01 9.20000E-01 9.20000E-01 9.18550E-019PI
 1  21  1FCA  P 9.18470E-01 9.20000E-01 9.18870E-01 9.20000E-01 9.18870E-01 9.18750E-019PI
 1  28  1FCA  P 9.13476E-01 9.20405E-01 9.23464E-01 9.20197E-01 9.22249E-01 9.17442E-010PI
 1  29  1FCA  P 9.16019E-01 9.24383E-01 9.21151E-01 9.19284E-01 9.22054E-01 9.25854E-010PI
 1  30  1FCA  P 9.24121E-01 9.17625E-01 9.12936E-01 9.00440E-01 9.31590E-01 9.22680E-010PI
 1  2FCA VPU922-2-1/16        1  11  11   0   0   0   0   0   0  11  11      1SI
 1  2FCA   1  1  0  0  0  0  0  0  1  1 0.0          0.0         0.0          0.0          0.0          2SI
 1  2FCA              0.0         0.0         0.0        9.19276E-01      3SI
 1   1  2FCA  P 4.61400E+01 4.58900E+01 4.63000E+01 4.62600E+01 4.61400E+01 4.60100E+011PI
 1   2  2FCA  P 4.62200E+01 4.62600E+01 4.61700E+01 4.59600E+01 4.59300E+01 4.60100E+011PI
 1   8  2FCA  P 4.61360E+01 4.58900E+01 4.62990E+01 4.62580E+01 4.60040E+01 4.60150E+012PI
 1   9  2FCA  P 4.62170E+01 4.62650E+01 4.61720E+01 4.59530E+01 4.59290E+01 4.60110E+012PI
 1  15  2FCA  P 9.19300E-01 9.19300E-01 9.19300E-01 9.20000E-01 9.19300E-01 9.19300E-019PI
 1  16  2FCA  P 9.19300E-01 9.20000E-01 9.19300E-01 9.19300E-01 9.19300E-01 9.20000E-019PI
 1  22  2FCA  P 9.12740E-01 9.15239E-01 9.05541E-01 9.24303E-01 9.09201E-01 9.13702E-010PI
 1  23  2FCA  P 9.26105E-01 9.17669E-01 9.13686E-01 9.13312E-01 9.11942E-01 8.73570E-010PI
 1  3FCA VPU922-1-1/16        1   3   3   0   0   0   0   0   0   3   3      1SI
 1  3FCA   1  1  0  0  0  0  0  0  1  1 0.0          0.0         0.0          0.0          0.0          2SI
 1  3FCA              0.0         0.0         0.0        9.18180E-01      3SI
 1   1  3FCA  P 2.23650E+01 2.23510E+01 2.23960E+01 0.0         0.0          0.0         1PI
 1   2  3FCA  P 2.23710E+01 2.23540E+01 2.24010E+01 0.0         0.0          0.0         2PI
 1   3  3FCA  P 9.17860E-01 9.17600E-01 9.18340E-01 0.0         0.0          0.0         9PI
 1   4  3FCA  P 9.18446E-01 9.12982E-01 9.22768E-01 0.0         0.0          0.0         0PI
 1  4FCA VPU92EK221/16        1   3   3   0   0   0   0   0   0   3   3      1SI
 1  4FCA   1  1  0  0  0  0  0  0  1  1 0.0          0.0         0.0          0.0          0.0          2SI
 1  4FCA              0.0         0.0         0.0        9.18585E-01      3SI
 1   1  4FCA  P 3.93810E+01 3.95540E+01 3.93790E+01 0.0         0.0          0.0         1PI
 1   2  4FCA  P 3.93950E+01 3.95660E+01 3.93910E+01 0.0         0.0          0.0         2PI
 1   3  4FCA  P 9.19960E-01 9.18220E-01 9.19960E-01 0.0         0.0          0.0         9PI
 1   4  4FCA  P 9.24025E-01 9.21065E-01 9.16687E-01 0.0         0.0          0.0         0PI
 1  5FCA VPU812-2-1/16        1   3   3   0   0   0   0   0   0   3   3      1SI
 1  5FCA   1  1  0  0  0  0  0  0  1  1 0.0          0.0         0.0          0.0          0.0          2SI
 1  5FCA              0.0         0.0         0.0        8.13052E-01      3SI
 1   1  5FCA  P 5.16900E+01 5.15300E+01 5.13600E+01 5.14200E+01 5.17600E+01 5.16100E+011PI
 1   3  5FCA  P 5.16930E+01 5.15300E+01 5.13610E+01 5.14210E+01 5.17600E+01 5.16130E+012PI
 1   5  5FCA  P 8.13000E-01 8.13000E-01 8.13000E-01 8.13300E-01 8.13000E-01 8.13000E-019PI
 1   7  5FCA  P 8.06074E-01 8.20798E-01 8.01917E-01 8.12920E-01 8.27550E-01 8.02510E-010PI
```

Table 3 Sample Output (continued)

```
1  6FCA VPU812-1-1/16        1   3   3   0   0   0   0   0   0   3   3       1SI
1  6FCA   1  1  0  0  0  0  0  0  1  1 0.0         0.0          0.0          0.0          0.0          2SI
1  6FCA              0.0          0.0          0.0          8.13117E-01     3SI
1   1  6FCA  P 2.63400E+01 2.64700E+01 2.63500E+01 0.0          0.0          0.0         1PI
1   2  6FCA  P 2.63390E+01 2.64650E+01 2.63540E+01 0.0          0.0          0.0         2PI
1   3  6FCA  P 8.13000E-01 8.13000E-01 8.13000E-01 0.0          0.0          0.0         9PI
1   4  6FCA  P 6.23255E-01 8.07017E-01 7.97446E-01 0.0          0.0          0.0         0PI
1  7FCA VPU752-2-1/16        1   3   3   0   0   0   0   0   0   3   3       1SI
1  7FCA   1  1  0  0  0  0  0  0  1  1 0.0         0.0          0.0          0.0          0.0          2SI
1  7FCA              0.0          0.0          0.0          7.56924E-01     3SI
1   1  7FCA  P 5.44700E+01 5.45600E+01 5.47700E+01 5.43200E+01 5.45000E+01 5.45400E+011PI
1   3  7FCA  P 5.44710E+01 5.45700E+01 5.47740E+01 5.43210E+01 5.45070E+01 5.45400E+012PI
1   5  7FCA  P 7.56900E-01 7.56900E-01 7.56900E-01 7.56900E-01 7.56900E-01 7.56900E-019PI
1   7  7FCA  P 7.53051E-01 7.48427E-01 7.70642E-01 7.56750E-01 7.64620E-01 7.59700E-010PI

             FCA PIT EVALUATION, 1978-09-28 H.NISHIMURA                     INFR

******************************************** PROBLEM NO.      1 ********************************************

MEASUREMENT OF WEIGHT
  MBA CODE NO.= FCA       KMP CODE NO.= V        TOTAL NUMBER OF PAIRED DATA SETS =     41      INFERENCE ABOUT MEAN DIFFERENCE = 1

  LEVEL OF SIGNIFICANCE (ALPHA) APPLIED FOR HYPOTHESIS TEST,H01,H02,H03,H04 AND H05
           0.50000E-01         0.50000E-01         0.50000E-01         0.50000E-01         0.50000E-01

  RANDOM AND SYSTEMATIC ERROR VARIANCES ASSIGNED BY SHIPPER(OPERATOR) AND RECEIVER(INSPECTOR)

           GROUP NO.      1                 SHIPPER      RECEIVER      SUM
           RANDOM ERROR VARIANCE            0.1000E-05   0.1000E-05   0.2000E-05
           SYSTEMATIC ERROR VARIANCE        0.1000E-05   0.1000E-05

           GROUP NO.      2                 SHIPPER      RECEIVER      SUM
           RANDOM ERROR VARIANCE            0.1000E-05   0.1000E-05   0.2000E-05
           SYSTEMATIC ERROR VARIANCE        0.1000E-05   0.1000E-05

           GROUP NO.      3                 SHIPPER      RECEIVER      SUM
           RANDOM ERROR VARIANCE            0.1000E-05   0.1000E-05   0.2000E-05
           SYSTEMATIC ERROR VARIANCE        0.1000E-05   0.1000E-05

           GROUP NO.      4                 SHIPPER      RECEIVER      SUM
           RANDOM ERROR VARIANCE            0.1000E-05   0.1000E-05   0.2000E-05
           SYSTEMATIC ERROR VARIANCE        0.1000E-05   0.1000E-05

           GROUP NO.      5                 SHIPPER      RECEIVER      SUM
           RANDOM ERROR VARIANCE            0.1000E-05   0.1000E-05   0.2000E-05
           SYSTEMATIC ERROR VARIANCE        0.1000E-05   0.1000E-05

           GROUP NO.      6                 SHIPPER      RECEIVER      SUM
           RANDOM ERROR VARIANCE            0.1000E-05   0.1000E-05   0.2000E-05
           SYSTEMATIC ERROR VARIANCE        0.1000E-05   0.1000E-05
```

Table 3 Sample Output (continued)

| | | SHIPPER | RECEIVER | SUM |
|---|---|---|---|---|
| GROUP NO. | 7 | | | |
| RANDOM ERROR VARIANCE | | 0.1000E-05 | 0.1000E-05 | 0.2000E-05 |
| SYSTEMATIC ERROR VARIANCE | | 0.1000E-05 | 0.1000E-05 | |

LIST OF MEASUREMENT INSTRUMENT NUMBERS

| | | | | |
|---|---|---|---|---|
| GROUP | 1 | SCALE NO. OF OPERATOR 1 | SCALE NO. OF INSPECTOR | 2 |
| GROUP | 2 | SCALE NO. OF OPERATOR 1 | SCALE NO. OF INSPECTOR | 2 |
| GROUP | 3 | SCALE NO. OF OPERATOR 1 | SCALE NO. OF INSPECTOR | 2 |
| GROUP | 4 | SCALE NO. OF OPERATOR 1 | SCALE NO. OF INSPECTOR | 2 |
| GROUP | 5 | SCALE NO. OF OPERATOR 1 | SCALE NO. OF INSPECTOR | 2 |
| GROUP | 6 | SCALE NO. OF OPERATOR 1 | SCALE NO. OF INSPECTOR | 2 |
| GROUP | 7 | SCALE NO. OF OPERATOR 1 | SCALE NO. OF INSPECTOR | 2 |

SHIPPER AND RECEIVER DATA

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| SHIPPER | 0.921290E+02 | 0.918790E+02 | 0.919590E+02 | 0.923930E+02 | 0.913600E+02 | 0.924000E+02 | 0.924520E+02 | 0.924670E+02 |
| RECEIVER | 0.921310E+02 | 0.918820E+02 | 0.919620E+02 | 0.923970E+02 | 0.913630E+02 | 0.924010E+02 | 0.924530E+02 | 0.924310E+02 |
| DIFFERENCE | -0.217175E-02 | -0.326545E-02 | -0.326261E-02 | -0.432902E-02 | -0.328400E-02 | -0.108166E-02 | -0.108105E-02 | 0.389320E-01 |

| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|
| SHIPPER | 0.921460E+02 | 0.916900E+02 | 0.915100E+02 | 0.920620E+02 | 0.923410E+02 | 0.913500E+02 | 0.915470E+02 | 0.461400E+02 |
| RECEIVER | 0.921640E+02 | 0.916940E+02 | 0.915160E+02 | 0.920640E+02 | 0.923620E+02 | 0.913530E+02 | 0.915480E+02 | 0.461360E+02 |
| DIFFERENCE | -0.195338E-01 | -0.436221E-02 | -0.655723E-02 | -0.217126E-02 | -0.227417E-01 | -0.328436E-02 | -0.109174E-02 | 0.867071E-02 |

| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|
| SHIPPER | 0.458900E+02 | 0.463000E+02 | 0.462600E+02 | 0.461400E+02 | 0.460100E+02 | 0.462200E+02 | 0.462800E+02 | 0.461700E+02 |
| RECEIVER | 0.458900E+02 | 0.462990E+02 | 0.462580E+02 | 0.460040E+02 | 0.460150E+02 | 0.462170E+02 | 0.462850E+02 | 0.461720E+02 |
| DIFFERENCE | 0.0 | 0.216070E-02 | 0.432308E-02 | 0.294756E+00 | -0.108675E-01 | 0.649126E-02 | -0.108041E-01 | -0.433150E-02 |

| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
|---|---|---|---|---|---|---|---|---|
| SHIPPER | 0.459600E+02 | 0.459300E+02 | 0.223650E+02 | 0.223510E+02 | 0.223960E+02 | 0.393810E+02 | 0.395540E+02 | 0.393790E+02 |
| RECEIVER | 0.459530E+02 | 0.459290E+02 | 0.223710E+02 | 0.223540E+02 | 0.224010E+02 | 0.393950E+02 | 0.395660E+02 | 0.393910E+02 |
| DIFFERENCE | 0.152306E-01 | 0.217811E-02 | -0.268278E-01 | -0.134234E-01 | -0.223259E-01 | -0.355524E-01 | -0.303385E-01 | -0.304733E-01 |

| | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|
| SHIPPER | 0.516900E+02 | 0.515300E+02 | 0.513600E+02 | 0.263400E+02 | 0.264700E+02 | 0.263500E+02 | 0.544700E+02 | 0.545600E+02 |
| RECEIVER | 0.516930E+02 | 0.515300E+02 | 0.513610E+02 | 0.263390E+02 | 0.264650E+02 | 0.263540E+02 | 0.544710E+02 | 0.545700E+02 |
| DIFFERENCE | -0.580433E-02 | 0.0 | -0.194783E-02 | 0.379623E-02 | 0.188879E-01 | -0.151810E-01 | -0.183486E-02 | -0.183271E-01 |

| | 41 |
|---|---|
| SHIPPER | 0.547700E+02 |
| RECEIVER | 0.547740E+02 |
| DIFFERENCE | -0.730274E-02 |

INPUT DATA SHOULD BE ANALIZED WITHOUT THEIR RE-ARRANGEMENT.

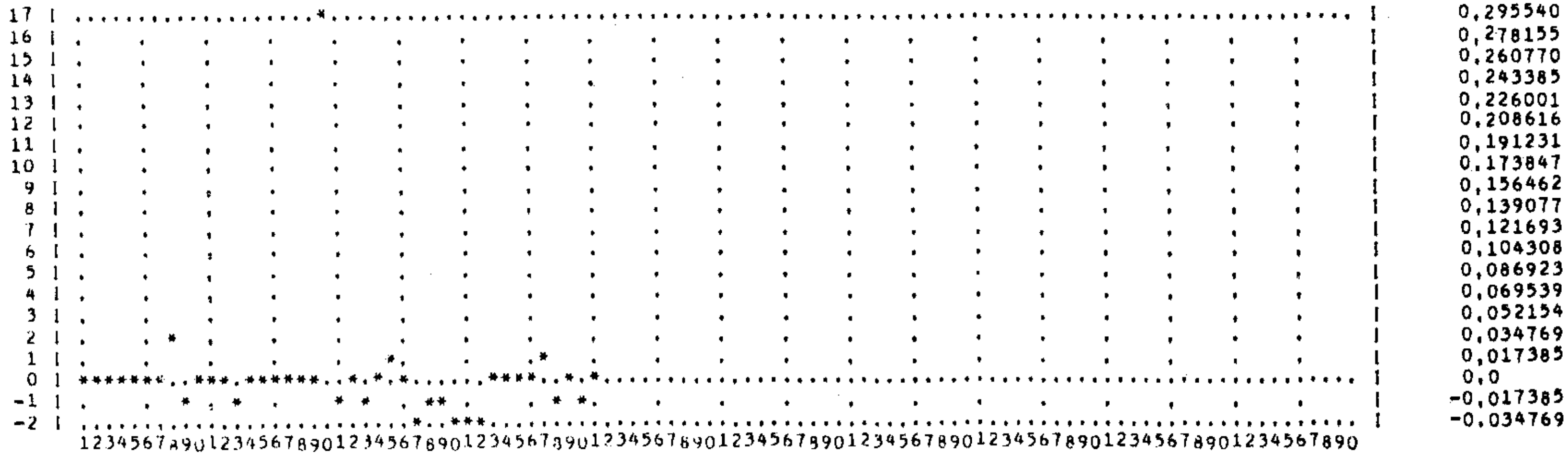
Table 3 Sample Output (continued)

```
NUMBER OF GROUPS     BOUNDARY NUMBER
       7                  15     26     29     32     35     38     41

 NUMBER OF DATA INCLUDED IN EACH GROUP
        1     2     3     4     5     6     7
       15    11     3     3     3     3     3


 SHIPPER AND RECEIVER DATA AFTER RE-ARRANGEMENT

                       1              2              3              4              5              6              7              8
  SHIPPER     0.223510E+02   0.223650E+02   0.223960E+02   0.263400E+02   0.263500E+02   0.264700E+02   0.393790E+02   0.393810E+02
  RECEIVER    0.223540E+02   0.223710E+02   0.224010E+02   0.263390E+02   0.263540E+02   0.264650E+02   0.393910E+02   0.393950E+02
 DIFFERENCE  -0.134234E-01  -0.268278E-01  -0.223259E-01   0.379623E-02  -0.151810E-01   0.188879E-01  -0.304733E-01  -0.355524E-01

                       9             10             11             12             13             14             15             16
  SHIPPER     0.395540E+02   0.458900E+02   0.459300E+02   0.459600E+02   0.461400E+02   0.460100E+02   0.461400E+02   0.461700E+02
  RECEIVER    0.395660E+02   0.458900E+02   0.459290E+02   0.459530E+02   0.460040E+02   0.460150E+02   0.461360E+02   0.461720E+02
 DIFFERENCE  -0.303385E-01   0.0            0.217811E-02   0.152306E-01   0.294756E+00  -0.108675E-01   0.867071E-02  -0.433150E-02

                      17             18             19             20             21             22             23             24
  SHIPPER     0.462200E+02   0.462600E+02   0.462800E+02   0.463000E+02   0.513600E+02   0.515300E+02   0.516900E+02   0.544700E+02
  RECEIVER    0.462170E+02   0.462580E+02   0.462850E+02   0.462990E+02   0.513610E+02   0.515300E+02   0.516930E+02   0.544710E+02
 DIFFERENCE   0.649126E-02   0.432308E-02  -0.108041E-01   0.216070E-02  -0.194783E-02   0.0           -0.580433E-02  -0.183486E-02

                      25             26             27             28             29             30             31             32
  SHIPPER     0.545600E+02   0.547700E+02   0.913500E+02   0.913600E+02   0.915100E+02   0.915470E+02   0.916900E+02   0.918790E+02
  RECEIVER    0.545700E+02   0.547740E+02   0.913530E+02   0.913630E+02   0.915160E+02   0.915480E+02   0.916940E+02   0.918820E+02
 DIFFERENCE  -0.183271E-01  -0.730274E-02  -0.328436E-02  -0.328400E-02  -0.655723E-02  -0.109174E-02  -0.436221E-02  -0.326545E-02

                      33             34             35             36             37             38             39             40
  SHIPPER     0.919590E+02   0.920620E+02   0.921290E+02   0.921460E+02   0.923410E+02   0.923930E+02   0.924000E+02   0.924670E+02
  RECEIVER    0.919620E+02   0.920640E+02   0.921310E+02   0.921640E+02   0.923620E+02   0.923970E+02   0.924010E+02   0.924310E+02
 DIFFERENCE  -0.326261E-02  -0.217126E-02  -0.217175E-02  -0.195338E-01  -0.227417E-01  -0.432902E-02  -0.108166E-02   0.389320E-01

                      41
  SHIPPER     0.924520E+02
  RECEIVER    0.924530E+02
 DIFFERENCE  -0.108105E-02
```

Table 3. Sample Output (continued)

PLOTTING OF SHIPPER - RECEIVER DIFFERENCES

(1) SR/D ARE PLOTTED AGAINST THE ORDER OF THE INPUT DATA
THE DATA FROM 1 TO 41 ARE INCLUDED.




(2) SR/D ARE PLOTTED AGAINST THE RECEIVER DATA (R)

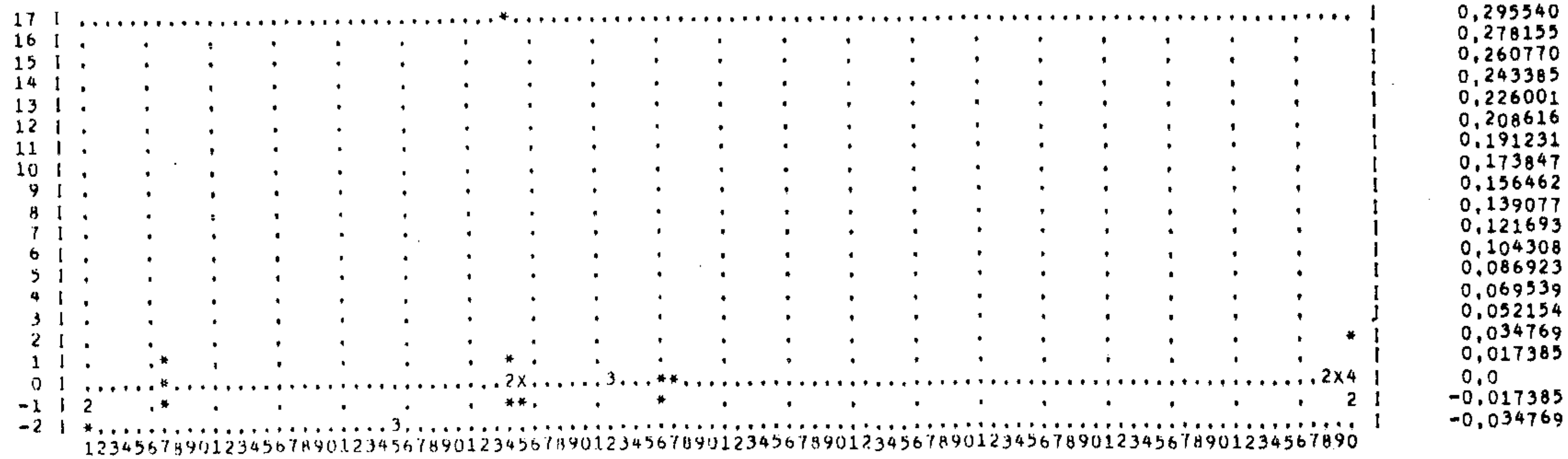


Table 3 Sample Output (continued)

STATISTICAL INFERENCES ON PAIRED DATA SETS WITH MULTI-GROUP

DATA GROUPS

GROUP 1

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| SHIPPER | 0.921290E+02 | 0.918790E+02 | 0.919590E+02 | 0.923930E+02 | 0.913600E+02 | 0.924000E+02 | 0.924520E+02 | 0.924670E+02 |
| RECEIVER | 0.921310E+02 | 0.918820E+02 | 0.919620E+02 | 0.923970E+02 | 0.913630E+02 | 0.924010E+02 | 0.924530E+02 | 0.924310E+02 |
| DIFFERENCE | -0.200081E-02 | -0.300026E-02 | -0.300026E-02 | -0.399971E-02 | -0.300026E-02 | -0.999451E-03 | -0.999451E-03 | 0.359993E-01 |

| | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|
| SHIPPER | 0.921460E+02 | 0.916900E+02 | 0.915100E+02 | 0.920620E+02 | 0.923410E+02 | 0.913500E+02 | 0.915470E+02 |
| RECEIVER | 0.921640E+02 | 0.916940E+02 | 0.915160E+02 | 0.920640E+02 | 0.923620E+02 | 0.913530E+02 | 0.915480E+02 |
| DIFFERENCE | -0.179996E-01 | -0.399971E-02 | -0.600052E-02 | -0.199890E-02 | -0.209999E-01 | -0.300026E-02 | -0.999451E-03 |

GROUP 2

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| SHIPPER | 0.461400E+02 | 0.458900E+02 | 0.463000E+02 | 0.462600E+02 | 0.461400E+02 | 0.460100E+02 | 0.462200E+02 | 0.462800E+02 |
| RECEIVER | 0.461360E+02 | 0.458900E+02 | 0.462990E+02 | 0.462580E+02 | 0.460040E+02 | 0.460150E+02 | 0.462170E+02 | 0.462850E+02 |
| DIFFERENCE | 0.400066E-02 | 0.0 | 0.100040E-02 | 0.199986E-02 | 0.136001E+00 | -0.500011E-02 | 0.300026E-02 | -0.500011E-02 |

| | 9 | 10 | 11 |
|---|---|---|---|
| SHIPPER | 0.461700E+02 | 0.459600E+02 | 0.459300E+02 |
| RECEIVER | 0.461720E+02 | 0.459530E+02 | 0.459290E+02 |
| DIFFERENCE | -0.199986E-02 | 0.699997E-02 | 0.100040E-02 |

GROUP 3

| | 1 | 2 | 3 |
|---|---|---|---|
| SHIPPER | 0.223650E+02 | 0.223510E+02 | 0.223960E+02 |
| RECEIVER | 0.223710E+02 | 0.223540E+02 | 0.224010E+02 |
| DIFFERENCE | -0.600004E-02 | -0.300026E-02 | -0.500011E-02 |

GROUP 4

| | 1 | 2 | 3 |
|---|---|---|---|
| SHIPPER | 0.393810E+02 | 0.395540E+02 | 0.393790E+02 |
| RECEIVER | 0.393950E+02 | 0.395660E+02 | 0.393910E+02 |
| DIFFERENCE | -0.140009E-01 | -0.120001E-01 | -0.120001E-01 |

GROUP 5

| | 1 | 2 | 3 |
|---|---|---|---|
| SHIPPER | 0.516900E+02 | 0.515300E+02 | 0.513600E+02 |
| RECEIVER | 0.516930E+02 | 0.515300E+02 | 0.513610E+02 |
| DIFFERENCE | -0.300026E-02 | 0.0 | -0.100040E-02 |

Table 3 Sample Output (continued)

GROUP 6

| | 1 | 2 | 3 |
|---|---|---|---|
| SHIPPER | 0.263400E+02 | 0.264700E+02 | 0.263500E+02 |
| RECEIVER | 0.263390E+02 | 0.264650E+02 | 0.263540E+02 |
| DIFFERENCE | 0.999928E-03 | 0.499964E-02 | -0.400019E-02 |

GROUP 7

| | 1 | 2 | 3 |
|---|---|---|---|
| SHIPPER | 0.544700E+02 | 0.545600E+02 | 0.547700E+02 |
| RECEIVER | 0.544710E+02 | 0.545700E+02 | 0.547740E+02 |
| DIFFERENCE | -0.499451E-03 | -0.999926E-02 | -0.399971E-02 |

SAMPLE AVERAGE(AVS,AVR), VARIANCES(SS2,SR2), COVARIANCES(SSR)

| GROUP | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| AVS | 0.919790E+02 | 0.461182E+02 | 0.223707E+02 | 0.394380E+02 | 0.515267E+02 | 0.263867E+02 | 0.546000E+02 |
| AVR | 0.919814E+02 | 0.461053E+02 | 0.223753E+02 | 0.394507E+02 | 0.515280E+02 | 0.263860E+02 | 0.546050E+02 |
| SS2 | 0.162724E+00 | 0.217563E-01 | 0.530336E-03 | 0.100930E-01 | 0.272333E-01 | 0.523331E-02 | 0.237000E-01 |
| SR2 | 0.161095E+00 | 0.230044E-01 | 0.566333E-03 | 0.998032E-02 | 0.275590E-01 | 0.473700E-02 | 0.238711E-01 |
| SSR | 0.161835E+00 | 0.215405E-01 | 0.547166E-03 | 0.100360E-01 | 0.273950E-01 | 0.497499E-02 | 0.237751E-01 |

********* HYPOTHESIS TESTS *********

(1) HYPOTHESIS H01-1 TEST ( H01-1,VRSE IS LESS THAN OR EQUAL TO VRRE / H11-1,VRSE IS GREATER THAN VRRE)

OBSERVED STATISTIC P = 0.1146066E+02
CRITICAL VALUE OF STATISTIC P = 0.2368479D+02 WITH 14 DEGREES OF FREEDOM AT THE 0.050 LEVEL OF SIGNIFICANCE

H01-1 IS NOT REJECTED, THEN PROCEED H01-2 TEST

(2) HYPOTHESIS H01-2 TEST ( H01-2,VRRE IS LESS THAN OR EQUAL TO VRSE / H11-2,VRRE IS GREATER THAN VRSE)

OBSERVED STATISTIC P = 0.1020281E+02
CRITICAL VALUE OF STATISTIC P = 0.2368479D+02 WITH 14 DEGREES OF FREEDOM AT THE 0.050 LEVEL OF SIGNIFICANCE

H01-2 IS NOT REJECTED, THE CONCLUSION IS THAT THE HYPOTHESIS (VRSE=VRRE) IS CONSISTENT WITH THE DATA,
ESTIMATED RANDOM ERROR VARIANCES ARE THEN,

| | GROUP 1 | GROUP 2 | GROUP 3 | GROUP 4 | GROUP 5 | GROUP 6 |
|---|---|---|---|---|---|---|
| VRSE | 0.8820781E-08 | 0.3948736E-06 | 0.2330910E-08 | 0.4288792E-09 | 0.4395286E-09 | 0.1460157E-07 |
| VRRE | 0.8820781E-08 | 0.3948736E-06 | 0.2330910E-08 | 0.4288792E-09 | 0.4395286E-09 | 0.1460157E-07 |

| | GROUP 7 | GROUP |
|---|---|---|
| VRSE | 0.3521872E-08 | |
| VRRE | 0.3521872E-08 | |

Table 3 Sample Output (continued)

```
(3)    HYPOTHESIS H02-1 TEST   ( H02-1,(VRSE+VRRE) IS LESS THAN OR EQUAL TO VRM / H12-1,(VRSE+VRRE) IS GREATER THAN VRM)

***TARGET VALUE ROU**2 =  0.2243433E+01  AND CRITICAL VALUE R1 FOR ALTERNATIVE HYPOTHESIS =  0.1090362E+03
       OBSERVED STATISTIC    P =  0.4114872E+01
       CRITICAL VALUE OF STATISTIC   R =  0.4860237D+02  WITH   34 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

       H02-1 IS NOT REJECTED. THEN PROCEED H02-2 TEST

(4)    HYPOTHESIS H02-2 TEST   ( H02-2,(VRSE+VRRE) IS GREATER THAN OR EQUAL TO VRM / H12-2,(VRSE+VRRE) IS LESS THAN VRM)

       OBSERVED STATISTIC    R =  0.4114872E+01
       CRITICAL VALUE OF STATISTIC   R =  0.2166420D+02  WITH   34 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

       H02-2 IS REJECTED, THE CONCLUSION IS THAT (VRSE+VRRE) IS LESS THAN VRM.
           ESTIMATED RANDOM ERROR VARIANCES ARE THEN,

                 GROUP  1          GROUP  2          GROUP  3          GROUP  4          GROUP  5          GROUP  6
          VRSE   0.8820781E-08     0.3948736E-06     0.2330910E-08     0.4288792E-09     0.4395286E-09     0.1460157E-07
          VRRE   0.8820781E-08     0.3948736E-06     0.2330910E-08     0.4288792E-09     0.4395286E-09     0.1460157E-07

                 GROUP  7          GROUP
          VRSE   0.3521872E-08
          VRRE   0.3521872E-08

(5)    HYPOTHESIS H04-1 TEST   ( H04-1,VRRE IS EQUAL TO VRR / H14-1,VRRE IS GREATER OR LESS THAN VRR)

*****NEGATIVE FIX-UP TAKEN AT GROUP  1, SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.1923420E-04
*****NEGATIVE FIX-UP TAKEN AT GROUP  2, SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.1022920E-04
*****NEGATIVE FIX-UP TAKEN AT GROUP  3, SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.1059724E-05
*****NEGATIVE FIX-UP TAKEN AT GROUP  4, SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.6489210E-05
*****NEGATIVE FIX-UP TAKEN AT GROUP  5, SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.1025738E-04
*****NEGATIVE FIX-UP TAKEN AT GROUP  6, SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.7516360E-05
*****NEGATIVE FIX-UP TAKEN AT GROUP  7, SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.7949934E-05
       OBSERVED STATISTIC  LAMDA4 =  0.1218067E+03
       CRITICAL VALUE OF STATISTIC  LAMDA4=  0.1406714D+02 WITH   7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

       H04-1 IS REJECTED. THE CONCLUSION IS THAT VRRE IS GREATER OR LESS THAN VRR.
           ESTIMATED RANDOM ERROR VARIANCES ARE THEN,

                 GROUP  1          GROUP  2          GROUP  3          GROUP  4          GROUP  5          GROUP  6
          VRSE   0.8820781E-08     0.3948736E-06     0.2330910E-08     0.4288792E-09     0.4395286E-09     0.1460157E-07
          VRRE   0.8820781E-08     0.3948736E-06     0.2330910E-08     0.4288792E-09     0.4395286E-09     0.1460157E-07

                 GROUP  7          GROUP
          VRSE   0.3521872E-08
          VRRE   0.3521872E-08
```

Table 3 Sample Output (continued)

```
(6)   HYPOTHESIS HO4-2 TEST   ( HO4-2.VRSE IS EQUAL TO VRS / H14-2.VRSE IS GREATER OR LESS THAN VRS)

*****NEGATIVE FIX-UP TAKEN AT GROUP  1. SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.1904160E-04
*****NEGATIVE FIX-UP TAKEN AT GROUP  2. SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.1081600E-04
*****NEGATIVE FIX-UP TAKEN AT GROUP  3. SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.1131654E-05
*****NEGATIVE FIX-UP TAKEN AT GROUP  4. SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.6416743E-05
*****NEGATIVE FIX-UP TAKEN AT GROUP  5. SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.1038003E-04
*****NEGATIVE FIX-UP TAKEN AT GROUP  6. SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.6803528E-05
*****NEGATIVE FIX-UP TAKEN AT GROUP  7. SO THAT VRSE(OR VRRE)= 0.0          AND VRXE= 0.8007311E-05
          OBSERVED STATISTIC  LAMDA4 =  0.1221910E+03
          CRITICAL VALUE OF STATISTIC  LAMDA4=   0.1406714D+02 WITH   7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

          HO4-2 IS REJECTED. THE CONCLUSION IS THAT VRSE IS GREATER OR LESS THAN VRS.
             ESTIMATED RANDOM ERROR VARIANCES ARE THEN.

                   GROUP  1        GROUP  2        GROUP  3        GROUP  4        GROUP  5        GROUP  6
             VRSE  0.8820781E-08   0.3948736E-06   0.2330910E-08   0.4288792E-09   0.4395286E-09   0.1460157E-07
             VRRE  0.8820781E-08   0.3948736E-06   0.2330910E-08   0.4288792E-09   0.4395286E-09   0.1460157E-07

                   GROUP  7        GROUP
             VRSE  0.3521872E-06
             VRRE  0.3521872E-08


   EVALUATED ESTIMATES OF THE RANDOM ERROR VARIANCES AND THEIR STANDARD DEVIATIONS OF EACH DATA GROUP

                   GROUP  1        GROUP  2        GROUP  3        GROUP  4        GROUP  5        GROUP  6
             VRSE  0.8820781E-08   0.3948736E-06   0.2330910E-08   0.4288792E-09   0.4395286E-09   0.1460157E-07
              S.D  0.9391902E-04   0.6283897E-03   0.4827949E-04   0.2070940E-04   0.2096494E-04   0.1208370E-03
             VRRE  0.8820781E-08   0.3948736E-06   0.2330910E-08   0.4288792E-09   0.4395286E-09   0.1460157E-07
              S.D  0.9391902E-04   0.6283897E-03   0.4827949E-04   0.2070940E-04   0.2096494E-04   0.1208370E-03

                   GROUP  7        GROUP
             VRSE  0.3521872E-08
              S.D  0.5934536E-04
             VRRE  0.3521872E-08
              S.D  0.5934536E-04


   FINAL ESTIMATES OF THE RANDOM ERROR VARIANCES AND STANDARD DEVIATIONS AVERAGED OVER THE DATA SET GROUPS

             FOR THE SHIPPER      VARIANCE =  0.6064774E-07        STANDARD DEVIATION =  0.2462676E-03
             FOR THE RECEIVER     VARIANCE =  0.6064774E-07        STANDARD DEVIATION =  0.2462676E-03
```

Table 3 Sample Output (continued)

```
FINAL ESTIMATE OF THE COMBINED SYSTEMATIC ERROR VARIANCE (VSS+VSR)

***FOR THE ESTIMATION OF SYSTEMATIC ERROR VARIANCE, THE ASSIGNED RANDOM ERROR VARIANCES ARE USED.

     FOR THE SHIPPER        VARIANCE =  0.6064774E-07           STANDARD DEVIATION =  0.2462676E-03
     FOR THE RECEIVER       VARIANCE =  0.6064774E-07           STANDARD DEVIATION =  0.2462676E-03

     COMBINED SYSTEMATIC    VARIANCE =  0.0                     STANDARD DEVIATION =  0.0

( 7)   HYPOTHESIS H06-1 TEST   ( H06-1,(VSSE+VSRE) IS LESS THAN OR EQUAL TO VSM / H16-1,(VSSE+VSRE) IS GREATER THAN VSM)

***TARGET VALUE ROU**2 =  0.6490480E+01  AND CRITICAL VALUE R1 FOR ALTERNATIVE HYPOTHESIS =  0.9130249E+02
       OBSERVED STATISTIC    R =  0.0
       CRITICAL VALUE OF STATISTIC   R =  0.1406714D+02  WITH    7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

       H06-1 IS NOT REJECTED. THEN PROCEED H06-2 TEST

( 8)   HYPOTHESIS H06-2 TEST   ( H06-2,(VSSE+VSRE) IS GREATER THAN OR EQUAL TO VSM / H16-2,(VSSE+VSRE) IS LESS THAN VSM)

       OBSERVED STATISTIC    R =  0.0
       CRITICAL VALUE OF STATISTIC   R =  0.2167350D+01  WITH    7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

       H06-2 IS REJECTED. THE CONCLUSION IS THAT (VSSE+VSRE) IS LESS THAN VSM.

( 9)   HYPOTHESIS H05 TEST   ( H05,AVS IS EQUAL TO AVR / H15,AVS IS NOT EQUAL TO AVR)

       BASED ON ESTIMATED ERRORS

                 GROUP  1          GROUP  2          GROUP  3          GROUP  4          GROUP  5          GROUP  6
    AVS-AVR   -0.2401352E-02     0.1290798E-01    -0.4667282E-02    -0.1266766E-01    -0.1334190E-02     0.6666183E-03
      SIG-D    0.8992422E-04     0.1050089E-03     0.2010767E-03     0.2010767E-03     0.2010767E-03     0.2010767E-03
          Z    0.2903290E+00     0.2665386E+01     0.1037584E+01     0.1597422E+01     0.1287728E+00     0.1256409E+00
  Z(1-AL/2)    0.1959964D+01     0.1959964D+01     0.1959964D+01     0.1959964D+01     0.1959964D+01     0.1959964D+01
       TEST        NOTR              RJCT              NOTR              NOTR              NOTR              NOTR

                 GROUP  7          GROUP
    AVS-AVR   -0.4999161E-02
      SIG-D    0.2010767E-03
          Z    0.4553473E+00
  Z(1-AL/2)    0.1959964D+01
       TEST        NOTR
```

Table 3 Sample Output (continued)

```
 BASED ON DESIGN VALUES OF ERRORS
                GROUP  1        GROUP  2        GROUP  3        GROUP  4        GROUP  5        GROUP  6
  AVS-AVR   -0.2401352E-02  0.1290798E-01  -0.4667287E-02  -0.1266766E-01  -0.1334190E-02  0.6666183E-03
    SIG-D    0.1460593E-02  0.1477098E-02   0.1632993E-02   0.1632993E-02   0.1632993E-02  0.1632993E-02
        Z    0.1787466E-01  0.1894859E+00   0.1277617E+00   0.1966967E+00   0.1585628E-01  0.1547064E-01
Z(1-AL/2)    0.1959964D+01  0.1959964D+01   0.1959964D+01   0.1959964D+01   0.1959964D+01  0.1959964D+01
     TEST       NOTR           NOTR            NOTR            NOTR            NOTR           NOTR

                GROUP  7        GROUP
  AVS-AVR   -0.4999161E-02
    SIG-D    0.1632993E-02
        Z    0.5606865E-01
Z(1-AL/2)    0.1959964D+01
     TEST       NOTR
***FOR THE ESTIMATION OF SYSTEMATIC ERROR VARIANCE, THE ASSIGNED RANDOM ERROR VARIANCES ARE NOT USED.

      THE RANDOM ERROR VARIANCES DERIVED FROM THE OBSERVED DATA (SS2, SR2, SSR)

      FOR THE SHIPPER        VARIANCE =  0.6064774E-07         STANDARD DEVIATION =  0.2462676E-03
      FOR THE RECEIVER       VARIANCE =  0.6064774E-07         STANDARD DEVIATION =  0.2462676E-03

      COMBINED SYSTEMATIC    VARIANCE =  0.0                   STANDARD DEVIATION =  0.0

( 7)   HYPOTHESIS H06-1 TEST   ( H06-1,(VSSE+VSRE) IS LESS THAN OR EQUAL TO VSM / H16-1,(VSSE+VSRE) IS GREATER THAN VSM)

***TARGET VALUE ROU**2 =  0.6490480E+01  AND CRITICAL VALUE R1 FOR ALTERNATIVE HYPOTHESIS =  0.9130249E+02
       OBSERVED STATISTIC    R =  0.0
       CRITICAL VALUE OF STATISTIC    R =  0.1406714D+02  WITH    7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

       H06-1 IS NOT REJECTED. THEN PROCEED H06-2 TEST

( 8)   HYPOTHESIS H06-2 TEST   ( H06-2,(VSSE+VSRE) IS GREATER THAN OR EQUAL TO VSM / H16-2,(VSSE+VSRE) IS LESS THAN VSM)

       OBSERVED STATISTIC    R =  0.0
       CRITICAL VALUE OF STATISTIC    R =  0.2167350D+01  WITH    7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

       H06-2 IS REJECTED, THE CONCLUSION IS THAT (VSSE+VSRE) IS LESS THAN VSM.
```

Table 3 Sample Output (continued)

( 9) HYPOTHESIS H05 TEST ( H05,AVS IS EQUAL TO AVR / H15,AVS IS NOT EQUAL TO AVR)

BASED ON ESTIMATED ERRORS

| | GROUP 1 | GROUP 2 | GROUP 3 | GROUP 4 | GROUP 5 | GROUP 6 |
|---|---|---|---|---|---|---|
| AVS-AVR | -0.2401352E-02 | 0.1290798E-01 | -0.4667282E-02 | -0.1266766E-01 | -0.1334190E-02 | 0.6666183E-03 |
| SIG-D | 0.8992422E-04 | 0.1050089E-03 | 0.2010767E-03 | 0.2010767E-03 | 0.2010767E-03 | 0.2010767E-03 |
| Z | 0.2903290E+00 | 0.2665366E+01 | 0.1037584E+01 | 0.1597422E+01 | 0.1287728E+00 | 0.1256409E+00 |
| Z(1-AL/2) | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 |
| TEST | NOTR | RJCT | NOTR | NOTR | NOTR | NOTR |

| | GROUP 7 | GROUP |
|---|---|---|
| AVS-AVR | -0.4999161E-02 | |
| SIG-D | 0.2010767E-03 | |
| Z | 0.4553473E+00 | |
| Z(1-AL/2) | 0.1959964D+01 | |
| TEST | NOTR | |

BASED ON DESIGN VALUES OF ERRORS

| | GROUP 1 | GROUP 2 | GROUP 3 | GROUP 4 | GROUP 5 | GROUP 6 |
|---|---|---|---|---|---|---|
| AVS-AVR | -0.2401352E-02 | 0.1290798E-01 | -0.4667282E-02 | -0.1266766E-01 | -0.1334190E-02 | 0.6666183E-03 |
| SIG-D | 0.1460593E-02 | 0.1477098E-02 | 0.1632993E-02 | 0.1632993E-02 | 0.1632993E-02 | 0.1632993E-02 |
| Z | 0.1787466E-01 | 0.1894859E+00 | 0.1277617E+00 | 0.1966967E+00 | 0.1585628E-01 | 0.1547064E-01 |
| Z(1-AL/2) | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 |
| TEST | NOTR | NOTR | NOTR | NOTR | NOTR | NOTR |

| | GROUP 7 | GROUP |
|---|---|---|
| AVS-AVR | -0.4999161E-02 | |
| SIG-D | 0.1632993E-02 | |
| Z | 0.5606865E-01 | |
| Z(1-AL/2) | 0.1959964D+01 | |
| TEST | NOTR | |

FINAL ESTIMATES OF THE RANDOM ERROR VARIANCES FOR EACH SCALE

| REPORT NO. | MBA | WEI | NO. OF SCALE |
|---|---|---|---|
| 1 | FCA | 1 | 2 |

THE SCALE NO. 1 VARIANCE 0.6064774E-07
THE SCALE NO. 2 VARIANCE 0.6064774E-07

Table 3 Sample Output (continued)

```
MEASUREMENT OF ELEMENT FACTOR


MEASUREMENT OF ISOTOPE FACTOR
  MBA CODE NO.= FCA        KMP CODE NO.= V        TOTAL NUMBER OF PAIRED DATA SETS =      41      INFERENCE ABOUT MEAN DIFFERENCE = 1

  LEVEL OF SIGNIFICANCE (ALPHA) APPLIED FOR HYPOTHESIS TEST,H01,H02,H03,H04 AND H05
           0.50000E-01          0.50000E-01          0.50000E-01          0.50000E-01          0.50000E-01

  RANDOM AND SYSTEMATIC ERROR VARIANCES ASSIGNED BY SHIPPER(OPERATOR) AND RECEIVER(INSPECTOR)

           GROUP NO.      1                   SHIPPER     RECEIVER      SUM
           RANDOM ERROR VARIANCE              0.2500E-04  0.2500E-04  0.5000E-04
           SYSTEMATIC ERROR VARIANCE          0.2500E-04  0.2500E-04

           GROUP NO.      2                   SHIPPER     RECEIVER      SUM
           RANDOM ERROR VARIANCE              0.2500E-04  0.2500E-04  0.5000E-04
           SYSTEMATIC ERROR VARIANCE          0.2500E-04  0.2500E-04

           GROUP NO.      3                   SHIPPER     RECEIVER      SUM
           RANDOM ERROR VARIANCE              0.2500E-04  0.2500E-04  0.5000E-04
           SYSTEMATIC ERROR VARIANCE          0.2500E-04  0.2500E-04

           GROUP NO.      4                   SHIPPER     RECEIVER      SUM
           RANDOM ERROR VARIANCE              0.2500E-04  0.2500E-04  0.5000E-04
           SYSTEMATIC ERROR VARIANCE          0.2500E-04  0.2500E-04

           GROUP NO.      5                   SHIPPER     RECEIVER      SUM
           RANDOM ERROR VARIANCE              0.2500E-04  0.2500E-04  0.5000E-04
           SYSTEMATIC ERROR VARIANCE          0.2500E-04  0.2500E-04

           GROUP NO.      6                   SHIPPER     RECEIVER      SUM
           RANDOM ERROR VARIANCE              0.2500E-04  0.2500E-04  0.5000E-04
           SYSTEMATIC ERROR VARIANCE          0.2500E-04  0.2500E-04

           GROUP NO.      7                   SHIPPER     RECEIVER      SUM
           RANDOM ERROR VARIANCE              0.2500E-04  0.2500E-04  0.5000E-04
           SYSTEMATIC ERROR VARIANCE          0.2500E-04  0.2500E-04

  LIST OF MEASUREMENT INSTRUMENT NUMBERS
           GROUP     1 SCALE NO. OF OPERATOR     1 SCALE NO. OF INSPECTOR    2
           GROUP     2 SCALE NO. OF OPERATOR     1 SCALE NO. OF INSPECTOR    2
           GROUP     3 SCALE NO. OF OPERATOR     1 SCALE NO. OF INSPECTOR    2
           GROUP     4 SCALE NO. OF OPERATOR     1 SCALE NO. OF INSPECTOR    2
           GROUP     5 SCALE NO. OF OPERATOR     1 SCALE NO. OF INSPECTOR    2
           GROUP     6 SCALE NO. OF OPERATOR     1 SCALE NO. OF INSPECTOR    2
           GROUP     7 SCALE NO. OF OPERATOR     1 SCALE NO. OF INSPECTOR    2
```

Table 3 Sample Output (continued)

SHIPPER AND RECEIVER DATA

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| SHIPPER | 0.919680E+00 | 0.917900E+00 | 0.918860E+00 | 0.918890E+00 | 0.920000E+00 | 0.917060E+00 | 0.917900E+00 | 0.917680E+00 |
| RECEIVER | 0.913476E+00 | 0.920405E+00 | 0.923464E+00 | 0.920197E+00 | 0.922249E+00 | 0.917442E+00 | 0.916019E+00 | 0.924383E+00 |
| DIFFERENCE | 0.674582E+00 | -0.272938E+00 | -0.501088E+00 | -0.142193E+00 | -0.244457E+00 | -0.416978E-01 | 0.204957E+00 | -0.730386E+00 |
| | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| SHIPPER | 0.918340E+00 | 0.920000E+00 | 0.920000E+00 | 0.918550E+00 | 0.918470E+00 | 0.920000E+00 | 0.918870E+00 | 0.919300E+00 |
| RECEIVER | 0.921161E+00 | 0.919264E+00 | 0.922056E+00 | 0.925854E+00 | 0.924121E+00 | 0.917625E+00 | 0.912936E+00 | 0.912740E+00 |
| DIFFERENCE | -0.307175E+00 | 0.778051E-01 | -0.223532E+00 | -0.795122E+00 | -0.615252E+00 | 0.258174E+00 | 0.645761E+00 | 0.713554E+00 |
| | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| SHIPPER | 0.919300E+00 | 0.919300E+00 | 0.920000E+00 | 0.919300E+00 | 0.919300E+00 | 0.919300E+00 | 0.920000E+00 | 0.919300E+00 |
| RECEIVER | 0.915239E+00 | 0.905541E+00 | 0.924303E+00 | 0.909201E+00 | 0.913702E+00 | 0.926105E+00 | 0.917869E+00 | 0.913686E+00 |
| DIFFERENCE | 0.441772E+00 | 0.149663E+01 | -0.467760E+00 | 0.109859E+01 | 0.608920E+00 | -0.740182E+00 | 0.231642E+00 | 0.610716E+00 |
| | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| SHIPPER | 0.919300E+00 | 0.919300E+00 | 0.917880E+00 | 0.917600E+00 | 0.918340E+00 | 0.919960E+00 | 0.918220E+00 | 0.919960E+00 |
| RECEIVER | 0.913312E+00 | 0.911942E+00 | 0.918446E+00 | 0.912982E+00 | 0.922768E+00 | 0.924025E+00 | 0.921065E+00 | 0.916687E+00 |
| DIFFERENCE | 0.651312E+00 | 0.800382E+00 | -0.617180E-01 | 0.503226E+00 | -0.482207E+00 | -0.441910E+00 | -0.309839E+00 | 0.355810E+00 |
| | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| SHIPPER | 0.813000E+00 | 0.813000E+00 | 0.813000E+00 | 0.813000E+00 | 0.813000E+00 | 0.813000E+00 | 0.756900E+00 | 0.756900E+00 |
| RECEIVER | 0.808074E+00 | 0.820798E+00 | 0.801917E+00 | 0.823255E+00 | 0.807017E+00 | 0.797446E+00 | 0.753051E+00 | 0.748427E+00 |
| DIFFERENCE | 0.605916E+00 | -0.959200E+00 | 0.136321E+01 | -0.126134E+01 | 0.735965E+00 | 0.191313E+01 | 0.508561E+00 | 0.111945E+01 |
| | 41 | | | | | | | |
| SHIPPER | 0.756900E+00 | | | | | | | |
| RECEIVER | 0.770642E+00 | | | | | | | |
| DIFFERENCE | -0.181551E+01 | | | | | | | |

INPUT DATA SHOULD BE ANALIZED WITHOUT THEIR RE-ARRANGEMENT.

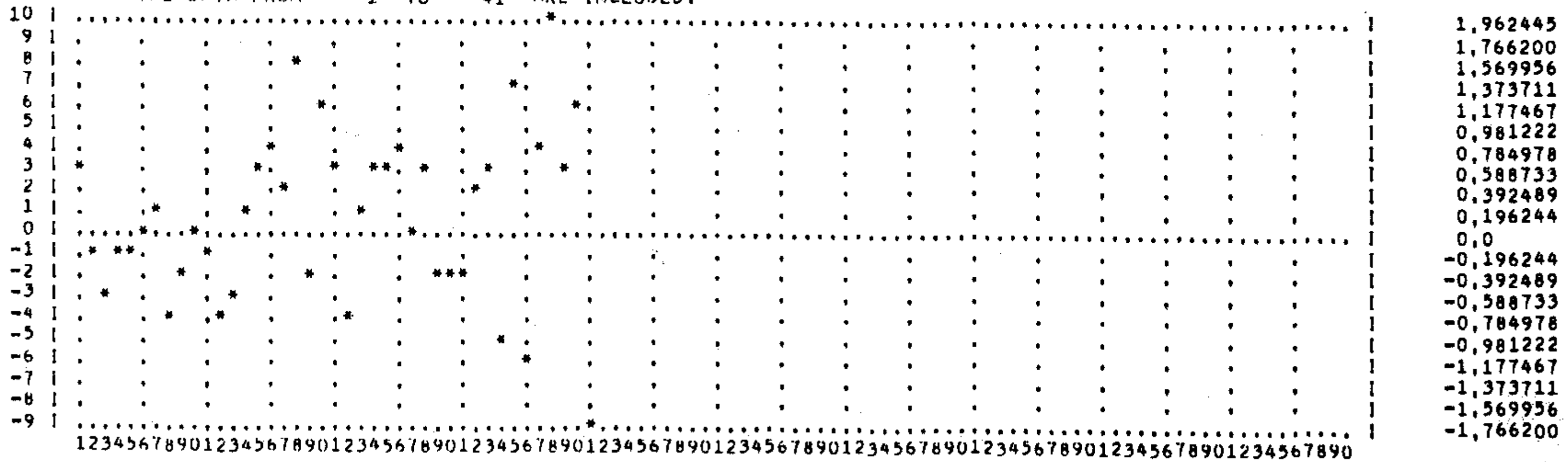
Table 3 Sample Output (continued)

```
NUMBER OF GROUPS     BOUNDARY NUMBER
       7                  15     26     29     32     35     38     41

 NUMBER OF DATA INCLUDED IN EACH GROUP
          1      2      3      4      5      6      7
         15     11      3      3      3      3      3


 SHIPPER AND RECEIVER DATA AFTER RE-ARRANGEMENT

                     1              2              3              4              5              6              7              8
  SHIPPER      0.756900E+00   0.756900E+00   0.756900E+00   0.813000E+00   0.813000E+00   0.813000E+00   0.813000E+00   0.813000E+00
  RECEIVER     0.748427E+00   0.753051E+00   0.770642E+00   0.797446E+00   0.801917E+00   0.807017E+00   0.808074E+00   0.820798E+00
 DIFFERENCE    0.111945E+01   0.508561E+00  -0.161551E+01   0.191313E+01   0.136321E+01   0.735965E+00   0.605916E+00  -0.959200E+00

                     9             10             11             12             13             14             15             16
  SHIPPER      0.813000E+00   0.919300E+00   0.919300E+00   0.919300E+00   0.919300E+00   0.918870E+00   0.917600E+00   0.919300E+00
  RECEIVER     0.823255E+00   0.905541E+00   0.909201E+00   0.911942E+00   0.912740E+00   0.912936E+00   0.912982E+00   0.913312E+00
 DIFFERENCE   -0.126134E+01   0.149663E+01   0.109859E+01   0.800382E+00   0.713554E+00   0.645761E+00   0.503226E+00   0.651312E+00

                    17             18             19             20             21             22             23             24
  SHIPPER      0.919680E+00   0.919300E+00   0.919300E+00   0.919300E+00   0.917900E+00   0.919960E+00   0.917060E+00   0.920000E+00
  RECEIVER     0.913476E+00   0.913686E+00   0.913702E+00   0.915239E+00   0.916019E+00   0.916687E+00   0.917442E+00   0.917625E+00
 DIFFERENCE    0.674582E+00   0.610716E+00   0.608920E+00   0.441772E+00   0.204957E+00   0.355810E+00  -0.416978E-01   0.258174E+00

                    25             26             27             28             29             30             31             32
  SHIPPER      0.920000E+00   0.917880E+00   0.920000E+00   0.918890E+00   0.917900E+00   0.918220E+00   0.919340E+00   0.920000E+00
  RECEIVER     0.917869E+00   0.918446E+00   0.919284E+00   0.920197E+00   0.920405E+00   0.921065E+00   0.921161E+00   0.922056E+00
 DIFFERENCE    0.231642E+00  -0.617180E-01   0.778051E-01  -0.142193E+00  -0.272938E+00  -0.309839E+00  -0.307175E+00  -0.223532E+00

                    33             34             35             36             37             38             39             40
  SHIPPER      0.920000E+00   0.918340E+00   0.918860E+00   0.919960E+00   0.918470E+00   0.920000E+00   0.917680E+00   0.918550E+00
  RECEIVER     0.922249E+00   0.922768E+00   0.923464E+00   0.924025E+00   0.924121E+00   0.924303E+00   0.924383E+00   0.925854E+00
 DIFFERENCE   -0.244457E+00  -0.462207E+00  -0.501088E+00  -0.441910E+00  -0.615252E+00  -0.467760E+00  -0.730386E+00  -0.795122E+00

                    41
  SHIPPER      0.919300E+00
  RECEIVER     0.926105E+00
 DIFFERENCE   -0.740182E+00
```

Table 3 Sample Output (continued)

PLOTTING OF SHIPPER - RECEIVER DIFFERENCES

(1) SR/D ARE PLOTTED AGAINST THE ORDER OF THE INPUT DATA
THE DATA FROM 1 TO 41 ARE INCLUDED.




(2) SR/D ARE PLOTTED AGAINST THE RECEIVER DATA (R)

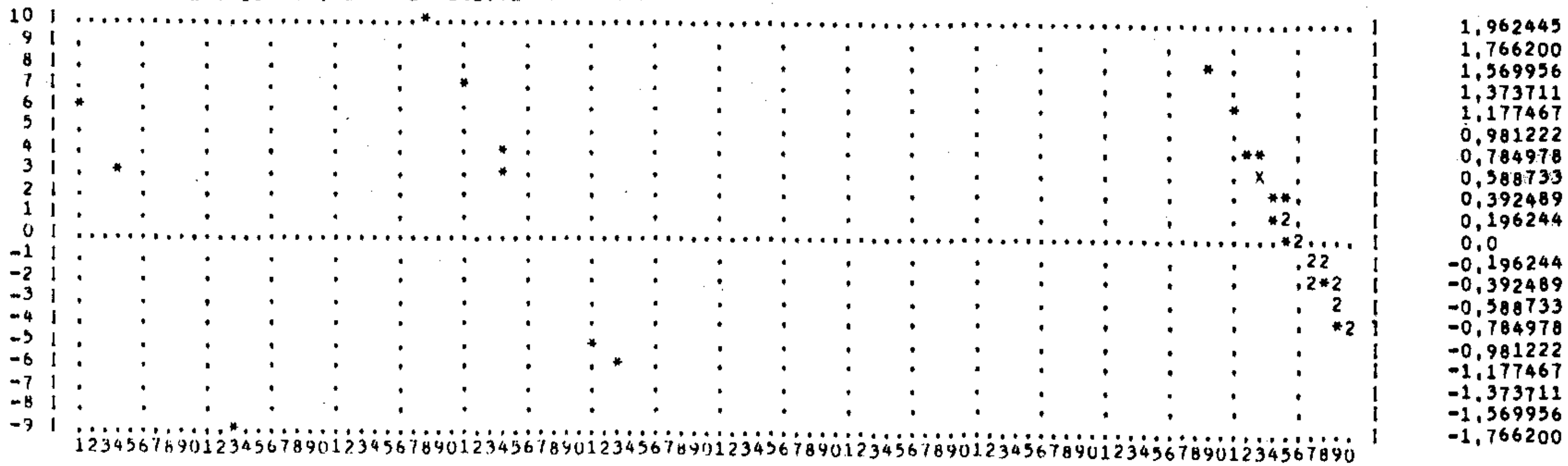


Table 3 Sample Output (continued)

STATISTICAL INFERENCES ON PAIRED DATA SETS WITH MULTI-GROUP

DATA GROUPS

GROUP 1

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| SHIPPER | 0.919680E+00 | 0.917900E+00 | 0.918860E+00 | 0.918890E+00 | 0.920000E+00 | 0.917060E+00 | 0.917900E+00 | 0.917680E+00 |
| RECEIVER | 0.913476E+00 | 0.920405E+00 | 0.923464E+00 | 0.920197E+00 | 0.922249E+00 | 0.917442E+00 | 0.916019E+00 | 0.924383E+00 |
| DIFFERENCE | 0.620399E-02 | -0.250530E-02 | -0.460429E-02 | -0.130659E-02 | -0.224900E-02 | -0.382394E-03 | 0.188130E-02 | -0.670260E-02 |

| | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|
| SHIPPER | 0.918340E+00 | 0.920000E+00 | 0.920000E+00 | 0.918550E+00 | 0.918470E+00 | 0.920000E+00 | 0.918870E+00 |
| RECEIVER | 0.921161E+00 | 0.919284E+00 | 0.922056E+00 | 0.925854E+00 | 0.924121E+00 | 0.917625E+00 | 0.912936E+00 |
| DIFFERENCE | -0.282091E-02 | 0.715807E-03 | -0.205649E-02 | -0.730360E-02 | -0.565091E-02 | 0.237520E-02 | 0.593370E-02 |

GROUP 2

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| SHIPPER | 0.919300E+00 | 0.919300E+00 | 0.919300E+00 | 0.920000E+00 | 0.919300E+00 | 0.919300E+00 | 0.919300E+00 | 0.920000E+00 |
| RECEIVER | 0.912740E+00 | 0.915239E+00 | 0.905541E+00 | 0.924303E+00 | 0.909201E+00 | 0.913702E+00 | 0.926105E+00 | 0.917869E+00 |
| DIFFERENCE | 0.655970E-02 | 0.406121E-02 | 0.137585E-01 | -0.430340E-02 | 0.100993E-01 | 0.559780E-02 | -0.680450E-02 | 0.213110E-02 |

| | 9 | 10 | 11 |
|---|---|---|---|
| SHIPPER | 0.919300E+00 | 0.919300E+00 | 0.919300E+00 |
| RECEIVER | 0.913686E+00 | 0.913312E+00 | 0.911942E+00 |
| DIFFERENCE | 0.561431E-02 | 0.598751E-02 | 0.735791E-02 |

GROUP 3

| | 1 | 2 | 3 |
|---|---|---|---|
| SHIPPER | 0.917680E+00 | 0.917600E+00 | 0.918340E+00 |
| RECEIVER | 0.918446E+00 | 0.912982E+00 | 0.922768E+00 |
| DIFFERENCE | -0.566497E-03 | 0.461760E-02 | -0.442830E-02 |

GROUP 4

| | 1 | 2 | 3 |
|---|---|---|---|
| SHIPPER | 0.919960E+00 | 0.918220E+00 | 0.919960E+00 |
| RECEIVER | 0.924025E+00 | 0.921065E+00 | 0.916687E+00 |
| DIFFERENCE | -0.406539E-02 | -0.284500E-02 | 0.327331E-02 |

GROUP 5

| | 1 | 2 | 3 |
|---|---|---|---|
| SHIPPER | 0.813000E+00 | 0.813000E+00 | 0.813000E+00 |
| RECEIVER | 0.808074E+00 | 0.820798E+00 | 0.801917E+00 |
| DIFFERENCE | 0.492610E-02 | -0.779830E-02 | 0.110829E-01 |

Table 3 Sample Output (continued)

```
 GROUP     6

                   1               2               3
  SHIPPER     0.813000E+00    0.813000E+00    0.813000E+00
  RECEIVER    0.823255E+00    0.807017E+00    0.797446E+00
DIFFERENCE   -0.102547E-01    0.598340E-02    0.155538E-01

 GROUP     7

                   1               2               3
  SHIPPER     0.756900E+00    0.756900E+00    0.756900E+00
  RECEIVER    0.753051E+00    0.748427E+00    0.770642E+00
DIFFERENCE    0.384930E-02    0.847310E-02   -0.137416E-01

 SAMPLE AVERAGE(AVS,AVR),   VARIANCES(SS2,SR2),   COVARIANCES(SSR)

  GROUP            1               2               3               4               5               6               7
  AVS         0.918813E+00    0.919427E+00    0.917940E+00    0.919380E+00    0.813000E+00    0.813000E+00    0.756900E+00
  AVR         0.920045E+00    0.914876E+00    0.918066E+00    0.920592E+00    0.810263E+00    0.809239E+00    0.757373E+00
  SS2         0.916669E-06    0.801811E-07    0.139597E-06    0.100921E-05    0.0             0.0             0.0
  SR2         0.153048E-04    0.361794E-04    0.240496E-04    0.136317E-04    0.927193E-04    0.170225E-03    0.137385E-03
  SSR        -0.368486E-06    0.869359E-06    0.179323E-05   -0.411195E-06    0.0             0.0             0.0

********* HYPOTHESIS TESTS *********

 (1)    HYPOTHESIS H01-1 TEST   ( H01-1,VRSE IS LESS THAN OR EQUAL TO VRRE / H11-1,VRSE IS GREATER THAN VRRE)

          OBSERVED STATISTIC  P =  0.3906927E+00
          CRITICAL VALUE OF STATISTIC  P =  0.1550731D+02  WITH    8 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

          H01-1 IS NOT REJECTED, THEN PROCEED H01-2 TEST

 (2)    HYPOTHESIS H01-2 TEST   ( H01-2,VRRE IS LESS THAN OR EQUAL TO VRSE / H11-2,VRRE IS GREATER THAN VRSE)
*****STATISTIC P OR (1-P) WAS ZERO AT GROUP    2, SO IT WAS KEPT AWAY FROM THIS HYPOTHESIS TESTING
          OBSERVED STATISTIC  P =  0.3708370E+02
          CRITICAL VALUE OF STATISTIC  P =  0.1259159D+02  WITH    6 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

          H01-2 IS REJECTED. THE CONCLUSION IS THAT VRSE IS LESS THAN VRRE.
              ESTIMATED RANDOM ERROR VARIANCES ARE THEN;

                  GROUP  1         GROUP  2         GROUP  3         GROUP  4         GROUP  5         GROUP  6
          VRSE   0.1085821E-05    0.0              0.0              0.1193964E-05    0.0              0.0
          VRRE   0.1812896E-04    0.4083638E-04    0.2445103E-04    0.1612721E-04    0.1402778E-03    0.2575378E-03

                  GROUP  7         GROUP
          VRSE   0.0
          VRRE   0.2398078E-03
```

Table 3 Sample Output (continued)

```
(3)   HYPOTHESIS H02-1 TEST   ( H02-1,(VRSE+VRRE) IS LESS THAN OR EQUAL TO VRM / H12-1,(VRSE+VRRE) IS GREATER THAN VRM)

***TARGET VALUE ROU**2 =  0.2243433E+01  AND CRITICAL VALUE R1 FOR ALTERNATIVE HYPOTHESIS =  0.1090362E+03
      OBSERVED STATISTIC    R =  0.4072324E+02
      CRITICAL VALUE OF STATISTIC    R =  0.4860237D+02  WITH   34 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

      H02-1 IS NOT REJECTED. THEN PROCEED H02-2 TEST


(4)   HYPOTHESIS H02-2 TEST   ( H02-2,(VRSE+VRRE) IS GREATER THAN OR EQUAL TO VRM / H12-2,(VRSE+VRRE) IS LESS THAN VRM)

      OBSERVED STATISTIC    R =  0.4072324E+02
      CRITICAL VALUE OF STATISTIC    R =  0.2166428D+02  WITH   34 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

      H02-2 IS NOT REJECTED. THE CONCLUSION IS THAT THE HYPOTHESIS (VRSE+VRRE)=VRM IS CONSISTENT WITH THE DATA.
          ESTIMATED RANDOM ERROR VARIANCES ARE THEN,

                  GROUP  1          GROUP  2          GROUP  3          GROUP  4          GROUP  5          GROUP  6
         VRSE   0.2825483E-05     0.0               0.0               0.3446546E-05     0.0               0.0
         VRRE   0.4717452E-04     0.5000000E-04     0.5000000E-04     0.4655345E-04     0.5000000E-04     0.5000000E-04

                  GROUP  7          GROUP
         VRSE   0.0
         VRRE   0.5000000E-04

***ALTHOUGH THE NOMINAL VALUES WERE ALLOWED IN THE ABOVE TEST, THEY SHOULD BE KEPT AWAY FROM THE TEST,  AS THE RESULT,


(3)   HYPOTHESIS H02-1 TEST   ( H02-1,(VRSE+VRRE) IS LESS THAN OR EQUAL TO VRM / H12-1,(VRSE+VRRE) IS GREATER THAN VRM)

***TARGET VALUE ROU**2 =  0.2441957E+01  AND CRITICAL VALUE R1 FOR ALTERNATIVE HYPOTHESIS =  0.1009435E+03
      OBSERVED STATISTIC    R =  0.1521830E+02
      CRITICAL VALUE OF STATISTIC    R =  0.4133714D+02  WITH   28 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

      H02-1 IS NOT REJECTED. THEN PROCEED H02-2 TEST


(4)   HYPOTHESIS H02-2 TEST   ( H02-2,(VRSE+VRRE) IS GREATER THAN OR EQUAL TO VRM / H12-2,(VRSE+VRRE) IS LESS THAN VRM)

      OBSERVED STATISTIC    R =  0.1521830E+02
      CRITICAL VALUE OF STATISTIC    R =  0.1692788D+02  WITH   28 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

      H02-2 IS REJECTED. THE CONCLUSION IS THAT (VRSE+VRRE) IS LESS THAN VRM.
          ESTIMATED RANDOM ERROR VARIANCES ARE THEN,

                  GROUP  1          GROUP  2          GROUP  3          GROUP  4          GROUP  5          GROUP  6
         VRSE   0.1085821E-05     0.0               0.0               0.1193964E-05     0.0               0.0
         VRRE   0.1812896E-04     0.4083638E-04     0.2445103E-04     0.1612721E-04     0.1402778E-03     0.2575378E-03

                  GROUP  7          GROUP
         VRSE   0.0
         VRRE   0.2398078E-03
```

Table 3 Sample Output (continued)

```
(5)    HYPOTHESIS H04-1 TEST   ( H04-1,VRRE IS EQUAL TO VRR / H14-1,VRRE IS GREATER OR LESS THAN VRR)

*****NEGATIVE FIX-UP TAKEN AT GROUP  1, SO THAT VRSE(OR VRRE)= 0.1085821E-05 AND VRXE= 0.0
*****NEGATIVE FIX-UP TAKEN AT GROUP  2, SO THAT VRSE(OR VRRE)= 0.0           AND VRXE= 0.9485000E-07
*****WARNING   ITERATION NO. REACHED 1000, BUT CONVERGENCE FACTOR WAS NOT SATISFIED, I.E. TEMP=   0.0001 AT GROUP  3
*****NEGATIVE FIX-UP TAKEN AT GROUP  3, SO THAT VRSE(OR VRRE)= 0.0           AND VRXE= 0.1656715E-06
*****NEGATIVE FIX-UP TAKEN AT GROUP  4, SO THAT VRSE(OR VRRE)= 0.1193964E-05 AND VRXE= 0.0
          OBSERVED STATISTIC  LAMDA4 =  0.1454032E+02
          CRITICAL VALUE OF STATISTIC  LAMDA4=   0.9487729D+01 WITH    7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

          H04-1 IS REJECTED, THE CONCLUSION IS THAT VRRE IS GREATER OR LESS THAN VRR.
              ESTIMATED RANDOM ERROR VARIANCES ARE THEN.

                      GROUP  1          GROUP  2          GROUP  3          GROUP  4          GROUP  5          GROUP  6
              VRSE    0.1085821E-05     0.0               0.0               0.1193964E-05     0.0               0.0
              VRRE    0.1812896E-04     0.4083638E-04     0.2445103E-04     0.1612721E-04     0.1402778E-03     0.2575378E-03

                      GROUP  7          GROUP
              VRSE    0.0
              VRRE    0.2398078E-03

(6)    HYPOTHESIS H04-2 TEST   ( H04-2,VRSE IS EQUAL TO VRS / H14-2,VRSE IS GREATER OR LESS THAN VRS)

*****NEGATIVE FIX-UP TAKEN AT GROUP  1, SO THAT VRSE(OR VRRE)= 0.1812896E-04 AND VRXE= 0.0
*****NEGATIVE FIX-UP TAKEN AT GROUP  2, SO THAT VRSE(OR VRRE)= 0.4279834E-04 AND VRXE= 0.0
*****NEGATIVE FIX-UP TAKEN AT GROUP  3, SO THAT VRSE(OR VRRE)= 0.2854172E-04 AND VRXE= 0.0
*****NEGATIVE FIX-UP TAKEN AT GROUP  4, SO THAT VRSE(OR VRRE)= 0.1612721E-04 AND VRXE= 0.0
          OBSERVED STATISTIC  LAMDA4 =  0.1143981E+03
          CRITICAL VALUE OF STATISTIC  LAMDA4=   0.9487729D+01 WITH    7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

          H04-2 IS REJECTED. THE CONCLUSION IS THAT VRSE IS GREATER OR LESS THAN VRS.
              ESTIMATED RANDOM ERROR VARIANCES ARE THEN.

                      GROUP  1          GROUP  2          GROUP  3          GROUP  4          GROUP  5          GROUP  6
              VRSE    0.1085821E-05     0.0               0.0               0.1193964E-05     0.0               0.0
              VRRE    0.1812896E-04     0.4083638E-04     0.2445103E-04     0.1612721E-04     0.1402778E-03     0.2575378E-03

                      GROUP  7          GROUP
              VRSE    0.0
              VRRE    0.2398078E-03
```

Table 3  Sample Output (continued)

```
EVALUATED ESTIMATES OF THE RANDOM ERROR VARIANCES AND THEIR STANDARD DEVIATIONS OF EACH DATA GROUP

              GROUP  1          GROUP  2          GROUP  3          GROUP  4          GROUP  5          GROUP  6
      VRSE   0.1085821E-05     0.0               0.0               0.1193964E-05     0.0               0.0
       S.D   0.1042027E-02     0.0               0.0               0.1092687E-02     0.0               0.0
      VRRE   0.1812896E-04     0.4083638E-04     0.2445103E-04     0.1612721E-04     0.1402778E-03     0.2575378E-03
       S.D   0.4257811E-02     0.6390335E-02     0.4944798E-02     0.4015869E-02     0.1184389E-01     0.1604798E-01

              GROUP  7          GROUP
      VRSE   0.0
       S.D   0.0
      VRRE   0.2398078E-03
       S.D   0.1548573E-01


FINAL ESTIMATES OF THE RANDOM ERROR VARIANCES AND STANDARD DEVIATIONS AVERAGED OVER THE DATA SET GROUPS

      FOR THE SHIPPER        VARIANCE =  0.5412868E-06          STANDARD DEVIATION =  0.7357219E-03
      FOR THE RECEIVER       VARIANCE =  0.5206671E-04          STANDARD DEVIATION =  0.7215727E-02


***ALTHOUGH THE NOMINAL VALUES WERE ALLOWED IN THE ABOVE TEST, THEY SHOULD BE KEPT AWAY FROM THE TEST.  AS THE RESULT,


FINAL ESTIMATES OF THE RANDOM ERROR VARIANCES AND STANDARD DEVIATIONS AVERAGED OVER THE DATA SET GROUPS

      FOR THE SHIPPER        VARIANCE =  0.6280288E-06          STANDARD DEVIATION =  0.7924827E-03
      FOR THE RECEIVER       VARIANCE =  0.2655353E-04          STANDARD DEVIATION =  0.5153012E-02


FINAL ESTIMATE OF THE COMBINED SYSTEMATIC ERROR VARIANCE (VSS+VSR)

***FOR THE ESTIMATION OF SYSTEMATIC ERROR VARIANCE, THE ASSIGNED RANDOM ERROR VARIANCES ARE USED.

      FOR THE SHIPPER        VARIANCE =  0.6280288E-06          STANDARD DEVIATION =  0.7924827E-03
      FOR THE RECEIVER       VARIANCE =  0.2655353E-04          STANDARD DEVIATION =  0.5153012E-02

      COMBINED SYSTEMATIC    VARIANCE =  0.1800178E-05          STANDARD DEVIATION =  0.1341707E-02

( 7)   HYPOTHESIS HC6-1 TEST   ( H06-1,(VSSE+VSRE) IS LESS THAN OR EQUAL TO VSM / H16-1,(VSSE+VSRE) IS GREATER THAN VSM)

***TARGET VALUE ROU**2 =  0.6490480E+01  AND CRITICAL VALUE R1 FOR ALTERNATIVE HYPOTHESIS =  0.9130249E+02
     OBSERVED STATISTIC    R =  0.2520249E+00
     CRITICAL VALUE OF STATISTIC   R =  0.1406714D+02  WITH    7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

     H06-1 IS NOT REJECTED. THEN PROCEED H06-2 TEST
```

Table 3 Sample Output (continued)

( 8) HYPOTHESIS H06-2 TEST ( H06-2.(VSSE+VSRE) IS GREATER THAN OR EQUAL TO VSM / H16-2.(VSSE+VSRE) IS LESS THAN VSM)

OBSERVED STATISTIC R = 0.2520249E+00
CRITICAL VALUE OF STATISTIC R = 0.2167350D+01 WITH 7 DEGREES OF FREEDOM AT THE 0.050 LEVEL OF SIGNIFICANCE

H06-2 IS REJECTED. THE CONCLUSION IS THAT (VSSE+VSRE) IS LESS THAN VSM.

( 9) HYPOTHESIS H05 TEST ( H05.AVS IS EQUAL TO AVR / H15.AVS IS NOT EQUAL TO AVR)

BASED ON ESTIMATED ERRORS

| | GROUP 1 | GROUP 2 | GROUP 3 | GROUP 4 | GROUP 5 | GROUP 6 |
|---|---|---|---|---|---|---|
| AVS-AVR | -0.1231432E-02 | 0.4550874E-02 | -0.1257360E-03 | -0.1212358E-02 | 0.2736911E-02 | 0.3760844E-02 |
| SIG-D | 0.1900600E-02 | 0.2066695E-02 | 0.3295557E-02 | 0.3295557E-02 | 0.3295557E-02 | 0.3295557E-02 |
| Z | 0.7051675E+00 | 0.2394975E+01 | 0.4156392E-01 | 0.4001355E+00 | 0.1021507E+01 | 0.1403673E+01 |
| Z(1-AL/2) | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 |
| TEST | NOTR | RJCT | NOTR | NOTR | NOTR | NOTR |

| | GROUP 7 | GROUP |
|---|---|---|
| AVS-AVR | -0.4730821E-03 | |
| SIG-D | 0.3295557E-02 | |
| Z | 0.1896571E+00 | |
| Z(1-AL/2) | 0.1959964D+01 | |
| TEST | NOTR | |

BASED ON DESIGN VALUES OF ERRORS

| | GROUP 1 | GROUP 2 | GROUP 3 | GROUP 4 | GROUP 5 | GROUP 6 |
|---|---|---|---|---|---|---|
| AVS-AVR | -0.1231432E-02 | 0.4550874E-02 | -0.1257360E-03 | -0.1212358E-02 | 0.2736911E-02 | 0.3760844E-02 |
| SIG-D | 0.7302967E-02 | 0.7385489E-02 | 0.8164966E-02 | 0.8164966E-02 | 0.8164966E-02 | 0.8164966E-02 |
| Z | 0.1835202E+00 | 0.6701903E+00 | 0.1677610E-01 | 0.1615034E+00 | 0.4123023E+00 | 0.5665529E+00 |
| Z(1-AL/2) | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 | 0.1959964D+01 |
| TEST | NOTR | NOTR | NOTR | NOTR | NOTR | NOTR |

| | GROUP 7 | GROUP |
|---|---|---|
| AVS-AVR | -0.4730821E-03 | |
| SIG-D | 0.8164966E-02 | |
| Z | 0.7654972E-01 | |
| Z(1-AL/2) | 0.1959964D+01 | |
| TEST | NOTR | |

Table 3 Sample Output (continued)

```
***FOR THE ESTIMATION OF SYSTEMATIC ERROR VARIANCE, THE ASSIGNED RANDOM ERROR VARIANCES ARE NOT USED.

      THE RANDOM ERROR VARIANCES DERIVED FROM THE OBSERVED DATA (SS2, SR2, SSR)

      FOR THE SHIPPER        VARIANCE =  0.3511175E-06          STANDARD DEVIATION =  0.5925517E-03
      FOR THE RECEIVER       VARIANCE =  0.5269286E-04          STANDARD DEVIATION =  0.7258985E-02

      COMBINED SYSTEMATIC    VARIANCE =  0.0                    STANDARD DEVIATION =  0.0

( 7)   HYPOTHESIS H06-1 TEST   ( H06-1,(VSSE+VSRE) IS LESS THAN OR EQUAL TO VSM / H16-1,(VSSE+VSRE) IS GREATER THAN VSM)

***TARGET VALUE ROU**2 =  0.6490480E+01  AND CRITICAL VALUE R1 FOR ALTERNATIVE HYPOTHESIS =  0.9130249E+02
   OBSERVED STATISTIC    R =  0.0
   CRITICAL VALUE OF STATISTIC   R =  0.1406714D+02  WITH    7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

   H06-1 IS NOT REJECTED, THEN PROCEED H06-2 TEST

( 8)   HYPOTHESIS H06-2 TEST   ( H06-2,(VSSE+VSRE) IS GREATER THAN OR EQUAL TO VSM / H16-2,(VSSE+VSRE) IS LESS THAN VSM)

   OBSERVED STATISTIC    R =  0.0
   CRITICAL VALUE OF STATISTIC   R =  0.2167350D+01  WITH    7 DEGREES OF FREEDOM AT THE   0.050 LEVEL OF SIGNIFICANCE

   H06-2 IS REJECTED, THE CONCLUSION IS THAT (VSSE+VSRE) IS LESS THAN VSM.

( 9)   HYPOTHESIS H05 TEST   ( H05,AVS IS EQUAL TO AVR / H15,AVS IS NOT EQUAL TO AVR)

   BASED ON ESTIMATED ERRORS

                 GROUP  1        GROUP  2        GROUP  3        GROUP  4        GROUP  5        GROUP  6
   AVS-AVR   -0.1231432E-02   0.4550874E-02  -0.1257360E-03  -0.1212358E-02   0.2736911E-02   0.3760844E-02
     SIG-D    0.1880496E-02   0.2195946E-02   0.4204917E-02   0.4204917E-02   0.4204917E-02   0.4204917E-02
         Z    0.7127065E+00   0.2254009E+01   0.3257526E-01   0.3136018E+00   0.8005947E+00   0.1100113E+01
 Z(1-AL/2)    0.1959964D+01   0.1959964D+01   0.1959964D+01   0.1959964D+01   0.1959964D+01   0.1959964D+01
      TEST        NOTR            RJCT            NOTR            NOTR            NOTR            NOTR

                 GROUP  7        GROUP
   AVS-AVR   -0.4730821E-03
     SIG-D    0.4204917E-02
         Z    0.1486417E+00
 Z(1-AL/2)    0.1959964D+01
      TEST        NOTR
```

Table 3 Sample Output (continued)

```
BASED ON DESIGN VALUES OF ERRORS

                 GROUP  1          GROUP  2          GROUP  3          GROUP  4          GROUP  5          GROUP  6
 AVS-AVR     -0.1231432E-02     0.4550874E-02    -0.1257360E-03    -0.1212358E-02     0.2736911E-02     0.3760844E-02
   SIG-D      0.7302967E-02     0.7385489E-02     0.8164966E-02     0.8164966E-02     0.8164966E-02     0.8164966E-02
       Z      0.1835202E+00     0.6701903E+00     0.1677610E-01     0.1615034E+00     0.4123023E+00     0.5665529E+00
Z(1-AL/2)     0.1959964D+01     0.1959964D+01     0.1959964D+01     0.1959964D+01     0.1959964D+01     0.1959964D+01
    TEST          NOTR              NOTR              NOTR              NOTR              NOTR              NOTR

                 GROUP  7          GROUP
 AVS-AVR     -0.4730821E-03
   SIG-D      0.8164966E-02
       Z      0.7654972E-01
Z(1-AL/2)     0.1959964D+01
    TEST          NOTR


FINAL ESTIMATES OF THE RANDOM ERROR VARIANCES FOR EACH SCALE
       REPORT NO,  MBA   WEI    NO. OF SCALE
            1      FCA    3          2
        THE SCALE NO.  1          VARIANCE  0.6280288E-06
        THE SCALE NO.  2          VARIANCE  0.2655353E-04


            FCA PIT EVALUATION, 1978-09-28 H,NISHIMURA                       INVR


   VARIABLES   PAIRED COMPARISONS

        ALPHA               BETA
   0.50000E-01          0.50000E-01

CASE NO. =  1    ORG. CODE = JAER    FAC. CODE = FCA    MBA CODE = FCA    DATE OF INS. REPORT = 780925    INS. REPORT NO. =   1
     INVENTORY VERIFICATION DATA

          STRATA    SCALES    ANAL.S    NDAS
             7         2         0        2

     MEASUREMENT-ERROR COEFFICIENTS OF VARIATION
                    SCALE         SYSTEMATIC          RANDOM.DESIGN        RANDOM.ESTIMATE
                        1         1.00000E-03         1.00000E-03           2.46268E-04
                        2         1.00000E-03         1.00000E-03           2.46268E-04
         NDA INSTRUMENT           SYSTEMATIC          RANDOM.DESIGN        RANDOM.ESTIMATE
                        1         5.00000E-03         5.00000E-03           7.92483E-04
                        2         5.00000E-03         5.00000E-03           5.15301E-03
```

Table 3 Sample Output (continued)

MATERIAL CODE = P

| STRA-TUM | MATERIAL | ITEM | METHOD | SAMPLE SIZE WEIGHT OP. | SAMPLE SIZE WEIGHT INS. | ELEMENT FAC. OP. | ELEMENT FAC. INS. | ISOTOPE FAC. OP. | ISOTOPE FAC. INS. | MEASUREMENT OPERATOR SCALE | MEASUREMENT OPERATOR ANAL. | MEASUREMENT OPERATOR NDA | INSPECTOR SCALE | INSPECTOR ANAL. | INSPECTOR NDA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | FCA V PU92 | | 1 | 15 | 15 | 0 | 0 | 15 | 15 | 1 | 0 | 1 | 2 | 0 | 2 |
| 2 | FCA V PU92 | | 1 | 11 | 11 | 0 | 0 | 11 | 11 | 1 | 0 | 1 | 2 | 0 | 2 |
| 3 | FCA V PU92 | | 1 | 3 | 3 | 0 | 0 | 3 | 3 | 1 | 0 | 1 | 2 | 0 | 2 |
| 4 | FCA V PU92 | | 1 | 3 | 3 | 0 | 0 | 3 | 3 | 1 | 0 | 1 | 2 | 0 | 2 |
| 5 | FCA V PU81 | | 1 | 3 | 3 | 0 | 0 | 3 | 3 | 1 | 0 | 1 | 2 | 0 | 2 |
| 6 | FCA V PU81 | | 1 | 3 | 3 | 0 | 0 | 3 | 3 | 1 | 0 | 1 | 2 | 0 | 2 |
| 7 | FCA V PU75 | | 1 | 3 | 3 | 0 | 0 | 3 | 3 | 1 | 0 | 1 | 2 | 0 | 2 |

| STRATUM | DIFFERENCE | OP. WEIGHT | INS. WEIGHT | OP. E FACTOR | INS. E FACTOR | OP. I FACTOR | INS. I FACTOR |
|---|---|---|---|---|---|---|---|
| 1 | -2.17370E+02 | | | 0.0 | 0.0 | 9.18813E-01 | 9.20045E-01 |
| 2 | 6.36497E+02 | | | 0.0 | 0.0 | 9.19427E-01 | 9.14876E-01 |
| 3 | -1.44064E+00 | | | 0.0 | 0.0 | 9.17940E-01 | 9.18066E-01 |
| 4 | -3.81270E+00 | | | 0.0 | 0.0 | 9.19380E-01 | 9.20592E-01 |
| 5 | 9.26888E+01 | | | 0.0 | 0.0 | 8.13000E-01 | 8.10263E-01 |
| 6 | 1.83866E+01 | | | 0.0 | 0.0 | 8.13000E-01 | 8.09239E-01 |
| 7 | -2.09721E+01 | | | 0.0 | 0.0 | 7.56900E-01 | 7.57373E-01 |

```
RESULTS OF CALCULATIONS
    ESTIMATED DIFFERENCE BETWEEN OPERATOR'S AND INSPECTOR'S MEASURED QUANTITIES =          5.03977E+02
    VARIANCE OF THE DIFFERENCE(OBS.) =      2.25891E+06     ITS STANDARD DEVIATION =      1.50297E+03
    ITS SYSTEMATIC PART =                   2.16169E+06                                   1.47027E+03
    ITS RANDOM PART =                       9.72243E+04                                   3.11808E+02
    VARIANCE OF THE DIFFERENCE(DES.) =      2.34686E+06     ITS STANDARD DEVIATION =      1.53195E+03
    ITS SYSTEMATIC PART =                   2.16169E+06                                   1.47027E+03
    ITS RANDOM PART =                       1.85170E+05                                   4.30314E+02
    (DIFFERENCE)/(ITS STANDARD DEVIATION) =                                               3.35321E-01
    CRITICAL VALUE OF STATISTICS Z =                                                      1.95996E+00

***** D=0
    ATTAINED GOAL QUANTITY M =    4.94433E+03  AND CRITICAL VALUE FOR ALTERNATIVE M1 =    7.41649E+03
```