CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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MINES BRANCH INVESTIGATION REPORT IR 71-63

# STATISTICAL REVIEW OF THE "CANADIAN SAMPLING PROCEDURE FOR MECHANICAL SAMPLING, (SECOND DRAFT)", DOCUMENT ISO/TC-102/SC-1 (CANADA-2) 177E

by

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MINERAL SCIENCES DIVISION



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## SUMMARY

The second draft of the Canadian proposal for the sampling procedure for mechanical sampling submitted to ISO/TC-102 has been reviewed from the statistical point of view. The sampling scheme was found to be reasonable but the formulae used to evaluate the results were found to be unsuitable. A more conventional scheme for evaluating the results from the sampling scheme by analysis of variance techniques is presented. The experimental results presented in the Appendices B, C, and D of the second draft were re-computed by this method. The second draft, along with its Appendices, is given as an Appendix to the present report for comparison purposes.

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## INTRODUCTION

During recent discussions between the author and Mr. N.S. Eaton, Chairman, CAC*/ISO/TC-102[1], on the subject of the second draft of "Canadian Sampling Procedure for Mechanical Sampling", Document ISO/TC-102/SC-1 (Canada-2) 177E[2], the author expressed his disagreement with the formulae used to evaluate the data. Formulae (2) and (3), found in the Appendix A of the above document**, use the standard deviation of the range as a measure of the analysis and preparation errors. In the opinion of the author, these formulae are not suitable for this purpose. The standard deviation of the range is not usually used directly as a measure of a variation. For this reason, it was agreed that the author would review the statistical aspects of the above document and would re-compute the data presented in Appendices B, C and D of the second draft by a more conventional method. This report gives the results of that study.

## SAMPLING AND PREPARATION PROCEDURE

The sampling and preparation procedure described in Appendix A of the above document can be illustrated schematically in Figure 1. The number of increments*** necessary to obtain a certain precision depends on the quality variation (intrinsic variation) within the consignment and on the characteristic variations associated with various steps throughout the procedure.

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*CAC = Canadian Advisory Committee
ISO = International Standards Organization
TC = Technical Committee
SC = Sub-Committee

**The complete document, with its own Appendices, is given as an Appendix to this report (see pages 33 to 55 ).

***For definition of the various terms used herein, see the Appendix, pages 37 to 39.

Suppose that the number of increments required in order to make a satisfactory assessment of the consignment was estimated to be k. These increments were then divided at random into r sub-samples with c increments forming each sub-sample. Since the number of sub-samples must be an integer, it is obvious that k must be an integral multiple of c; also k = cr.

Each sub-sample was then submitted to a screening (sieving) analysis. Having passed through this analysis, the size fractions were then re-combined to form the original r sub-samples. These sub-samples then underwent a division process to provide m final samples from each sub-sample. Each of these final samples was then analysed for the quality to be determined, with n replicate analyses being performed for each final sample, i.e., a total of n x m x r analyses.

From the above procedure, the following statistics were required to be estimated:

1. The top size of the consignment.
2. The analysis error.
3. The preparation error.
4. The quality (intrinsic) variation throughout the consignment.
5. Total variation of the property to be analysed.
6. The number of increments necessary to achieve a certain required degree of precision.

The top size of the consignment was determined directly from the sieving test. All the other statistical parameters can be estimated simultaneously by the analysis of variance method.

The basic assumption of this method is that the total variations of the analysed values are caused by:

1. The variation between the sub-samples, i.e., the intrinsic variation of the consignment.
2. The variation due to the sample preparation (i.e., due to lack of mixing, etc.).
3. The variation due to the analytical error.

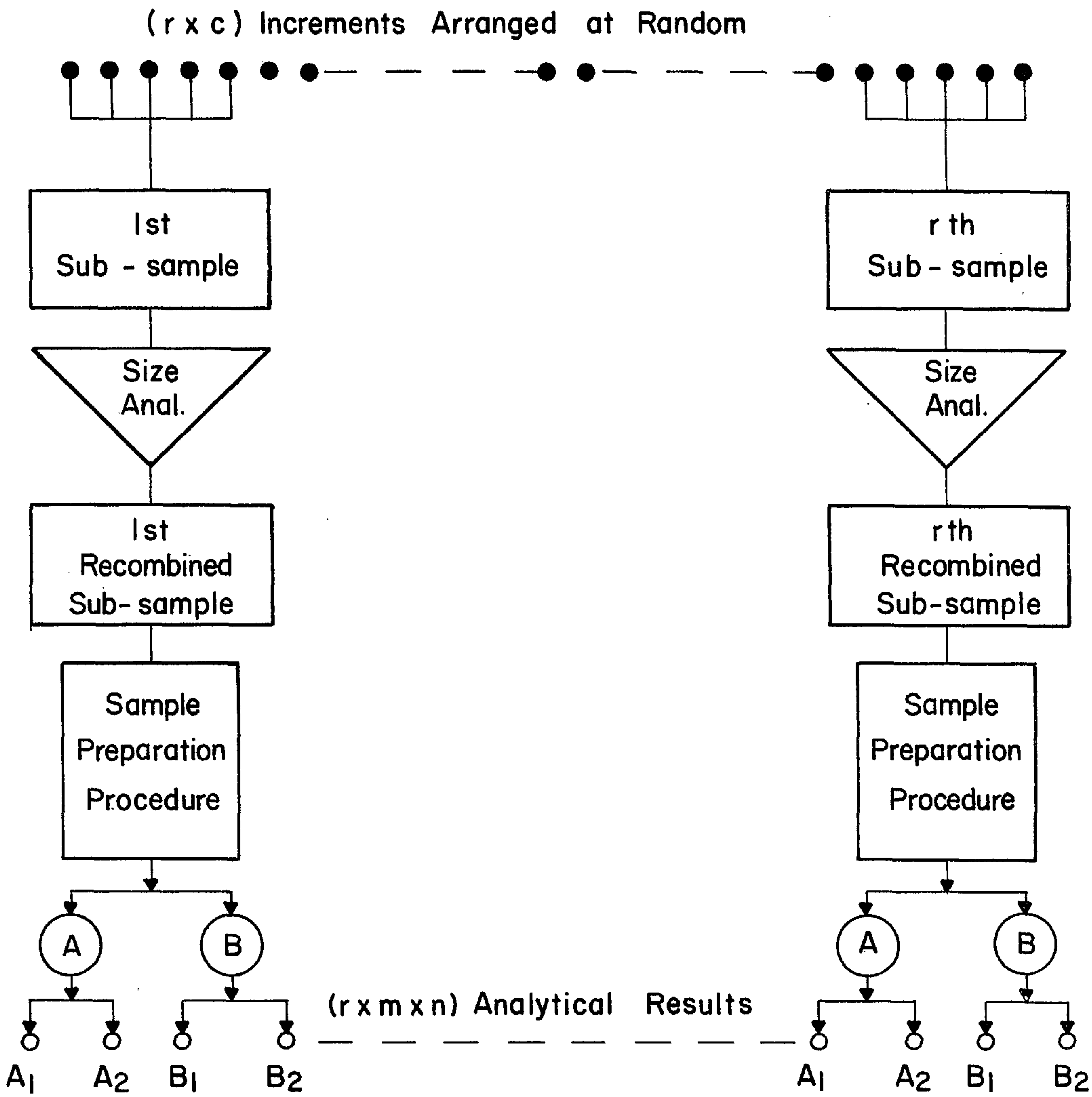



Figure 1. Sampling and Preparation Scheme.

Having estimated the various causes of variation, one can then estimate the number of increments necessary to obtain results with any required degree of precision.

## MATHEMATICAL DEVELOPMENT

Based on the above assumption concerning the causes of variation, the following mathematical model can be used to describe the sampling and analysis procedure:

$$x_{ijv} = u + b_i + y_{ij} + z_{ijv} \qquad \text{(Eq. 1)}$$

where

$x_{ijv}$ = the individual value of the analytical result,
$u$ = the true value of the particular quality to be determined,
$b_i$ = the deviation due to the quality variation of the sub-samples,
$y_{ij}$ = the deviation due to the preparation error, and
$z_{ijv}$ = the deviation due to the analytical error.

A further assumption will be that $b_i$, $y_{ij}$ and $z_{ijv}$ are independent, normally-distributed variables with means of zero and variances of $\psi^2$, $\omega^2$ and $\sigma^2$, respectively.

The splitting of the sums of squares of the various deviations from the means leads to the following analysis of variance table[3].

TABLE 1

Analysis of Variance

| Source of Variation | Sums of Squares | Degrees of Freedom | Mean* Squares | Quantity Estimated |
|---|---|---|---|---|
| Between Sub-samples | $mn \sum_{i=1}^{i=r} (\bar{x}_{i..} - \bar{x}_{...})^2$ | $(r - 1)$ | $S_3^2$ | $\sigma^2 + n\omega^2 + mn\psi^2$ |
| Preparation | $n \sum_{i=1}^{i=r} \sum_{j=1}^{j=m} (\bar{x}_{ij.} - \bar{x}_{i..})^2$ | $r(m - 1)$ | $S_2^2$ | $\sigma^2 + n\omega^2$ |
| Analyses | $\sum_{i=1}^{i=r} \sum_{j=1}^{j=m} \sum_{v=1}^{v=n} (x_{ijv} - \bar{x}_{ij.})^2$ | $rm(n - 1)$ | $S_1^2$ | $\sigma^2$ |
| Total | $\sum_{i=1}^{i=r} \sum_{j=1}^{j=m} \sum_{v=1}^{v=n} (x_{ijv} - \bar{x}_{...})^2$ | $rmn - 1$ | $S_{total}^2$ | |

*Note: "Mean Squares" is the ratio between the sums of squares and its number of degrees of freedom.

The quantities with a bar (superscript) and dots (subscript) are the means of those particular variables. The number of the dots corresponds to the level of summation, thus:

$$\bar{x}_{i..} = \sum_{j=1}^{j=m} \sum_{v=1}^{v=n} x_{ijv}/mn$$

$$\bar{x}_{ij.} = \sum_{v=1}^{v=n} x_{ijv}/n$$

From the Table 1, the variance components, $\psi^2$, $\omega^2$ and $\sigma^2$, can be estimated by the following formulae:

$$\sigma = S_1 \qquad \text{(Eq. 2)}$$

$$\omega = \left\{ \frac{S_2^2 - S_1^2}{n} \right\}^{\frac{1}{2}} \qquad \text{(Eq. 3)}$$

$$\psi = \left\{ \frac{S_3^2 - S_2^2}{mn} \right\}^{\frac{1}{2}} \qquad \text{(Eq. 4)}$$

The true value, u, can be estimated by the grand mean:

$$\bar{x}_{...} = \sum_{i=1}^{i=r} \sum_{j=1}^{j=m} \sum_{v=1}^{v=n} x_{ijv}/rmn \qquad \text{(Eq. 5)}$$

with a variance of

$$V[\bar{x}_{...}] = V[\bar{b}_{.}] + V[\bar{y}_{..}] + V[\bar{z}_{...}]$$

$$= \frac{\psi^2}{r} + \frac{\omega^2}{rm} + \frac{\sigma^2}{rmn}$$

$$= \frac{mn\psi^2 + n\omega^2 + \sigma^2}{rmn}$$

$$V[\bar{x}_{...}] = \frac{S_3^2}{rmn} \qquad \text{(Eq. 6)}$$

The 95% confidence interval of the mean can then be computed as:

$$\bar{x}_{...} - t_{0.975,(r-1)} V[\bar{x}_{...}]^{\frac{1}{2}} \leq u \leq \bar{x}_{...} + t_{0.975,(r-1)} V[\bar{x}_{...}]^{\frac{1}{2}}$$

.......(Eq. 7)

where $t_{0.975,(r-1)}$ = the value from the t-distribution with degrees of freedom of (r-1) and a 5% level of significance. These values, for various values of r, are listed in Table 11.

The precision, as it is defined in the ISO/TC-102/SC-1 (Canada-2) 177E document (see Appendix, page 39) can then be computed as:

$$P = t_{0.975,(r-1)} \left( \frac{S_3^2}{rmn} \right)^{\frac{1}{2}}$$

$$= t_{0.975,(r-1)} \left\{ \frac{mn\psi^2 + n\omega^2 + \sigma^2}{rmn} \right\}^{\frac{1}{2}}$$

$$= t_{0.975,(r-1)} \left\{ \frac{\psi^2}{r} + \frac{\omega^2}{rm} + \frac{\sigma^2}{rmn} \right\}^{\frac{1}{2}} \qquad \text{(Eq. 8)}$$

If the quality variation is expressed as Q, the standard deviation of the particular characteristic throughout the consighment, and c is the number of increments to form a sub-sample, then

$$Q^2 = c\psi^2 \qquad \text{(Eq. 9)}$$

Thus:

$$P = t_{0.975,(r-1)} \left\{ \frac{Q^2}{rc} + \frac{\omega^2}{rm} + \frac{\sigma^2}{rmn} \right\}^{\frac{1}{2}} \qquad \text{(Eq. 10)}$$

where

rc = k, the number of increments,

rm = total number of final samples being analysed,

rmn = total number of analyses performed.

Q, $\omega$, $\sigma$ are the standard deviations of the intrinsic variation, the preparation and the analyses, respectively.

The relative precision can also be defined as:

$$P_{rel} = \frac{P}{\bar{x}} \times 100\% \qquad \text{(Eq. 11)}$$

and the total variation as:

$$\sigma_{total} = \left\{ \sigma^2 + \omega^2 + \psi^2 \right\}^{\frac{1}{2}} \qquad \text{(Eq. 12)}$$

## RE-COMPUTATION OF THE EXAMPLES PRESENTED IN APPENDICES B, C, AND D OF ISO/TC-102/SC-1 (CANADA-2) 177E

In these examples the following parameters were used:

$$c = 5$$

$$r = 20$$

$$m = 2$$

$$n = 2$$

The computations in the present review were performed on a CDC 6600 digital computer; the results and the original data are listed in Tables 2 to 10.

## TABLE 2a

APPENDIX B. RUN-OF-THE-MINE, SAMPLED BEFORE BLENDING - PERCENT IRON

RAW DATA

| A1 | A2 | B1 | B2 |
|---|---|---|---|
| 57.64 | 57.98 | 58.04 | 58.06 |
| 58.45 | 58.31 | 57.15 | 57.33 |
| 59.83 | 59.77 | 59.67 | 59.66 |
| 60.40 | 60.59 | 60.40 | 60.58 |
| 60.73 | 60.74 | 60.81 | 60.90 |
| 58.78 | 59.12 | 58.53 | 58.96 |
| 61.05 | 61.06 | 60.65 | 60.66 |
| 60.02 | 60.08 | 59.61 | 59.59 |
| 62.29 | 62.19 | 61.56 | 61.38 |
| 63.91 | 63.65 | 63.57 | 63.58 |
| 59.85 | 59.67 | 59.51 | 59.52 |
| 57.67 | 57.49 | 56.83 | 56.60 |
| 61.18 | 60.91 | 61.59 | 61.65 |
| 63.28 | 63.42 | 63.45 | 63.18 |
| 60.30 | 60.43 | 60.94 | 60.76 |
| 58.27 | 58.48 | 59.00 | 58.97 |
| 59.39 | 59.29 | 58.74 | 58.49 |
| 58.82 | 58.56 | 58.98 | 58.97 |
| 60.20 | 60.10 | 59.87 | 59.78 |
| 59.71 | 59.94 | 60.28 | 60.10 |

## TABLE 2b

APPENDIX B. RUN-OF-THE-MINE, SAMPLED BEFORE BLENDING - PERCENT IRON

### ANALYSIS OF VARIANCE TABLE

| SOURCES OF VARIATION | SUMS OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARES |
|---|---|---|---|
| BETWEEN SUB-SAMPLES | 219.0098 | 19 | 11.5268 |
| PREPARATION | 5.0316 | 20 | .2516 |
| BETWEEN ANALYSES WITHIN FINAL SAMPLE | .6377 | 40 | .0159 |
| TOTAL | 224.6791 | 79 | 2.8440 |

| | F-RATIO | F-DISTRIBUTION |
|---|---|---|
| F.95( 19, 20) | 45.82 | 2.14 |
| F.95( 20, 40) | 15.78 | 1.84 |

| | | |
|---|---|---|
| GRAND MEAN | 60.0160 | |
| BETWEEN SUB-SAMPLES VARIANCE | 2.8188 | SIGNIFICANT |
| PREPARATION VARIANCE | .1178 | SIGNIFICANT |
| BETWEEN ANALYSES VARIANCE | .0159 | |
| TOTAL VARIANCE | 2.9526 | |
| VARIANCE OF THE GRAND MEAN | .1441 | |
| 95 PERCENT CONFIDENCE INTERVAL | 59.22 TO | 60.81 |
| RELATIVE PRECISION | 1.32 | PERCENT |

## TABLE 2c

APPENDIX B. RUN-OF-THE-MINE.SAMPLED BEFORE BLENDING - PERCENT IRON

NUMBER OF INCREMENTS REQUIRED FOR VARIOUS PRECISIONS

| NUMBER OF INC. | PRECISION PERCENT ABSOLUTE | PRECISION PERCENT RELATIVE |
|---|---|---|
| 20 | 2.70 | 4.50 |
| 40 | 1.42 | 2.36 |
| 60 | 1.08 | 1.80 |
| 80 | .90 | 1.51 |
| 100 | .79 | 1.32 |
| 120 | .72 | 1.19 |
| 140 | .66 | 1.10 |
| 160 | .61 | 1.02 |
| 180 | .57 | .96 |
| 200 | .54 | .90 |
| 220 | .52 | .86 |
| 240 | .49 | .82 |
| 260 | .47 | .79 |
| 280 | .45 | .76 |
| 300 | .44 | .73 |
| 320 | .42 | .71 |
| 340 | .41 | .68 |
| 360 | .40 | .66 |
| 380 | .39 | .65 |
| 400 | .38 | .63 |
| 420 | .37 | .61 |
| 440 | .36 | .60 |
| 460 | .35 | .59 |
| 480 | .34 | .57 |
| 500 | .34 | .56 |

## TABLE 3a

APPENDIX B. RUN-OF-THE-MINE, SAMPLED BEFORE BLENDING - PERCENT MOISTURE

RAW DATA

| A1 | A2 | B1 | B2 |
|---|---|---|---|
| 10.16 | 10.16 | 10.28 | 10.20 |
| 10.52 | 10.76 | 10.48 | 10.68 |
| 7.44 | 7.36 | 7.52 | 7.52 |
| 9.40 | 9.56 | 9.64 | 9.52 |
| 7.92 | 7.84 | 7.88 | 7.84 |
| 9.84 | 9.76 | 9.88 | 10.04 |
| 9.32 | 9.32 | 9.36 | 9.40 |
| 7.68 | 7.72 | 7.68 | 7.76 |
| 8.60 | 8.52 | 9.12 | 9.00 |
| 7.80 | 7.84 | 8.12 | 8.00 |
| 9.52 | 9.44 | 9.48 | 9.48 |
| 8.80 | 8.76 | 9.00 | 8.68 |
| 8.04 | 8.16 | 8.00 | 7.92 |
| 7.36 | 7.40 | 7.52 | 7.52 |
| 7.36 | 7.40 | 7.44 | 7.56 |
| 7.96 | 7.92 | 8.04 | 7.96 |
| 8.32 | 8.44 | 8.48 | 8.44 |
| 8.12 | 8.00 | 8.04 | 8.04 |
| 9.36 | 9.56 | 9.64 | 9.84 |
| 9.68 | 9.68 | 9.96 | 10.04 |

## TABLE 3b

APPENDIX B. RUN-OF-THE-MINE, SAMPLED BEFORE BLENDING - PERCENT MOISTURE

ANALYSIS OF VARIANCE TABLE

| SOURCES OF VARIATION | SUMS OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARES |
|---|---|---|---|
| BETWEEN SUB-SAMPLES | 78.2039 | 19 | 4.1160 |
| PREPARATION | .6204 | 20 | .0310 |
| BETWEEN ANALYSES WITHIN FINAL SAMPLE | .2552 | 40 | .0064 |
| TOTAL | 79.0795 | 79 | 1.0010 |

| | F-RATIO | F-DISTRIBUTION |
|---|---|---|
| F.95( 19, 20) | 132.69 | 2.14 |
| F.95( 20, 40) | 4.86 | 1.84 |

| | | | |
|---|---|---|---|
| GRAND MEAN | 8.7225 | | |
| BETWEEN SUB-SAMPLES VARIANCE | 1.0212 | | SIGNIFICANT |
| PREPARATION VARIANCE | .0123 | | SIGNIFICANT |
| BETWEEN ANALYSES VARIANCE | .0064 | | |
| TOTAL VARIANCE | 1.0399 | | |
| VARIANCE OF THE GRAND MEAN | .0514 | | |
| 95 PERCENT CONFIDENCE INTERVAL | 8.25 | TO | 9.20 |
| RELATIVE PRECISION | 5.44 | | PERCENT |

## TABLE 3c

APPENDIX B. RUN-OF-THE-MINE, SAMPLED BEFORE BLENDING - PERCENT MOISTURE

NUMBER OF INCREMENTS REQUIRED FOR VARIOUS PRECISIONS

| NUMBER OF INC. | PRECISION PERCENT ABSOLUTE | RELATIVE |
|---|---|---|
| 20 | 1.61 | 18.51 |
| 40 | .85 | 9.72 |
| 60 | .64 | 7.39 |
| 80 | .54 | 6.20 |
| 100 | .47 | 5.44 |
| 120 | .43 | 4.91 |
| 140 | .39 | 4.51 |
| 160 | .37 | 4.19 |
| 180 | .34 | 3.93 |
| 200 | .32 | 3.72 |
| 220 | .31 | 3.54 |
| 240 | .29 | 3.38 |
| 260 | .28 | 3.24 |
| 280 | .27 | 3.11 |
| 300 | .26 | 3.00 |
| 320 | .25 | 2.90 |
| 340 | .25 | 2.81 |
| 360 | .24 | 2.73 |
| 380 | .23 | 2.66 |
| 400 | .23 | 2.59 |
| 420 | .22 | 2.52 |
| 440 | .21 | 2.46 |
| 460 | .21 | 2.41 |
| 480 | .21 | 2.36 |
| 500 | .20 | 2.31 |

TABLE 4

Appendix B. Run-Of-The-Mine, Sampled Before Blending

| Statistic | Percent Iron | Percent Moisture |
|---|---|---|
| Grand Mean | 60.02 | 8.72 |
| Intrinsic Standard Deviation | 3.75 | 2.26 |
| Preparation Standard Deviation | 0.34 | 0.11 |
| Analyses Standard Deviation | 0.13 | 0.08 |
| Total Standard Deviation | 1.72 | 1.02 |
| Precision at 100 Increments | 0.79 | 0.47 |

TABLE 5a

APPENDIX C. IRON ORE CONCENTRATE - PERCENT IRON

RAW DATA

| A1 | A2 | B1 | B2 |
|---|---|---|---|
| 66.36 | 66.42 | 66.28 | 66.34 |
| 66.28 | 66.10 | 66.12 | 66.10 |
| 66.44 | 66.34 | 66.20 | 66.34 |
| 66.44 | 66.34 | 66.28 | 66.50 |
| 66.44 | 66.42 | 66.36 | 66.34 |
| 65.64 | 65.53 | 65.88 | 65.77 |
| 65.39 | 65.53 | 65.72 | 65.85 |
| 65.47 | 65.69 | 65.64 | 65.37 |
| 65.31 | 65.53 | 65.39 | 65.45 |
| 65.64 | 65.69 | 65.72 | 65.77 |
| 65.88 | 65.85 | 65.80 | 66.02 |
| 65.39 | 65.61 | 65.47 | 65.45 |
| 66.28 | 66.32 | 66.60 | 66.32 |
| 66.28 | 66.32 | 66.28 | 66.16 |
| 66.28 | 66.08 | 66.36 | 66.24 |
| 66.52 | 66.28 | 66.44 | 66.36 |
| 66.28 | 66.20 | 66.20 | 66.28 |
| 66.52 | 66.28 | 66.36 | 66.28 |
| 66.36 | 66.12 | 66.28 | 66.20 |
| 66.36 | 66.36 | 65.28 | 66.44 |

## TABLE 5b

APPENDIX C. IRON ORE CONCENTRATE - PERCENT IRON

ANALYSIS OF VARIANCE TABLE

| SOURCES OF VARIATION | SUMS OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARES |
|---|---|---|---|
| BETWEEN SUB-SAMPLES | 9.6077 | 19 | .5057 |
| PREPARATION | .2653 | 20 | .0133 |
| BETWEEN ANALYSES WITHIN FINAL SAMPLE | .4234 | 40 | .0106 |
| TOTAL | 10.2963 | 79 | .1303 |

| | F-RATIO | F-DISTRIBUTION |
|---|---|---|
| F.95( 19, 20) | 38.12 | 2.14 |
| F.95( 20, 40) | 1.25 | 1.84 |

| | | |
|---|---|---|
| GRAND MEAN | 66.0726 | |
| BETWEEN SUB-SAMPLES VARIANCE | .1231 | SIGNIFICANT |
| PREPARATION VARIANCE | .0013 | INSIGNIFICANT |
| BETWEEN ANALYSES VARIANCE | .0106 | |
| TOTAL VARIANCE | .1350 | |
| VARIANCE OF THE GRAND MEAN | .0063 | |
| 95 PERCENT CONFIDENCE INTERVAL | 65.91 TO | 66.24 |
| RELATIVE PRECISION | .25 | PERCENT |

## TABLE 5c

APPENDIX C. IRON ORE CONCENTRATE - PERCENT IRON

NUMBER OF INCREMENTS REQUIRED FOR VARIOUS PRECISIONS

| NUMBER OF INC. | PRECISION PERCENT ABSOLUTE | PRECISION PERCENT RELATIVE |
|---|---|---|
| 20 | .57 | .86 |
| 40 | .30 | .45 |
| 60 | .23 | .34 |
| 80 | .19 | .29 |
| 100 | .17 | .25 |
| 120 | .15 | .23 |
| 140 | .14 | .21 |
| 160 | .13 | .19 |
| 180 | .12 | .18 |
| 200 | .11 | .17 |
| 220 | .11 | .16 |
| 240 | .10 | .16 |
| 260 | .10 | .15 |
| 280 | .10 | .14 |
| 300 | .09 | .14 |
| 320 | .09 | .13 |
| 340 | .09 | .13 |
| 360 | .08 | .13 |
| 380 | .08 | .12 |
| 400 | .08 | .12 |
| 420 | .08 | .12 |
| 440 | .08 | .11 |
| 460 | .07 | .11 |
| 480 | .07 | .11 |
| 500 | .07 | .11 |

## TABLE 6a

APPENDIX C. IRON ORE CONCENTRATE - PERCENT MOISTURE

RAW DATA

| A1 | A2 | B1 | B2 |
|---|---|---|---|
| 2.84 | 2.80 | 2.68 | 2.72 |
| 2.72 | 2.60 | 2.64 | 2.60 |
| 2.76 | 2.80 | 2.80 | 2.72 |
| 2.80 | 2.80 | 2.80 | 2.84 |
| 2.84 | 2.80 | 2.84 | 2.88 |
| 2.48 | 2.52 | 2.36 | 2.40 |
| 2.64 | 2.64 | 2.68 | 2.64 |
| 2.64 | 2.64 | 2.64 | 2.64 |
| 2.72 | 2.72 | 2.72 | 2.76 |
| 2.52 | 2.56 | 2.48 | 2.48 |
| 2.20 | 2.16 | 2.04 | 2.04 |
| 2.64 | 2.60 | 2.68 | 2.64 |
| 3.00 | 2.96 | 2.96 | 2.96 |
| 2.64 | 2.64 | 2.60 | 2.60 |
| 2.60 | 2.60 | 2.56 | 2.60 |
| 2.64 | 2.68 | 2.56 | 2.60 |
| 2.44 | 2.44 | 2.40 | 2.36 |
| 2.00 | 1.96 | 1.88 | 1.92 |
| 2.80 | 2.80 | 2.76 | 2.76 |
| 2.92 | 2.96 | 2.96 | 2.96 |

## TABLE 6b

APPENDIX C. IRON ORE CONCENTRATE - PERCENT MOISTURE

ANALYSIS OF VARIANCE TABLE

| SOURCES OF VARIATION | SUMS OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARES |
|---|---|---|---|
| BETWEEN SUB-SAMPLES | 4.8391 | 19 | .2547 |
| PREPARATION | .0792 | 20 | .0040 |
| BETWEEN ANALYSES WITHIN FINAL SAMPLE | .0288 | 40 | .0007 |
| TOTAL | 4.9471 | 79 | .0626 |

| | F-RATIO | F-DISTRIBUTION |
|---|---|---|
| F.95( 19, 20) | 64.32 | 2.14 |
| F.95( 20, 40) | 5.50 | 1.84 |

| | | | |
|---|---|---|---|
| GRAND MEAN | 2.6210 | | |
| BETWEEN SUB-SAMPLES VARIANCE | .0627 | | SIGNIFICANT |
| PREPARATION VARIANCE | .0016 | | SIGNIFICANT |
| BETWEEN ANALYSES VARIANCE | .0007 | | |
| TOTAL VARIANCE | .0650 | | |
| VARIANCE OF THE GRAND MEAN | .0032 | | |
| 95 PERCENT CONFIDENCE INTERVAL | 2.50 | TO | 2.74 |
| RELATIVE PRECISION | 4.51 | | PERCENT |

## TABLE 6c

APPENDIX C. IRON ORE CONCENTRATE - PERCENT MOISTURE

NUMBER OF INCREMENTS REQUIRED FOR VARIOUS PRECISIONS

| NUMBER OF INC. | PRECISION PERCENT ABSOLUTE | PRECISION PERCENT RELATIVE |
|---|---|---|
| 20 | .40 | 15.32 |
| 40 | .21 | 8.05 |
| 60 | .16 | 6.12 |
| 80 | .13 | 5.13 |
| 100 | .12 | 4.51 |
| 120 | .11 | 4.07 |
| 140 | .10 | 3.73 |
| 160 | .09 | 3.47 |
| 180 | .09 | 3.25 |
| 200 | .08 | 3.08 |
| 220 | .08 | 2.93 |
| 240 | .07 | 2.80 |
| 260 | .07 | 2.68 |
| 280 | .07 | 2.58 |
| 300 | .07 | 2.49 |
| 320 | .06 | 2.40 |
| 340 | .06 | 2.33 |
| 360 | .06 | 2.26 |
| 380 | .06 | 2.20 |
| 400 | .06 | 2.14 |
| 420 | .05 | 2.09 |
| 440 | .05 | 2.04 |
| 460 | .05 | 1.99 |
| 480 | .05 | 1.95 |
| 500 | .05 | 1.91 |

TABLE 7

Appendix C. Iron Ore Concentrate

| Statistic | Percent Iron | Percent Moisture |
|---|---|---|
| Grand Mean | 66.07 | 2.62 |
| Intrinsic Standard Deviation | 0.78 | 0.56 |
| Preparation Standard Deviation | 0.04 (Ins) | 0.04 |
| Analyses Standard Deviation | 0.10 | 0.03 |
| Total Standard Deviation | 0.37 | 0.25 |
| Precision at 100 Increments | 0.17 | 0.12 |

Ins = Statistically insignificant at 5% level of significance.

## TABLE 8a

APPENDIX D. IRON ORE PELLETS - PERCENT IRON

RAW DATA

| A1 | A2 | B1 | B2 |
|---|---|---|---|
| 65.87 | 65.95 | 65.95 | 65.95 |
| 65.87 | 65.95 | 65.79 | 65.95 |
| 65.39 | 65.63 | 65.55 | 65.47 |
| 65.63 | 65.63 | 65.47 | 65.55 |
| 65.47 | 65.45 | 65.31 | 65.45 |
| 65.63 | 65.45 | 65.63 | 65.45 |
| 65.63 | 65.45 | 65.63 | 65.45 |
| 65.48 | 65.39 | 65.48 | 65.31 |
| 65.48 | 65.39 | 65.48 | 65.47 |
| 65.40 | 65.47 | 65.48 | 65.47 |
| 65.48 | 65.39 | 65.40 | 65.31 |
| 65.40 | 65.31 | 65.48 | 65.39 |
| 65.32 | 65.23 | 65.48 | 65.31 |
| 65.48 | 65.23 | 65.32 | 65.31 |
| 65.47 | 65.39 | 65.47 | 65.39 |
| 65.47 | 65.55 | 65.47 | 65.39 |
| 65.55 | 65.48 | 65.39 | 65.48 |
| 65.39 | 65.31 | 65.23 | 65.31 |
| 65.31 | 65.15 | 65.48 | 65.47 |
| 65.23 | 65.31 | 65.39 | 65.31 |

# TABLE 8b

APPENDIX D. IRON ORE PELLETS - PERCENT IRON

## ANALYSIS OF VARIANCE TABLE

| SOURCES OF VARIATION | SUMS OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARES |
|---|---|---|---|
| BETWEEN SUB-SAMPLES | 2.1153 | 19 | .1113 |
| PREPARATION | .1432 | 20 | .0072 |
| BETWEEN ANALYSES WITHIN FINAL SAMPLE | .2653 | 40 | .0066 |
| TOTAL | 2.5238 | 79 | .0319 |

| | F-RATIO | F-DISTRIBUTION |
|---|---|---|
| F.95( 19, 20) | 15.55 | 2.14 |
| F.95( 20, 40) | 1.08 | 1.84 |

| | | | |
|---|---|---|---|
| GRAND MEAN | 65.4766 | | |
| BETWEEN SUB-SAMPLES VARIANCE | .0260 | | SIGNIFICANT |
| PREPARATION VARIANCE | .0003 | | INSIGNIFICANT |
| BETWEEN ANALYSES VARIANCE | .0066 | | |
| TOTAL VARIANCE | .0329 | | |
| VARIANCE OF THE GRAND MEAN | .0014 | | |
| 95 PERCENT CONFIDENCE INTERVAL | 65.40 | TO | 65.55 |
| RELATIVE PRECISION | .12 | | PERCENT |

TABLE 8c

APPENDIX D. IRON ORE PELLETS - PERCENT IRON

NUMBER OF INCREMENTS REQUIRED FOR VARIOUS PRECISIONS

| NUMBER OF INC. | PRECISION PERCENT ABSOLUTE | PRECISION PERCENT RELATIVE |
|---|---|---|
| 20 | .27 | .41 |
| 40 | .14 | .21 |
| 60 | .11 | .16 |
| 80 | .09 | .14 |
| 100 | .08 | .12 |
| 120 | .07 | .11 |
| 140 | .06 | .10 |
| 160 | .06 | .09 |
| 180 | .06 | .09 |
| 200 | .05 | .08 |
| 220 | .05 | .08 |
| 240 | .05 | .07 |
| 260 | .05 | .07 |
| 280 | .04 | .07 |
| 300 | .04 | .07 |
| 320 | .04 | .06 |
| 340 | .04 | .06 |
| 360 | .04 | .06 |
| 380 | .04 | .06 |
| 400 | .04 | .06 |
| 420 | .04 | .06 |
| 440 | .04 | .05 |
| 460 | .03 | .05 |
| 480 | .03 | .05 |
| 500 | .03 | .05 |

## TABLE 9a

APPENDIX D. IRON ORE PELLETS - PERCENT MOISTURE

RAW DATA

| A1 | A2 | B1 | B2 |
|---|---|---|---|
| 1.04 | 1.01 | .90 | .86 |
| .98 | .96 | .96 | .83 |
| 1.03 | 1.11 | 1.18 | 1.07 |
| 1.08 | 1.08 | 1.07 | 1.03 |
| 1.09 | 1.04 | .98 | .99 |
| .57 | .50 | .48 | .42 |
| .73 | .76 | .80 | .74 |
| .66 | .58 | .68 | .67 |
| .74 | .71 | .81 | .76 |
| .87 | .83 | .82 | .81 |
| .95 | .89 | .90 | .89 |
| .83 | .90 | .96 | .90 |
| .90 | .86 | .95 | .94 |
| .82 | .79 | .71 | .73 |
| .65 | .79 | .67 | .76 |
| .73 | .79 | .69 | .75 |
| .96 | .75 | .90 | .78 |
| .85 | .95 | .71 | .80 |
| .74 | .82 | .80 | .75 |
| .82 | .84 | .83 | .90 |

## TABLE 9b

APPENDIX D. IRON ORE PELLETS - PERCENT MOISTURE

ANALYSIS OF VARIANCE TABLE

| SOURCES OF VARIATION | SUMS OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARES |
|---|---|---|---|
| BETWEEN SUB-SAMPLES | 1.5705 | 19 | .0827 |
| PREPARATION | .0933 | 20 | .0047 |
| BETWEEN ANALYSES WITHIN FINAL SAMPLE | .1019 | 40 | .0025 |
| TOTAL | 1.7657 | 79 | .0224 |

| | F-RATIO | F-DISTRIBUTION |
|---|---|---|
| F.95( 19, 20) | 17.72 | 2.14 |
| F.95( 20, 40) | 1.83 | 1.84 |

| | | | |
|---|---|---|---|
| GRAND MEAN | .8399 | | |
| BETWEEN SUB-SAMPLES VARIANCE | .0195 | | SIGNIFICANT |
| PREPARATION VARIANCE | .0011 | | INSIGNIFICANT |
| BETWEEN ANALYSES VARIANCE | .0025 | | |
| TOTAL VARIANCE | .0231 | | |
| VARIANCE OF THE GRAND MEAN | .0010 | | |
| 95 PERCENT CONFIDENCE INTERVAL | .77 | TO | .91 |
| RELATIVE PRECISION | 8.01 | | PERCENT |

## TABLE 9c

APPENDIX D. IRON ORE PELLETS - PERCENT MOISTURE

NUMBER OF INCREMENTS REQUIRED FOR VARIOUS PRECISIONS

| NUMBER OF INC. | PRECISION PERCENT ABSOLUTE | PRECISION PERCENT RELATIVE |
|---|---|---|
| 20 | .23 | 27.23 |
| 40 | .12 | 14.31 |
| 60 | .09 | 10.87 |
| 80 | .08 | 9.12 |
| 100 | .07 | 8.01 |
| 120 | .06 | 7.23 |
| 140 | .06 | 6.64 |
| 160 | .05 | 6.17 |
| 180 | .05 | 5.79 |
| 200 | .05 | 5.47 |
| 220 | .04 | 5.20 |
| 240 | .04 | 4.97 |
| 260 | .04 | 4.77 |
| 280 | .04 | 4.58 |
| 300 | .04 | 4.42 |
| 320 | .04 | 4.28 |
| 340 | .03 | 4.14 |
| 360 | .03 | 4.02 |
| 380 | .03 | 3.91 |
| 400 | .03 | 3.81 |
| 420 | .03 | 3.71 |
| 440 | .03 | 3.63 |
| 460 | .03 | 3.54 |
| 480 | .03 | 3.47 |
| 500 | .03 | 3.40 |

TABLE 10

Appendix D. Iron Ore Pellets

| Statistic | Percent Iron | Percent Moisture |
|---|---|---|
| Grand Mean | 65.48 | 0.84 |
| Intrinsic Standard Deviation | 0.36 | 0.31 |
| Preparation Standard Deviation | 0.02 (Ins) | 0.00 (Ins) |
| Analyses Standard Deviation | 0.08 | 0.05 |
| Total Standard Deviation | 0.18 | 0.15 |
| Precision at 100 Increments | 0.08 | 0.07 |

Ins = Statistically insignificant at 5% level of significance.

TABLE 11

Values of $t_{(r-1)}$ at 95% Percentage Point for

Various Numbers of Sub-Samples r[4]

| r | $t_{(r-1)}$ | r | $t_{(r-1)}$ | r | $t_{(r-1)}$ | r | $t_{(r-1)}$ |
|---|---|---|---|---|---|---|---|
| 2 | 12.706 | 12 | 2.201 | 22 | 2.080 | 41 | 2.021 |
| 3 | 4.303 | 13 | 2.179 | 23 | 2.074 | 61 | 2.000 |
| 4 | 3.182 | 14 | 2.160 | 24 | 2.069 | 121 | 1.980 |
| 5 | 2.776 | 15 | 2.145 | 25 | 2.064 | ∞ | 1.960 |
| 6 | 2.571 | 16 | 2.131 | 26 | 2.060 | | |
| 7 | 2.447 | 17 | 2.120 | 27 | 2.056 | | |
| 8 | 2.365 | 18 | 2.110 | 28 | 2.052 | | |
| 9 | 2.306 | 19 | 2.101 | 29 | 2.048 | | |
| 10 | 2.262 | 20 | 2.093 | 30 | 2.045 | | |
| 11 | 2.228 | 21 | 2.086 | 31 | 2.042 | | |

## DISCUSSION

Equation 8 shows that the precision of a sampling scheme depends on the square root of the quality (intrinsic) variance of the consignment, the preparation variance and the analyses variance, and inversely as the number of sub-samples (number of increments), the number of final samples taken from each sub-sample, and the number of replicate analyses performed for each final sample. The optimum values of c, r, m and n to obtain a certain required degree of precision for a particular quality of consignment depend on practical considerations. As an example, in the case of the chemical analyses presented in Appendix B of the ISO document, the major component of variance is the intrinsic variance, $Q^2$; thus, the only way that the precision can be improved is by increasing the number of increments. Having to increase the number of increments (r x c), one can then either increase r or c, depending on the cost of analysis and on the preparation capability. Increasing r will result in an increased of the number of analyses; on the other hand, increasing c will increase the amount of material per sub-sample to be handled and, presumably, will also increase the preparation variance, $\omega^2$. In another situation, for a particular quality, where $\sigma^2$ is the dominant component of variance, increasing n may be the most economical method to increase the precision.

Tables 2c, 3c, 5c, 6c, 8c, and 9c, show the effect of various magnitudes of variation of the qualities on the number of increments required to obtain various degrees of sampling precision. Another factor that also depends on the number of sub-samples is the quantity $t_{0.975,(r-1)}$. Table 11 shows this dependence; it is strongly dependent on r for the lower values of r, and then becomes nearly constant at $r \geq 20$.

## REFERENCES

1. Sutarno, "Visit to the Loading and Sampling Facilities of the Iron Ore Company of Canada in Sept-Iles, P. Q., and of the Quebec Cartier Mining Company in Port Cartier, P.Q., August 16-18, 1971", Mineral Sciences Division Visit Memorandum MSV 71-32 (1971).
2. "Canadian Sampling Procedure for Mechanical Sampling; Answer to Doc. 102/1N 162E", Document ISO/TC-102/SC-1 (Canada-2) 177E September, 1970.
3. K.A. Brownlee, "Statistical Theory and Methodology in Science and Engineering", Published by John Wiley and Sons, Inc., New York (1960), pp. 389-395.
4. W.H. Beyer, "Handbook of Tables for Probability and Statistics", Published by The Chemical Rubber Co., Cleveland, Ohio, 2nd Edition (1968).

# APPENDIX

ISO/TC 102/SC 1 (Canada-2) 177E
September 1970

# I S O

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

TECHNICAL COMMITTEE 102 - IRON ORES

SUB-COMMITTEE 1 - SAMPLING

Canadian Sampling

Procedure for Mechanical

Sampling (Second Draft)

- Answer to Doc. 102/1N 162E

ISO/TC 102/SC 1 (Canada-2) 17E

# IRON ORE COMPANY OF CANADA

OFFICES:
SEPT-ILES, QUEBEC
MONTREAL, QUEBEC
SCHEFFERVILLE, QUEBEC
LABRADOR CITY, NEWFOUNDLAND
ST. JOHN'S, NEWFOUNDLAND

Sept-Iles, Quebec,
January 14, 1970.

Secretariat of ISO/TC 102/SC 1,
Japanese Industrial Standards
Committee,
Agency of Industrial Science
and Technology,
Ministry of International
Trade and Industry,
3 - 1 Kasumigaseti 1, Chiyodaku,
Tokyo, Japan.

ATTENTION: Mr. S. Kurachi, Chief of Standards Division

Dear Sir,

Enclosed please find a copy of document CAC/ISO/TC 102/SC 1 M1 "Sampling and Preparation of Iron Ore - Second Draft".

This is the procedure referred to in item 3.1 of the letter from Mr. S. F. Coolsma of Canadian Standards Association to yourself on January 7, 1970.

We apologize for the delay and hope you will find this method useful in your preparation of a mechanical sampling method.

Thank you.

Yours truly,

N. S. Eaton,
CHAIRMAN CAC/ISO/TC 102.

NSE/ym
Encl.
C.C. Mr. S. F. Coolsma

## SAMPLING AND PREPARATION OF IRON ORE

### SECOND DRAFT

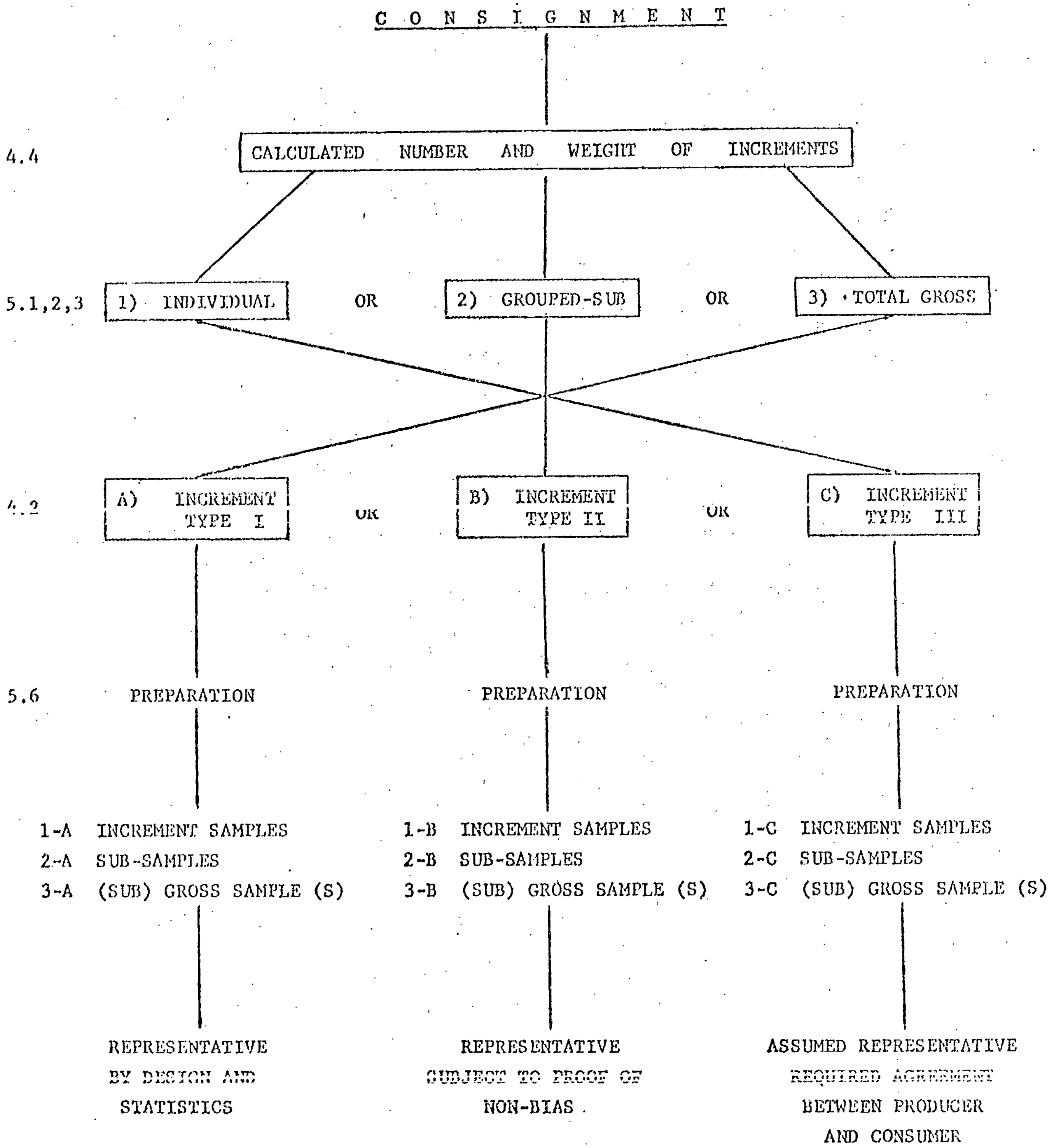
### I SCOPE

The method covers the procedures for obtaining representative samples of a consignment and for the preparation of final samples for all the determinations required under various conditions of sampling and preparation.

### II SUMMARY

The method is an increment sampling method where the number of increments is based on statistical analysis of the intrinsic variation of the characteristics desired within the ore type and the overall or total precision desired (4.4). The size of the increments is based on the top size of the ore type (4.5). The representativeness of the final sample (s) is a product of the manner in which the increments were taken (4.2). The increments are analysed individually, as sub-samples or as a gross sample (5.1 - 5.2 - 5.3).

The preparation procedures are based on a size weight ratio until the size sample is removed where crushing is continued with division in the same size weight ratio (5.6). The sample for moisture is removed before crushing or at greater than ½" (10 mm) and drying is then performed at 105 ± 5°C to constant weight. The analysis sample is then pulverized to pass 150 microns. The following flow sheet shows the possible methods with resultant samples.


CONSIGNMENT
4.4
CALCULATED NUMBER AND WEIGHT OF INCREMENTS
5.1,2,3
1) INDIVIDUAL
OR
2) GROUPED-SUB
OR
3) TOTAL GROSS
4.2
A) INCREMENT TYPE I
OR
B) INCREMENT TYPE II
OR
C) INCREMENT TYPE III
5.6
PREPARATION
PREPARATION
PREPARATION
1-A INCREMENT SAMPLES
2-A SUB-SAMPLES
3-A (SUB) GROSS SAMPLE (S)
1-B INCREMENT SAMPLES
2-B SUB-SAMPLES
3-B (SUB) GROSS SAMPLE (S)
1-C INCREMENT SAMPLES
2-C SUB-SAMPLES
3-C (SUB) GROSS SAMPLE (S)
REPRESENTATIVE BY DESIGN AND STATISTICS
REPRESENTATIVE SUBJECT TO PROOF OF NON-BIAS
ASSUMED REPRESENTATIVE REQUIRED AGREEMENT BETWEEN PRODUCER AND CONSUMER

## III TERMINOLOGY

### 3.1 CONSIGNMENT

The total quantity of ore to be sampled. (Such as a shipment, train load, or day's production).

### 3.2 INCREMENT

Quantity of ore obtained by a sampling device at one time with a single operation.

### 3.3 SUB-SAMPLE

Quantity of ore consisting of several increments taken from part of a consignment.

### 3.4 GROSS SAMPLE

The quantity of ore consisting of all the increments taken from a consignment.

### 3.5 SUB-GROSS SAMPLE

A sample representative of the gross sample.

### 3.6 PRIMARY INCREMENTS

Increments taken from a total presentation of the consignment.

### 3.7 SECONDARY INCREMENTS

Increments taken from primary increments or primary samples.

### 3.8 SPACING OF INCREMENTS (DEFINITION)

Systematic spacing is equal in time or position (tons) over the consignment. Random spacings are selected by chance in time or position over the consignment.

3.9 TOP SIZE

The length of a side of a square sieve opening upon which is retained .1 to 5 % of the ore.

3.10 ACCURACY

A measure of agreement between an experimental result and the true value.

3.11 ERROR

Difference of an observation or a group of observations from the best obtainable estimate of the true value.

3.12 BIAS (SYSTEMATIC ERROR)

An error that is consistently positive or negative. (The cause of bias can generally be detected and eliminated by correction of the method or revision of the equipment used for sample collection, storage, preparation, analysis or data presentation or any combination of these factors.)

3.13 CHANCE ERROR

An error which has equal probability of being positive or negative. The mean of the chance errors resulting from a series of observations approaches zero as the number of observations is increased.

3.14 SAMPLE PREPARATION

Includes (1) Division - Reduction in weight
(2) Crushing - Reduction in size to ½" (10 mm)
(3) Pulverizing - Reduction is size beyond ½" (10 mm) and
(4) Drying at 105° C ± 5°.

3.15 RIFFLE

Riffle is a stationary sampler for continuous diversion of a portion of the stream as a sample of that stream. (Jones Riffle consists of an assembly comprising an even number of equally sized chutes, adjacent chutes discharging in opposite sides).

3.16 INCREMENT DIVISION

That process of sample division whereby the entire sample is spread out on a flat surface with uniform thickness and rectangular shape. The surface is divided into segments of equal area. With a flat bottom tool a scoopful of sample of equal weight is taken from each segment and combined to form a divided sample.

3.17 FOREIGN MATERIAL

A substance not normally included in a consignment. (Must not exceed .1 % by weight).

3.18 VARIANCE $\sigma^2$

The average of the squared deviations from the mean.

3.19 STANDARD DEVIATION $\sigma$

The square root of the variance.

3.20 PRECISION

95 % confidence level or twice the standard deviation ($2\sigma$)

## IV SAMPLING PROCEDURE

4.1 Variation in handling procedures make it impossible to publish rigid rules for all parameters but the size of the increments and the minimum number of increments are defined and are based on the top size of the ore and the intrinsic variation of the characteristics to be tested. The representativeness of the final sample is also a factor of the method of collecting increment.

4.2 Method of collecting increments:

The representativeness of the final samples is directly related to the method of collecting the increments and is divided into the following three types and where possible Type I should be used. Type I will always take preference over Type II and likewise Type II over Type III.

TYPE I - Those increments which are collected in precise accord with previously assigned rules on timing and location that are free of any bias. (i.e.: All constituents or particles of a consignment have an equal probability of being sampled.) The size of increment and method of obtaining the increment are also engineered to be free of bias. Examples:

a) A full cross section cut from a stopped belt.

b) From a cutter moving across a falling stream at uniform speed taking a full cross section without allowing the receptacle to overflow.

c) From full grapples during discharge.

These increments form a statistically representative sample.

TYPE II - Some measure of human discretion is exercised in selection of the primary increments either by procedure or by design (part stream cut, etc..). The representativeness is then subject to proof of non-bias. Proof of non-bias is obtained periodically by check sampling of five (5) consignments by stopped belt method all within calculated precision or 9 out of 10 within precision and the other within 1.5 times precision or proof of 95 % within precision.

TYPE III - These increments are taken from a stationary consignment, i.e.: the entire consignment is not presented to the sampler. Guide lines for this procedure are given but the statistics are not valid and the samples are assumed to be representative. Agreement should be made between producer and consumer before this type of sampling is used.

4.3 The top size, the total precision of sampling the errors of preparation and analysis, and the intrinsic variation of the characteristic (s) desired are determined periodically by collecting 100 increments systematically or at random from an ore type, combining these in groups of 5 to form 20 sub-samples which are prepared in duplicate and analysed in duplicate as shown in Appendix "A".

These variables must be determined for each ore type and each sampling station as further blending would decrease the variations whereas possible segregation (moisture, size, etc..) would increase the variations at destination over origin.

Should this not be practical, agreement between producer and consumer should be obtained as to the size and number of increments to use and the number of samples to analyse.

4.4 The minimum number of increments required are calculated by the following formulae but must never be less than 10.

$$St = \sqrt{\frac{\sigma v^2}{5} + Sp^2 + Sa^2} \qquad ......(1)$$

WHERE St = Total Variation
Sp = Preparation Error
Sa = Analysis Error
AND $\sigma v$ = Intrinsic Variation

St, Sp and Sa are determined from 4.3 and $\sigma v$ is calculated by the following:

$$2\,\sigma t = 2\sqrt{\frac{\sigma v^2}{n} + \frac{Sp^2}{m} + \frac{Sa^2}{1}} \qquad ......(2)$$

WHERE $2\,\sigma t$ = Total Precision Desired
n = Number of Increments
m = Number of Repeated Preparations
1 = Number of Repeated Analysis

m and 1 will equal the number of increments, sub-samples or sub-gross samples used and will be 1 if only 1 gross sample is used.

4.5 The minimum size of increment is determined by the following table based on the top size of the ore type:

| TOP SIZE | | MINIMUM WEIGHT | |
|---|---|---|---|
| 10 mm | 3/8 " | 300 gm | 3/4 lb |
| 25 mm | 1 " | 800 gm | 2 lbs |
| 50 mm | 2 " | 4 kg | 9 lbs |
| 100 mm | 4 " | 12 kg | 26 lbs |
| 150 mm | 6 " | 20 kg | 44 lbs |
| 200 mm | 8 " | 28 kg | 62 lbs |
| 250 mm | 10 " | 36 kg | 80 lbs |

Variation in the construction of the sampling device, the flow or size consist of the ore, may make it impractical to collect increments as small as the minimum weight specified. In such cases, collect an increment of greater weight. However, do not reduce the minimum number of increments regardless of large excess of individual increment weight. (This weight usually can best be divided with secondary sampling following the same size weight ratio.)

4.6 DISTRIBUTION OF INCREMENTS

The increments are to be distributes throughout the entire consignment systematically with a random start. Should there be a sequence in movement of the consignment such that the sampling could become "in phase" with a changing variable, the sampling cycle should be altered or randomly selected.

4.7 DIMENSIONS OF THE SAMPLING DEVICE

The effective opening of the sampling device should have a minimum dimension of 3 times the top size of the ore.

4.8 PRESERVATION OF MOISTURE

The increments obtained during the sampling period shall be protected from changes in composition due to exposure to rain, snow, wind, sun, contact with absorbent materials and extremes of temperature. The circulation of air through equipment must be reduced to a minimum to prevent both loss of fines and moisture. Samples in which moisture content is important shall be protected from excessive air flow and then shall be stored in moisture-tight containers. Metal cans with air-tight lids or heavy vapor-impervious bags, properly sealed, are satisfactory for this purpose.

4.9 CONTAMINATION

The sampling arrangement shall be planned so that contamination of the increments with foreign material is avoided.

4.10 MECHANICAL SYSTEM FEATURES (FALLING STREAMS)

With mechanized systems, it is essential that the system as a whole including the sample cutter, chutes, conveyors, crushers and other devices be self-cleaning and non-clogging and be designed in a manner that will minimize the need for maintenance.

In the choice of mechanical sampling systems, it is necessary that over and above the strength requirements which would be calculated by engineers from bulk densities, speeds, etc... the system must meet the specifications of this method. i.e.:

1) The cycle of the sampler shall be fast enough to take required number of increments in the smallest consignment at the accuracy desired.

2) The cutter shall take a full cross section perpendicular to the stream at uniform speed with leading and trailing edges following the same plane.

3) The cutter shall have a minimum opening dimension of three times the top size of the ore.

4) The sampler shall operate at a speed such that the minimum weight will be equivalent to the weight of ore on the preceding conveyor for the cutter opening width at normal operating conditions or by the table 4.5, whichever is greater. The speed shall also be such that the cutter does not overflow.

EXAMPLE: Belt Speed - 580 ft/min.

Long Tons per hour - 4500

$$\therefore \quad \text{lbs./ft.} = \frac{4500 \times 2240}{580 \times 60} = 290$$

With a 4 inch cutter $= 4/12 \times 290 = 97$ lbs.

5) Secondary sampling required the same specifications.

## V PREPARATION PROCEDURE

The procedure of combining increments is divided into three methods.

5.1 Analyse every increment and average results by weight. (Although this would be the most accurate method, it is seldom practical.)

5.2 Combine increments to form sub-samples. Analyse each sub-sample and average the results by weight.

5.3 Combine all the increments to form a gross sample from which:

a) One sample will be taken the result reported

b) Sub-gross samples will be taken the average result reported

5.4 The preparation procedure following will be done on each increment in 5.1 each sub-sample in 5.2, on the gross sample in 5.3 (a), and on the sub-gross samples in 5.3 (b).

5.5 The procedure at this point is also dependent upon the determinations required and the following three factors are directly related to the preparation:

1) Is moisture to be determined?

2) Is size to be determined?

3) Volume & weight of sample (s) required?

Moisture determination limits the procedure to a minimum of handling, crushing to not less than ½" and that the samples are collected in moisture-tight containers. (Moisture should be determined as quickly as possible).

Size determination limits the procedure to no crushing until the size sample is removed at the proper weight to top size ratio. Total volume and weight required are of course directly related to the final gross samples needed and requires examination of the minimum weight and minimum number of increments at the outset to see that the final samples will be large enough.

5.6 Reduction of sample weight whether increment, sub-samples, gross sample, or sub-gross sample.

5.6.1 Division of samples to reduce the weight are subject to the following rules:

1) Use dividing equipment (riffles) that will provide a divided sample with the same size distribution as the original sample. Test equipment for bias.

2) Use secondary increments: The secondary sampler must be out of phase with primary, if fed directly. e.g.: Primary set at ton interval, secondary at time interval, or different timing cycles, or blend the entire primary sample. In any case, the minimum size and number of increments must be adhered to.

2.1) Tertiary sampling may be applied under the same restrictions as secondary sampling.

3) Increment division: Proceed as defined in 3.15 taking at least 16 areas.

4) At 2" (50 mm) and over cone and quartering or alternate shovel method may be used to divide samples down to a minimum weight of 300 lbs. (135 Kg).

5.6.2 Crushing - Division Ratio: Should size not be required or after removal of the size sample, the following schedule of crushing is to be followed in conjunction with division 5.6.1.

| TOP SIZE | | | MINIMUM TOTAL WEIGHT | |
|---|---|---|---|---|
| 8 " | 200 | mm | 19,200 lbs | 8,600 kg |
| 4 " | 100 | mm | 2,400 lbs | 1,080 kg |
| 2 " | 50 | mm | 300 lbs | 135 kg |
| 1 " | 25 | mm | 40 lbs | 18 kg |
| ½ " | 10 | mm | 5 lbs | 2.3 kg |
| .04 " | 1 | mm | 1 lb | .45 kg |
| .006 " | .15 | mm | ¼ lb | .100 kg |

(The table from ½ " to 8 " is based on a cubic factor with a 4 " cube as the base with a Sp. Gr. of 5.0 i.e.: 5 x 62.4 x 1/3 x 1/3 = 12 lbs. In order that this piece represents less than .5 % of the total weight, a factor of 200 must be applied or 200 x 12 = 2,400 lbs.) The last two sizes are based on practical two stages pulverizing to a 150 micron sample of 100 grams.

5.7 Drying - The moisture sample is to be removed during the crushing-division above at ½ " or greater.

The remaining sample may then be dried to constant weight at $105^{\circ}C \pm 5^{\circ}C$ for further crushing and division. (5.3)

5.8 Pulverizing - Is then performed on dry samples on the last two weight-size ratios of 5.6.2 if required.

## VI FINAL SAMPLE (S)

The final samples in size and weight are dependent on the characteristics to be tested but the following general rules apply.

1) Analysis sample should be at least 100 grams dried at $105 \pm 5^{\circ}C$ and pulverized to at least 150 microns.

2) Size sample should be relative to the table in 5.6.2.

3) Moisture sample should not be crushed below ½ " and should be at least 2.3 kg in weight.

## APPENDIX "A"

### A - REQUIRED

1) Determine top sizes of the ore type.

2) Determine the total variation of the characteristic desired.

3) Determine the standard deviation of duplicate analyses for the characteristic desired.

4) Determine the standard deviation of duplicate preparations for the characteristic desired.

5) Calculate the intrinsic variation.

6) Calculate the number of increments required.

### B - PROCEDURE

Obtain 100 increments systematically or randomly throughout a consignment (s) of the ore type desired to evaluate.

Combine these increments in sequence or randomly in groups of 5 to form 20 sub-samples.

Sieve the entire sub-samples through a sieve or sieves down to 10 mm to determine the top size, i.e.: the largest sieve greater than 10 mm containing .1 to 5 % by weight. Weigh plus and minus portions and re-combine. Record top size. (1)

Prepare samples for the characteristic desired obtaining two samples A and B from each re-combined sub-samples above.

Determine each sample for the characteristic desired in duplicate, i.e.: A1 - A2 and B1 - B2

Determine the mean of $\overline{A}$ the mean of $\overline{B}$ the individual analysis ranges $|A1 - A2|$ and $|B1 - B2|$ and the individual preparation ranges $|\overline{A} - \overline{B}|$.

THEREFORE: (2) $$St = \frac{\sigma\overline{A} + \sigma\overline{B}}{2}$$

(3) $$Sa = \frac{\sigma|A1 - A2| + \sigma|B1 - B2|}{2}$$

(4) $$Sp = \sigma|\overline{A} - \overline{B}|$$

THAN: (5) $\sigma_v$ is calculated from (1) of 4.4.

(6) The number of increments is calculated from (2) of 4.4.

Examples are shown in the following appendicies:

"B" A run of the mine ore unblended.

"C" A concentrate

"D" Pellets

Each type is taken at a separate sampling station with a separate falling stream mechanical sampler.

APPENDIX "B"

RUN OF THE MINE ORE SAMPLED BEFORE BLENDING

| Samp. | IRON | | | | | | | | | MOISTURE | | | | | | | | | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| # | A1 | A2 | Ā | A1-A2 | B1 | B2 | B̄ | B1-B2 | Ā-B̄ | A1 | A2 | Ā | A1-A2 | B1 | B2 | B̄ | B1-B2 | Ā-B̄ | +2" |
| 1 | 57.64 | 57.98 | 57.81 | .34 | 58.04 | 58.06 | 58.05 | .02 | .24 | 10.16 | 10.16 | 10.16 | .00 | 10.28 | 10.20 | 10.24 | .08 | .08 | 0.8 |
| 2 | 58.45 | 58.31 | 58.38 | .14 | 57.15 | 57.33 | 57.24 | .18 | 1.14 | 10.52 | 10.76 | 10.64 | .24 | 10.48 | 10.68 | 10.58 | .20 | .06 | 0.7 |
| 3 | 59.83 | 59.77 | 59.80 | .06 | 59.67 | 59.60 | 59.64 | .07 | .16 | 7.44 | 7.36 | 7.40 | .08 | 7.52 | 7.52 | 7.52 | .00 | .12 | 0.0 |
| 4 | 60.40 | 60.50 | 60.45 | .10 | 60.40 | 60.58 | 60.49 | .18 | .04 | 9.40 | 9.56 | 9.48 | .16 | 9.64 | 9.52 | 9.58 | .12 | .10 | 0.8 |
| 5 | 60.73 | 60.74 | 60.74 | .01 | 60.81 | 60.90 | 60.85 | .09 | .11 | 7.92 | 7.84 | 7.88 | .08 | 7.88 | 7.84 | 7.86 | .04 | .02 | 2.8 |
| 6 | 58.78 | 59.12 | 58.95 | .34 | 58.53 | 58.96 | 58.75 | .43 | .20 | 9.84 | 9.76 | 9.80 | .08 | 9.88 | 10.04 | 9.96 | .16 | .16 | 0.0 |
| 7 | 61.05 | 61.06 | 61.06 | .01 | 60.65 | 60.66 | 60.66 | .01 | .40 | 9.32 | 9.32 | 9.32 | .00 | 9.36 | 9.40 | 9.38 | .04 | .06 | 1.9 |
| 8 | 60.02 | 60.08 | 60.05 | .06 | 59.61 | 59.59 | 59.60 | .02 | .45 | 7.68 | 7.72 | 7.70 | .04 | 7.68 | 7.76 | 7.72 | .08 | .02 | 2.7 |
| 9 | 62.29 | 62.19 | 62.24 | .10 | 61.56 | 61.38 | 61.47 | .18 | .77 | 8.60 | 8.52 | 8.56 | .08 | 9.12 | 9.00 | 9.06 | .12 | .50 | 0.8 |
| 10 | 63.91 | 63.65 | 63.78 | .26 | 63.57 | 63.58 | 63.58 | .01 | .20 | 7.80 | 7.84 | 7.82 | .04 | 8.12 | 8.00 | 8.06 | .12 | .24 | 2.8 |
| 11 | 59.85 | 59.67 | 59.76 | .18 | 59.51 | 59.52 | 59.52 | .01 | .24 | 9.52 | 9.44 | 9.48 | .08 | 9.48 | 9.48 | 9.48 | .00 | .00 | 0.0 |
| 12 | 57.67 | 57.48 | 57.58 | .19 | 56.83 | 56.60 | 56.72 | .23 | .86 | 8.80 | 8.76 | 8.78 | .04 | 9.00 | 8.68 | 8.84 | .32 | .06 | 0.0 |
| 13 | 61.18 | 60.91 | 61.05 | .27 | 61.59 | 61.65 | 61.62 | .06 | .57 | 8.04 | 8.16 | 8.10 | .12 | 8.00 | 7.92 | 7.96 | .08 | .14 | 1.9 |
| 14 | 63.28 | 63.42 | 63.35 | .14 | 63.45 | 63.18 | 63.32 | .27 | .03 | 7.36 | 7.40 | 7.38 | .04 | 7.52 | 7.52 | 7.52 | .00 | .14 | 1.0 |
| 15 | 60.30 | 60.43 | 60.37 | .13 | 60.94 | 60.76 | 60.85 | .18 | .48 | 7.36 | 7.40 | 7.38 | .04 | 7.44 | 7.56 | 7.50 | .12 | .12 | 0.0 |
| 16 | 58.27 | 58.48 | 58.38 | .21 | 59.00 | 58.97 | 58.99 | .03 | .61 | 7.96 | 7.92 | 7.94 | .04 | 8.04 | 7.96 | 8.00 | .08 | .06 | 1.1 |
| 17 | 59.39 | 59.29 | 59.34 | .10 | 58.74 | 58.48 | 58.61 | .26 | .73 | 8.32 | 8.44 | 8.38 | .12 | 8.48 | 8.44 | 8.46 | .04 | .08 | 1.6 |
| 18 | 58.82 | 58.56 | 58.69 | .26 | 58.98 | 58.97 | 58.98 | .01 | .29 | 8.12 | 8.00 | 8.06 | .12 | 8.04 | 8.04 | 8.04 | .00 | .02 | 2.1 |
| 19 | 60.20 | 60.10 | 60.15 | .10 | 59.87 | 59.78 | 59.83 | .09 | .32 | 9.36 | 9.56 | 9.46 | .20 | 9.64 | 9.84 | 9.74 | .20 | .28 | 0.9 |
| 20 | 59.71 | 59.94 | 59.83 | .23 | 60.28 | 60.10 | 60.19 | .18 | .36 | 9.68 | 9.68 | 9.68 | .00 | 9.96 | 10.04 | 10.00 | .08 | .32 | 0.9 |
| Mean | | | 60.09 | .16 | | | 59.95 | .13 | .41 | | | 8.67 | .08 | | | 8.76 | .09 | .13 | 1.14 |
| σ | | | 1.63 | .10 | | | 1.72 | .11 | .28 | | | .98 | .06 | | | 1.00 | .08 | .12 | |

APPENDIX "B"

CALCULATIONS

1) Top Size:- + 2" is 1.14 % which is between .5 and 5%, therefore, minimum increment weight must be 9 lbs.

2) Total Variation of Iron:- St

$$= \frac{\sigma \overline{A} + \sigma \overline{B}}{2} = \frac{1.63 + 1.72}{2} = 1.68$$

3) Precision of Analysis:- Sa

$$= \frac{\sigma |A1 - A2| + \sigma |B1 - B2|}{2} = \frac{.10 + .11}{2}$$

$$Sa = .105$$

4) Precision of Preparation:- Sp

$$= \sigma |\overline{A} - \overline{B}| = .28$$

5) Intrinsic variation $\sigma v$ is calculated from formula (1) of 4.4.

$$St = \sqrt{\frac{\sigma v^2}{5} + Sp^2 + Sa^2} \quad \text{......(1)}$$

$$1.68 = \sqrt{\frac{\sigma v^2}{5} + .28^2 + .105^2}$$

$$\sigma v = 3.7$$

6) The number of increments (n) is then calculated from formula (2) of 4.4.

$$2\sigma t = 2\sqrt{\frac{\sigma v^2}{n} + \frac{Sp^2}{m} + \frac{Sa^2}{1}} \quad \text{......(2)}$$

Using a precision of 2 x .40 and 1 gross sample we have

$$.40 = \sqrt{\frac{3.7^2}{n} + \frac{.28^2}{1} + \frac{.105^2}{1}}$$

$$n = 194$$

7) To obtain a precision of 2 x .20 take 2n increments taking 4 sub-samples for preparation and analysis from each n.

$$\frac{2\sigma t}{\sqrt{2}} = 2\sqrt{\frac{\sigma v^2}{n} + \frac{Sp^2}{m} + \frac{Sa^2}{1}}$$

$$\frac{2 \times .20}{\sqrt{2}} = 2\sqrt{\frac{3.7^2}{n} + \frac{.28^2}{4} + \frac{.105^2}{4}}$$

$$n = 227$$

APPENDIX C IRON ORE CONCENTRATE

| | IRON | | | | | | | | | MOISTURE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLE | $A_1$ | $A_2$ | $\bar{A}$ | $A_1-A_2$ | $B_1$ | $B_2$ | $\bar{B}$ | $B_1-B_2$ | $\bar{A}-\bar{B}$ | $A_1$ | $A_2$ | $\bar{A}$ | $A_1-A_2$ | $B_1$ | $B_2$ | $\bar{B}$ | $B_1-B_2$ | $\bar{A}-\bar{B}$ | % + 10 |
| # 1 | 66.36 | 66.42 | 66.39 | .06 | 66.28 | 66.34 | 66.31 | .06 | .08 | 2.84 | 2.80 | 2.82 | .04 | 2.68 | 2.72 | 2.70 | .04 | .12 | 3.0 |
| 2 | 66.28 | 66.10 | 66.19 | .18 | 66.12 | 66.10 | 66.11 | .02 | .08 | 2.72 | 2.60 | 2.66 | .12 | 2.64 | 2.60 | 2.62 | .04 | .04 | 3.1 |
| 3 | 66.44 | 66.34 | 66.39 | .10 | 66.20 | 66.34 | 66.27 | .14 | .12 | 2.76 | 2.80 | 2.78 | .04 | 2.80 | 2.72 | 2.76 | .08 | .02 | 3.1 |
| 4 | 66.44 | 66.34 | 66.39 | .10 | 66.28 | 66.50 | 66.39 | .22 | .00 | 2.80 | 2.80 | 2.80 | .00 | 2.80 | 2.84 | 2.82 | .04 | .02 | 2.9 |
| 5 | 66.44 | 66.42 | 66.43 | .02 | 66.36 | 66.34 | 66.35 | .02 | .08 | 2.84 | 2.80 | 2.82 | .04 | 2.84 | 2.88 | 2.86 | .04 | .04 | 3.4 |
| 6 | 65.64 | 65.53 | 65.58 | .11 | 65.88 | 65.77 | 65.83 | .11 | .25 | 2.48 | 2.52 | 2.50 | .04 | 2.36 | 2.40 | 2.38 | .04 | .12 | 3.8 |
| 7 | 65.39 | 65.53 | 65.46 | .14 | 65.72 | 65.85 | 65.78 | .13 | .32 | 2.64 | 2.64 | 2.64 | .00 | 2.68 | 2.64 | 2.66 | .04 | .02 | 3.5 |
| 8 | 65.47 | 65.69 | 65.58 | .22 | 65.64 | 65.37 | 65.51 | .27 | .07 | 2.64 | 2.64 | 2.64 | .00 | 2.64 | 2.64 | 2.64 | .00 | .00 | 3.9 |
| 9 | 65.31 | 65.53 | 65.42 | .22 | 65.39 | 65.45 | 65.42 | .06 | .00 | 2.72 | 2.72 | 2.72 | .00 | 2.72 | 2.76 | 2.74 | .04 | .02 | 3.9 |
| 10 | 65.64 | 65.69 | 65.67 | .05 | 65.72 | 65.77 | 65.75 | .05 | .08 | 2.52 | 2.56 | 2.54 | .04 | 2.48 | 2.48 | 2.48 | .00 | .06 | 4.1 |
| 11 | 65.88 | 65.85 | 65.87 | .03 | 65.80 | 66.02 | 65.91 | .22 | .04 | 2.20 | 2.16 | 2.18 | .04 | 2.04 | 2.04 | 2.04 | .00 | .14 | 4.1 |
| 12 | 65.39 | 65.61 | 65.50 | .22 | 65.47 | 65.45 | 65.46 | .02 | .04 | 2.64 | 2.60 | 2.62 | .04 | 2.68 | 2.64 | 2.66 | .04 | .04 | 3.7 |
| 13 | 66.28 | 66.32 | 66.30 | .04 | 66.60 | 66.32 | 66.46 | .28 | .16 | 3.00 | 2.96 | 2.98 | .04 | 2.96 | 2.96 | 2.96 | .00 | .02 | 3.4 |
| 14 | 66.28 | 66.32 | 66.30 | .04 | 66.28 | 66.16 | 66.22 | .12 | .08 | 2.64 | 2.64 | 2.64 | .00 | 2.60 | 2.60 | 2.60 | .00 | .04 | 3.2 |
| 15 | 66.28 | 66.08 | 66.18 | .20 | 66.36 | 66.24 | 66.30 | .12 | .12 | 2.60 | 2.60 | 2.60 | .00 | 2.56 | 2.60 | 2.58 | .04 | .02 | 3.4 |
| 16 | 66.52 | 66.28 | 66.40 | .24 | 66.44 | 66.36 | 66.40 | .08 | .00 | 2.64 | 2.68 | 2.66 | .04 | 2.56 | 2.60 | 2.58 | .04 | .08 | 3.5 |
| 17 | 66.28 | 66.20 | 66.24 | .08 | 66.20 | 66.28 | 66.24 | .08 | .00 | 2.44 | 2.44 | 2.44 | .00 | 2.40 | 2.36 | 2.38 | .04 | .06 | 3.9 |
| 18 | 66.52 | 66.28 | 66.40 | .24 | 66.36 | 66.28 | 66.32 | .08 | .08 | 2.00 | 1.96 | 1.98 | .04 | 1.88 | 1.92 | 1.90 | .04 | .08 | 4.0 |
| 19 | 66.36 | 66.12 | 66.24 | .24 | 66.28 | 66.20 | 66.24 | .08 | .00 | 2.80 | 2.80 | 2.80 | .00 | 2.76 | 2.76 | 2.76 | .00 | .04 | 4.4 |
| 20 | 66.36 | 66.36 | 66.36 | .00 | 66.28 | 66.44 | 66.36 | .16 | .00 | 2.92 | 2.96 | 2.94 | .04 | 2.96 | 2.96 | 2.96 | .00 | .02 | 4.4 |
| MEAN | | | 66.06 | .125 | | | 66.08 | .116 | .08 | | | 2.63 | .028 | | | 2.60 | .028 | .050 | 3.6 |
| σ | | | .39 | .083 | – | | .33 | .077 | .082 | | | .73 | .028 | | | .26 | .022 | .033 | |

## APPENDIX "C"

## CALCULATIONS

1) Top Size:- + 10 mesh (1.68 mm) = 3.6 %
As this is less than 10 mm, the minimum increment weight must be 300 gm.

2) Total Variation of Iron:- St

$$= \frac{\sigma \bar{A} + \sigma \bar{B}}{2} = \frac{.39 + .33}{2} = .36$$

3) Precision of Analysis:- Sa

$$= \frac{\sigma|A1 - A2| + \sigma|B1 - B2|}{2} = \frac{.083 + .077}{2} = .08$$

4) Precision of Preparation:- Sp

$$= \sigma|\bar{A} - \bar{B}| = .082$$

5) Intrinsic variation $\sigma v$ is calculated from (1) of 4.4.

$$St = \sqrt{\frac{\sigma v^2}{5} + Sp^2 + Sa^2}$$

$$.36 = \sqrt{\frac{\sigma v^2}{5} + .08^2 + .08^2}$$

$$\sigma v = .76$$

6) The number of increments (n) is then calculated from (2) of 4.4.

$$2\sigma p = 2\sqrt{\frac{\sigma v^2}{n} + \frac{Sp^2}{m} + \frac{Sa^2}{1}}$$

Using 1 gross sample and a precision of 2 x .20 we have.

$$.20 = \sqrt{\frac{.76^2}{n} + .08^2 + .08^2}$$

$$n = 21$$

## IRON ORE PELLETS

APPENDIX "D"

| SAMPLE # | IRON $A_1$ | IRON $A_2$ | IRON $\bar{A}$ | IRON $A_1-A_2$ | IRON $B_1$ | IRON $B_2$ | IRON $\bar{B}$ | IRON $B_1-B_2$ | IRON $\bar{A}-\bar{B}$ | MOISTURE $A_1$ | MOISTURE $A_2$ | MOISTURE $\bar{A}$ | MOISTURE $A_1-A_2$ | MOISTURE $B_1$ | MOISTURE $B_2$ | MOISTURE $\bar{B}$ | MOISTURE $B_1-B_2$ | MOISTURE $\bar{A}-\bar{B}$ | SIZE −7/8 + 1/2" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 65.87 | 65.95 | 65.91 | .08 | 65.95 | 65.95 | 65.95 | .00 | .04 | 1.04 | 1.01 | 1.03 | .03 | .90 | .86 | .88 | .04 | .15 | .3 |
| 2 | 65.87 | 65.95 | 65.91 | .08 | 65.79 | 65.95 | 65.87 | .16 | .04 | .98 | .96 | .97 | .02 | .96 | .83 | .90 | .13 | .07 | .6 |
| 3 | 65.39 | 65.63 | 65.51 | .24 | 65.55 | 65.47 | 65.51 | .08 | .00 | 1.03 | 1.11 | 1.07 | .08 | 1.18 | 1.07 | 1.12 | .11 | .05 | 1.2 |
| 4 | 65.63 | 65.63 | 65.63 | .00 | 65.47 | 65.55 | 65.51 | .08 | .12 | 1.08 | 1.08 | 1.08 | .00 | 1.07 | 1.03 | 1.05 | .04 | .03 | .2 |
| 5 | 65.47 | 65.45 | 65.46 | .02 | 65.31 | 65.45 | 65.38 | .14 | .08 | 1.09 | 1.04 | 1.06 | .05 | .98 | .99 | .98 | .01 | .08 | 1.0 |
| 6 | 65.63 | 65.45 | 65.54 | .18 | 65.63 | 65.45 | 65.54 | .18 | .00 | .57 | .50 | .53 | .07 | .48 | .42 | .45 | .06 | .08 | .4 |
| 7 | 65.63 | 65.45 | 65.54 | .18 | 65.63 | 65.45 | 65.54 | .18 | .00 | .73 | .76 | .74 | .03 | .80 | .74 | .77 | .06 | .03 | .2 |
| 8 | 65.48 | 65.39 | 65.44 | .09 | 65.48 | 65.31 | 65.40 | .17 | .04 | .66 | .58 | .62 | .04 | .68 | .67 | .68 | .01 | .06 | 2.0 |
| 9 | 65.48 | 65.39 | 65.44 | .09 | 65.48 | 65.47 | 65.48 | .01 | .04 | .74 | .71 | .73 | .03 | .81 | .76 | .79 | .05 | .06 | 1.3 |
| 10 | 65.40 | 65.47 | 65.44 | .07 | 65.48 | 65.47 | 65.48 | .01 | .04 | .87 | .83 | .85 | .04 | .82 | .81 | .82 | .01 | .03 | .8 |
| 11 | 65.48 | 65.39 | 65.44 | .09 | 65.40 | 65.31 | 65.36 | .09 | .08 | .95 | .89 | .92 | .06 | .90 | .89 | .89 | .01 | .03 | 1.4 |
| 12 | 65.40 | 65.31 | 65.35 | .09 | 65.48 | 65.39 | 65.44 | .09 | .09 | .83 | .90 | .86 | .07 | .96 | .90 | .93 | .06 | .07 | 4.5 |
| 13 | 65.32 | 65.23 | 65.28 | .09 | 65.48 | 65.31 | 65.39 | .17 | .11 | .90 | .86 | .88 | .04 | .95 | .94 | .95 | .01 | .07 | 3.2 |
| 14 | 65.48 | 65.23 | 65.35 | .25 | 65.32 | 65.31 | 65.32 | .01 | .03 | .82 | .79 | .81 | .03 | .71 | .73 | .72 | .02 | .09 | .6 |
| 15 | 65.47 | 65.39 | 65.43 | .08 | 65.47 | 65.39 | 65.43 | .08 | .00 | .65 | .79 | .72 | .14 | .67 | .76 | .71 | .09 | .01 | .3 |
| 16 | 65.47 | 65.55 | 65.51 | .08 | 65.47 | 65.39 | 65.43 | .08 | .08 | .73 | .79 | .76 | .06 | .69 | .75 | .72 | .06 | .04 | 1.1 |
| 17 | 65.55 | 65.48 | 65.52 | .07 | 65.39 | 65.48 | 65.44 | .09 | .08 | .96 | .76 | .86 | .20 | .90 | .78 | .84 | .12 | .02 | 5.5 |
| 18 | 65.39 | 65.31 | 65.35 | .08 | 65.23 | 65.31 | 65.27 | .08 | .08 | .85 | .95 | .90 | .10 | .71 | .80 | .75 | .09 | .15 | 10.4 |
| 19 | 65.31 | 65.15 | 65.23 | .16 | 65.48 | 65.47 | 65.48 | .01 | .25 | .74 | .82 | .78 | .08 | .80 | .75 | .77 | .05 | .01 | 3.8 |
| 20 | 65.23 | 65.31 | 65.27 | .08 | 65.39 | 65.31 | 65.35 | .08 | .08 | .82 | .84 | .83 | .02 | .83 | .90 | .86 | .07 | .03 | 1.7 |
| MEAN | | | 65.48 | .105 | | | 65.47 | .09 | .06 | | | .85 | .06 | | | .83 | .06 | .06 | 2.0 |
| $\sigma$ | | | .20 | .064 | | | .16 | .059 | .056 | | | .14 | .045 | | | .14 | .037 | .039 | |

## APPENDIX "D"

## CALCULATIONS

1) Top Size:- + ¾" = 2.0 % therefore, the minimum weight per increment must be 2 lbs.

2) Total Variation of Iron:- St

$$= \frac{\sigma \bar{A} + \sigma \bar{B}}{2} = \frac{.20 + .16}{2} = .18$$

3) Precision of Analysis:- Sa

$$= \frac{\sigma|A1 - A2| + \sigma|B1 - B2|}{2} = \frac{.064 + .059}{2} = .06$$

4) Precision of Preparation:- Sp

$$= \sigma|\bar{A} - \bar{B}| = .056 = .06$$

5) Intrinsic variation $\sigma v$ is calculated from (1) of 4.4.

$$St = \sqrt{\frac{\sigma v^2}{5} + Sp^2 + Sa^2}$$

$$.18 = \sqrt{\frac{\sigma v^2}{5} + .06^2 + .06^2}$$

$$\sigma v = .36$$

6) The number of increments are calculated from (2) of 4.4.

$$2\sigma t = \sqrt{\frac{\sigma v^2}{n} \quad \frac{Sp^2}{m} \quad \frac{Sa^2}{1}}$$

Using 1 gross sample and a precision of 2 x .20 we have

$$.20 = \sqrt{\frac{.36^2}{n} + .06^2 + .06^2}$$

$$n = 4$$

As n is less than 10, we take 10 increments and substitute 10 for n and calculate the precision.

$$\sigma t = \sqrt{\frac{.36^2}{10} + .06^2 + .06^2}$$

$$\sigma t = .14 \quad \text{OR} \quad 2\sigma t = .28$$