#332
5/9/80

DR. 1162

MASTER

Y-12

Y-2219

OAK
RIDGE
Y-12
PLANT

UNION
CARBIDE

A STATISTICAL ANALYSIS OF NUCLEAR MATERIAL
WEIGHING SYSTEMS AT THE OAK RIDGE
Y-12 PLANT

A. H. Hammer

April 1980

OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Reference to a company or product name does not imply approval or recommendation of the product by Union Carbide Corporation or the Department of Energy to the exclusion of others that may meet specifications.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
Price: Printed Copy A03; Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, nor assumes any legal liability or responsibility for any third party's use or the results of such use of any information, apparatus, product or process disclosed in this report, nor represents that its use by such third party would not infringe privately owned rights.

Date of Issue: April 30, 1980
Distribution Category: UC-15

Y-2219

**A STATISTICAL ANALYSIS OF NUCLEAR MATERIAL
WEIGHING SYSTEMS AT THE OAK RIDGE
Y-12 PLANT**

A. H. Hammer
Statistical Quality Control Department
Quality Division

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Oak Ridge Y-12 Plant

P. O. Box Y, Oak Ridge, Tennessee 37830

Prepared for the Department of Energy
Under US Government Contract W-7405-eng-26

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

See

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ABSTRACT

The variation in weight measurements on the electronic scales purchased for the Dynamic Special Nuclear Materials Control and Accountability System (DYMCAS) has been characterized and estimated to be more than is acceptable when using the current weighing methods. New weighing procedures have been developed which substantially reduce this variation and bring the weight errors within the Y-12 Plant Nuclear Materials Control and Accountability Department's desired ± 2 -g accuracy.

CONTENTS

SUMMARY	5
INTRODUCTION	6
AN ANALYSIS OF WEIGHING SYSTEMS	9
Experimental Work	9
Equipment Orientation	9
Effects of Environmental Changes	9
Estimating the Systematic and Random Weighing Errors	10
Experiment to Reduce Systematic Weighing Errors	13
Search for Weight and Time Limitations of Proposed Weighing Method	15
CONCLUSIONS AND RECOMMENDATIONS	19
Recommended Weighing Method for 40-kg Scales	19
ACKNOWLEDGMENTS	21

SUMMARY

A series of experiments has been conducted to characterize and estimate expected weight errors on new scales acquired for the Dynamic Special Nuclear Materials Control and Accountability System (DYMCAS). The physical environment affects weight errors. By using the current weighing method, operationally significant scale-to-scale, setup-to-setup, and weight-to-weight variations were found. Short-term systematic errors exist which can create biased inventories and unnecessarily large uncertainties on measured inventories. An operationally efficient weighing method which involved setting the scale for a specific weight range was developed and proved to reduce, substantially, these systematic errors. By using this recommended method, the DYMCAS scales can perform within the ± 2 -g limit desired by the Y-12 Plant Nuclear Materials Control and Accountability Department (NMC&A).

INTRODUCTION

In May, 1979, the Oak Ridge Y-12 Plant^(a) began a statistical evaluation of Toledo/8130^(b) electronic scales to determine if the scales could meet the needs of NMC&A. Although the Toledo/8130 scales meet the stringent sensitivity and tolerance requirements of the Y-12 Plant's equipment specifications, it was necessary to estimate the magnitude of weight errors in comparison with NMC&A's desired ± 2 -g accuracy and to isolate the sources of variation in those errors. Error estimates will be necessary for the calculation of the uncertainty of the Special Nuclear Material (SNM) inventory which will be required under anticipated Department of Energy regulations. As the investigation proceeded, one experiment suggested the direction and scope of the next. As knowledge of the Toledo scales increased, the original goal of characterization was fulfilled; and a new goal of reducing the error was also achieved.

The inquiry passed through five distinct phases: (1) equipment familiarization, (2) testing for effects of physical changes in the scale, (3) estimating the systematic and random weighing errors, (4) comparing the current weighing method with a proposed method intended to reduce systematic error, and (5) defining the limitations of the proposed method.

The term, error, refers to the difference (in grams) between the observed weight and the true weight of the object being weighed. Errors are classified as either systematic, assigned to a specific source or interaction of sources, or random (unexplained by the experiment).

The term, zero, refers to the action of a scale operator when setting the scale to read accurately at a given weight level. A scale can be zeroed at any weight level to the maximum capacity of the scale. To zero, place the proper certified standard or combination of standards on the scale platform and correct any error in the digital readout by simply turning the zero adjustment knob clockwise to increase the reading or counterclockwise to reduce the reading. See Figure 1.

(a) Operated by the Union Carbide Corporation, Nuclear Division, for the Department of Energy.

(b) Toledo Scale Company, Toledo, Ohio.

Figure 1. SCALE CONTROL PANEL.

192437

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

AN ANALYSIS OF WEIGHING SYSTEMS

EXPERIMENTAL WORK

Equipment Orientation

Prior to the establishment of a mode of investigation, arrangements for an orientation session on the Toledo/8130 scales with the Y-12 Plant Maintenance Division Scale and Balance Shop personnel were completed. A Y-12 employee, formerly with Toledo, demonstrated the procedure for zeroing and operating the electronic load-cell scales. The sensitivity of the scales to their physical environment was exhibited. Noticeable reading changes occurred with changes in wind currents, in the location of the weight on the scale platform, and in the amount of other weight on the same table as the scales. A Y-12 Plant electrical engineer described some of the tests, that the Maintenance Division had performed, which indicated substantial reading changes were experienced with vibration, unevenness of the scale platform (tilt), and location shifts of the weight on the platform. Y-12 experimenters then practiced zeroing and operating the scales by using the same procedure followed by the scale operators in the plant.

Current Weighing Method - To weigh an object, first set the scale to read 00000 with no load on the scale platform. Place the object to be weighed on the platform center. Allow the scale to stabilize and observe the measured weight.

Effects of Environmental Changes

Questions raised by the demonstration in the scale shop and by observing audit weighings in the plant led to the planning and conducting of an initial experiment to evaluate the effects of scale platform tilting, weight location, proportion of capacity used, and scale-to-scale variation on the accuracy and repeatability of the Toledo scales acquired for DYMCAS.

Experimental Procedure - After reviewing data collected by the Maintenance Division, the experiment was focused on what was thought to be a relevant range of levels in the factors of interest. Three levels of tilt (0, 1, and 2°), three directions (120° apart), and two levels of capacity (1/3- and 2/3-) were investigated on three scales chosen at random. Two of the scales were 40-kg capacity, and one was 20 kg. This is the same ratio of 40- to 20-kg scales that will be used in DYMCAS. There were 54 possible combinations of tilt, direction, proportion of capacity used, and scales. All 54 combinations were observed randomly. Within each of these setups, a certified standard weight was randomly placed at each of four locations; three of them were offset 3 in from the center and one was at the center, Figure 2. One reading was taken at each offset location, and three readings were taken at the center which gave a total of 324 observations. Data collection took approximately 6 hours. One digital readout was used for all three platforms. Electrical power was maintained to all three scales during the experiment.

Highlights - The following observations were noted:

1. Across the entire range of experimental conditions, the weight errors ranged from -11 to +16 g, which was greater than anticipated.
2. Errors varied for different-sized standards. Weight-to-weight variation accounted for over 40% of the total error variation when the scale was level and the weight centered.
3. The weight error varied considerably when the weight was placed at different locations on the scale platform. For observations to be repeatable, the weight had to be placed in the identical location. Obviously, the center location is the easiest to define.
4. There is a difference among scales. The difference was evident in the high-capacity observations of Scales 1 and 3 in Figure 3. Both scales are 40 kg.
5. As shown in Figure 3, the more the scale was tilted the less the observed weight.
6. Using leveled scales with the weights centered on the platform and within a given setup, the observed repeatability was close to ± 1 g; however, this should not be interpreted as ± 1 g accuracy. As shown in Figure 3, some significant biases existed.
7. In this experiment, the great extent of setup-to-setup variation was first realized.

Estimating the Systematic and Random Weighing Errors

Impressed by the relative size of the weighing errors that were observed during the experiments in the Y-12 Scale and Balance Shop and concerned about the degree of setup-to-setup variation possible in routine scale operations within the plant, the experimenters decided that information was needed as to the accuracy of the scales now in their operating environment in the Y-12 Plant. Therefore, a control program to determine the levels of accuracy and repeatability and to investigate suspected determinants of weight-error variability was planned and implemented.

Control Program Procedure - After error variability was observed and analyzed under controlled conditions in the Scale and Balance Shop, the analysis of weight error variability in the plant concentrated on the effects of scale, weight, and setup variation. Tilt, wind, and vibration effects could not be controlled, but record was made as to when these conditions were observed. Originally, six Toledo/8130 scales (four 40-kg and two 20-kg) in five material balance areas (MBA), four weights (20, 40, 60, and 80% of scale capacity), and ten setups of each scale were to be investigated. Later, all the DYMCA scales were included. During each setup, the four standard weights were randomly weighed (five times each on the platform center) and the error was recorded. Scales were observed only when in a condition acceptable in their area. The statistics cited were derived from the original 1200 observations. Later observations are consistent with them.

Figure 2. TOLEDO/8130 SCALE PLATFORM.

192438

Figure 3. WEIGHT ERRORS BY PHYSICAL FACTORS. (Refer to Figure 2 for location identification.)

Highlights - The observations noted were:

1. Across all scales, capacities, and setups, the observed weight errors ranged from -8 to +12 g. The distribution of errors is given in Figure 4.
2. Setup-to-setup variation, by far the largest source of variation, was so large that no observed scale was found to be in statistical control. Average errors varied from setup to setup. For example, one 20-kg scale had an average error shift of over 5.5 g between 9:20 a.m. on July 11, 1979, and 10:40 a.m. on July 12, 1979. See Table 1 and Figures 5, 6, and 7.
3. As weight increased, error variation was magnified. This can be seen in the confidence limits in Table 2.
4. Scale environments varied from area to area and from setup to setup. In over one-third of the original 60 setups observed, the scale platform was found to have 0.5 degree or more of tilt. This was a sufficient tilt to affect the scales. While wind speed was not a measurable determinant of weight error variability, it is believed that wind speed and its variability adversely affected the scales. Vibration significantly increased weight error variability.

Figure 4. DISTRIBUTION OF WEIGHT ERRORS. (Observed weight errors ranged from -8 to +12 g; error values of < 1% of the total distribution are not shown; distribution based on original 1200 observations of the scale control program.)

Table 1

VARIANCE COMPONENT ESTIMATES FROM SCALE CONTROL PROGRAM⁽¹⁾

Source of Variation	40-kg Scale		20-kg Scale	
	Estimate (g ²)	Percentage (%)	Estimate (g ²)	Percentage (%)
Scale	0.0778	2	0.4484	11
Weight	0.2526	7	0.2886	7
Setup (Scale) ⁽²⁾	1.3845	41	2.0074	50
Weight* Setup (Scale) ⁽²⁾	0.4140	12	0.5592	14
Systematic	2.1288	62	3.3039	82
Random	1.2675	37	0.7038	18
Total	3.3963	99	4.0076	100

(1) Calculated from original 1200 observations.

(2) The source of variation setup and its interaction with the main effect weight are both defined nested within the main effect scale.

Experiment to Reduce Systematic Weighing Errors

During the reviews of the systematic and random error estimates necessary for the calculation of SNM inventory uncertainty, it became apparent that a vast and expensive information system with continuous updating would be required for every DYMCAS scale if use of the current weighing method was continued. Estimates of systematic and random error would need to be updated monthly. Continuous analysis would be required to determine weight class biases, class frequencies per month, class frequencies per setup, and the number of setups per month for every individual scale. Therefore, a search for ways to reduce the systematic error was begun. After exploring several alternatives, the decision to extensively test the most promising one was made.

Proposed Weighing Method - Estimate, by some practical

means, the weight of an object. Place a certified standard which is sufficiently near this estimated weight on the scale platform center. (The term, sufficiently, is defined in the **Search for Weight and Time Limitations of Proposed Weighing Methods, Highlights** section of this report.) Allow the scale to stabilize. Adjust the scale for the correct weight of the standard. Remove the standard, and place the object to be weighed on the platform center. Allow the scale to stabilize and observe the weight.

Experimental Procedure - Three 40-kg scales purchased for DYMCAS were randomly selected. For 3 separate days, both the current and the proposed weighing methods were used to randomly weigh certified standards of 26, 28, 30, 32, and 34 kg (two times each

Figure 5. EXAMPLE OF WEIGHT ERRORS USING CURRENT WEIGHING METHOD. (Data is from first 50 observations of Scale M51414 with a 32-kg standard.)

Figure 6. EXAMPLE OF AVERAGE WEIGHT ERRORS PER SETUP USING CURRENT WEIGHING METHOD. (Data is from first 50 observations of Scale M51414 with a 32-kg standard; data points represent average errors per setup based on five observations.)

with each method on each scale). This range of weights was chosen because it had shown the greatest weight errors. When using the proposed method, each scale was zeroed at 30 kg.

Highlights - Observations of note were:

1. As shown in Table 3 and Figure 8, the proposed method substantially reduced three sources of systematic error and their interactions: scale-to-scale, setup-to-setup, and weight-to-weight variations. Therefore, measurements were more accurate and repeatable. Ninety-five-percent confidence intervals around individual weighings were cut by over

Figure 7. EXAMPLE OF WEIGHT ERROR RANGE PER SETUP USING CURRENT WEIGHING METHOD. (Data is from first 50 observations of Scale M51414 with a 32-kg standard; range equals largest error minus smallest error for setup with five observations.)

Table 2
CONFIDENCE LIMITS FOR WEIGHT ERRORS USING CURRENT METHOD

Series-Scale Weight	Weight (g)	Limit		Average Error ⁽¹⁾ (g)	Limit		Number of Observations	Range (g)	Standard Deviation (g)
		Upper 99 (g)	Upper 95 (g)		Lower 95 (g)	Lower 99 (g)			
M51414-40 kg	8 000	3	2	0.1	-2	-3	50	5	1.04
M51414-40 kg	16 000	4	3	-0.4	-4	-5	50	10	1.84
M51414-40 kg	24 000	5	4	0.3	-4	-5	50	9	1.96
M51414-40 kg	32 000	9	7	1.8	-4	-5	50	13	2.79
M80007-40 kg	8 000	2	1	-0.4	-2	-2	50	3	0.75
M80007-40 kg	16 000	2	1	-0.7	-3	-3	50	4	1.04
M80007-40 kg	24 000	2	2	-0.3	-2	-3	50	4	1.03
M80007-40 kg	32 000	4	4	0.8	-2	-3	50	5	1.42
M51445-20 kg	4 000	2	1	-0.9	-3	-4	50	3	1.06
M51445-20 kg	8 000	2	1	-1.6	-5	-6	50	5	1.58
M51445-20 kg	12 000	4	3	-1.9	-7	-8	50	8	2.34
M51445-20 kg	16 000	6	4	-1.5	-7	-9	50	11	2.90
M29577-20 kg	4 000	2	2	0.5	-1	-1	50	4	0.73
M29577-20 kg	8 000	4	3	0.2	-3	-4	50	9	1.50
M29577-20 kg	12 000	3	2	-0.4	-3	-4	50	6	1.21
M29577-20 kg	16 000	2	1	-1.5	-4	-5	50	7	1.36
M80003-40 kg	8 000	1	1	-0.3	-1	-2	50	3	0.60
M80003-40 kg	16 000	1	1	-0.8	-2	-3	50	4	0.77
M80003-40 kg	24 000	2	1	-1.2	-4	-5	50	8	1.35
M80003-40 kg	32 000	3	2	0.3	-2	-2	50	5	1.03
M51419-40 kg	8 000	4	3	0.8	-2	-3	40	9	1.36
M51419-40 kg	16 000	5	4	0.6	-3	-4	50	7	1.72
M51419-40 kg	24 000	6	5	0.3	-4	-6	50	9	2.28
M51419-40 kg	32 000	9	7	0.5	-6	-8	50	17	3.27

(1) Average of first 50 observations in scale control program.

40%. The end result will be that inventory errors, which were the result of weighing errors, will be reduced.

2. The proposed method will not necessarily increase the amount of time and expense required to weigh parts. In fact, it may reduce the time and expense involved since the daily check-weight procedure (which takes more than 30 min in some areas) could be eliminated. By recording the amount of adjustment necessary to zero the scales, the information required for detecting significant scale problems would still be available. Broad administrative limits, such as ± 10 g, could be established for the error correction adjustment to provide a decision rule for calling Maintenance personnel.

Table 3
ESTIMATES OF WEIGHT ERROR FROM EXPERIMENT
TO REDUCE SYSTEMATIC ERROR IN WEIGHING

	Current Method (g ²)	Proposed Method (g ²)	Change (%)
Systematic Error	0.659	3.057	-78
Random Error	0.567	0.556	2

Search for Weight and Time Limitations of Proposed Weighing Method

After the initial experiment which demonstrated the superiority of the proposed weighing method, two experiments to define its limitation were designed and conducted.

Experimental Procedure for Evaluating Weight Range Limits - To determine the distance of the object's true weight from the scale zero level and yet to continue to give acceptable results for NMC&A, an experiment with three zero levels (10, 20, and 30 kg) and weight increments of 1 kg from -5 kg to +5 kg about the zero level was designed and performed. Observations were randomly made on each of these combinations (three times during two setups of each scale). This was done for three 40-kg DYMCAS scales providing a total of 594 observations. At the beginning of each setup, standards equal to the zero level (10, 20, or 30 kg) were placed on the scale platform center, and the scale was adjusted to read the

Figure 8. WEIGHT ERRORS BY WEIGHING METHOD.

standard value. After removal of the standards, the scale was allowed to stabilize, while empty. Then, the standards were replaced to double check zeroing, and any necessary adjustments were made and double checked. Once the scale was zeroed, the zero adjustment knob was not physically touched for the duration of the setup, which lasted from 30 to 90 min and included 33 separate weighings. The size and significance of each source of variation and its interaction with the other sources were estimated and analyzed statistically. Estimates of variation were compared with variation estimates for the current method and calculated from 1200 observations gathered for the scale control program. Because of the very large size of the samples, the statistical tests were powerful and extremely sensitive.

Experimental Procedure for Evaluating Time Limits - In addition to the information collected from the weight limit experiment, specific tests were run to find the effects of time on scale readings. By using four 40-kg DYMCAS scales, the experimenter zeroed each scale at either 20 or 30 kg. Every 5 min for 2 hours, standard weights equal to the zero level were placed on the scale, observed, and recorded. Two of the scales were checked at random times to further observe drift. On one scale, it was necessary to miss some observations. The time effects on the scale readings were analyzed using appropriate methods.

Highlights - Noteworthy observations were:

1. With the 40-kg scales, the magnitude of difference between the zero level and the weight of the object became more critical as the weight increased. This is shown in Figure 9. For weights < 25 kg, 40-kg scales will provide the desired ± 2 -g accuracy when

Figure 9. WEIGHT ERRORS BY ZERO LEVEL USING PROPOSED METHOD.
(Data from 40-kg Scale M62966, Setup 1.)

zeroed within 5 kg of the object's true weight. For weights > 25 kg, the 40-kg scales must be zeroed within 2 kg of the object's true weight to obtain acceptable accuracy.

2. As exhibited in Figure 10, there was no distinguishable scale reading drift over time. Rather than time itself affecting the scales, changes in scale zero levels were suspected to be physical disturbances to the scales such as vibrations from pumps and forklifts, moving the scales, or turning the zero adjustment knob. These physical agitations effected short-term biases and variability in the scale readings.

Figure 10. WEIGHT ERRORS ACROSS TIME. (Data from 20-kg Scale M62966, 20-kg Scale M62981, 30-kg Scale M62971, and 30-kg Scale M62961.)

3. The proposed method will be superior to the current method in terms of accuracy and repeatability. After comparing the latest experiments with the extensive data collected on the current method, systematic error and random error are both reduced by more than 70%, Table 4. Unlike the current method, the zeroing process will not be repeated unless the scales are adversely affected or the relative weight range changes. The proposed weighing process should not substantially impair efficiency.

It is extremely difficult to know definitely that a scale is zeroed where it is desired, whether it be at zero or at 30 kg. Since a DYMCAS scale reads only to ± 1 g, it may be in error ± 0.5 g at the desired zero level, yet read as though perfectly zeroed. To decrease zeroing errors, the operator must zero the scale with the desired standards, remove them, and then replace them to double check the zero level. When placing weights of any nature on the scale, the operator should allow the scale to stabilize with the platform clear. This is not very time consuming when using the lighter weights, and it is inexpensive insurance at the

heavier levels where little weighing is done. The scale operator should verify the zero level periodically or when any doubt exists as to its location. Unless there is a change in either the true or the desired zero level, the zero adjustment knob is best left untouched. When changes in the true zero level occur, they are usually evident by a change in the scale reading when it is stabilized while empty. Continual unnecessary fine tuning of the scale must be avoided. During the latest tests, each scale was zeroed at the beginning of each setup, and the adjustment knob was not physically touched thereafter. The experimenters attributed the significant reduction in random error to this "lack" of physically touching the zero adjustment knob.

Table 4
WEIGHT ERRORS

By Weighing Method			
	Current ⁽¹⁾ (g ²)	Proposed ⁽²⁾ (g ²)	Reduction (%)
Systematic Error	2.13	0.60	72
Random Error	1.27	0.38	70
By Zero Level Using the Proposed Method ⁽³⁾			
	Zeroed at 10 kg (g ²)	Zeroed at 20 kg (g ²)	Zeroed at 30 kg (g ²)
Systematic Error	0.15	0.21	0.90
Random Error	0.16	0.27	0.72

(1) Based on original 1200 observations of scale control program.

(2) Based on experiment to evaluate weight range limits.

(3) Estimates based on application of proposed weighing method within the limitations specified in this report.

CONCLUSIONS AND RECOMMENDATIONS

Since May 1979, the evaluation of the DYMCAS scales in terms of NMC&A's requirements has required more than 3000 weighings of certified standards and numberless accountability-weighing observations to gain insight into the likely problems that will affect DYMCAS weighings. Following predetermined experimental designs, more than twenty Toledo/8130 scales have been tested under ideal and operational environments in an attempt to estimate weight error variability and to characterize the sources of that variability. At this time, the following inferences are in order:

1. The DYMCAS scales are susceptible to their physical environment. Wind, vibration, platform unevenness, and movement affect them. The experimenters recommend that scale operators be made aware of these factors. In general, however, it would be uneconomical to expend scarce resources for extensive environmental modifications at this time. If each scale operator exercises the care due any precision instrument, that should prove sufficient.
2. Under the current weighing method, there is operationally significant scale-to-scale variation, setup-to-setup variation, and weight-to-weight variation. Because of these systematic errors; the 95-percent confidence interval for individual weighings approaches ± 4 g, which is unacceptable for NMC&A's purposes.
3. Based on experience with the scales, an operationally efficient weighing method is proposed which substantially reduces every estimated source of variation and the random error component. With the proposed method, accuracy and repeatability are within NMC&A's desired ± 2 g. The recommendation is that this weighing method be adopted.

RECOMMENDED WEIGHING METHOD FOR 40-kg SCALES

1. Estimate the object's weight by some practical means.
2. If the object weighs less than 25 kg, select a certified weight standard that weighs within 5 kg of the object.
3. If the object weighs 25 kg or more, select a certified weight standard that weighs within 2 kg of the object.
4. Place the certified standard on the scale platform center, and allow the scale to stabilize.
5. Adjust the scale to indicate the correct weight for the standard by turning the zero adjustment knob clockwise to increase the reading or counterclockwise to reduce the reading.

6. Remove the standard, and allow the scale to stabilize while empty.
7. Double check the zeroing process by returning the standard to the scale platform center, and allow the scale to stabilize. If there is any doubt regarding the actual zero level of the scale at any time before or during its use, repeat Step 7.
8. If the scale reads correctly, do not adjust.
9. If the scale reads incorrectly, adjust the scale to read correctly; and repeat Step 6.
10. Make note of the scale reading when the scale is stabilized while empty.
11. The scale is now ready for use.
12. Place the object to be weighed on the scale platform center, and allow the scale to stabilize.
13. Observe the weight of the object.
14. Remove the object.
15. After the scale stabilizes, observe the scale reading. If the reading is not identical with Step 10, return to Step 4.
16. If the upcoming part to be weighed is estimated to be < 25 kg and within 5 kg of the weight at which the scale is zeroed, go to Step 12.
17. If the upcoming part to be weighed is estimated to be 25 kg or more and within 2 kg of the weight at which the scale is zeroed, go to Step 12.
18. If neither Step 16 nor Step 17 apply, return to Step 2.

ACKNOWLEDGMENTS

The author wishes to acknowledge Don Garren of the Oak Ridge Y-12 Plant Maintenance Division for his unique assistance and guidance as to the behavior of the Toledo/8130 scales.

Distribution

Department of Energy - Idaho Falls

Kodman, G. P.
Martin, H. R.

Department of Energy - Oak Ridge

Hickman, H. D./Harris, R. A.
Leed, R. E.
Poteat, R. M.

Department of Energy - Savannah River

Skinner, A. J.

E. I. Dupont de Nemours - Aiken

Dickenson, W. T.

Goodyear Atomic Corporation

Murrell, J./DeVito, V.

Lawrence Livermore Laboratory

Arnold, W. F.
Meadors, O. L./Lowe, V. W., Jr.

Los Alamos Scientific Laboratory

Hoyt, H. C.

National Lead Company of Ohio

Gessiness, B.

Oak Ridge Gaseous Diffusion Plant

Armstrong, R. C.
Stief, S. S.
Wheeler, L. E.
Wilcox, W. J., Jr.

Oak Ridge National Laboratory

Austin, H. C./Benson, C. W.
Hopkins, C. C.

Oak Ridge Y-12 Plant

Bernander, N. K.
Bostock, D. J.
Bryant, D. P.
Dodson, W. H./Googin, J. M.

Ebert, J. W./Bright, G. R.

Fraser, R. J.

Hammer, A. H. (20)

Holland, C. W.

Keith, A.

Kite, H. T.

Leete, R. S., Jr.

Mason, D. L.

Mee, W. T.

Mills, J. M., Jr.

Smith, H. F., Jr.

Stoner, H. H.

White, J. C.

Williams, R. D.

Yaggi, W. J.

Y-12 Central Files (master copy)

Y-12 Central Files (route copy)

Y-12 Central Files (Y-12RC)

Y-12 Central Files (5)

Paducah Gaseous Diffusion Plant

Bewley, H. D.

Kraemer, B. T./Kohler, E. A.

Rockwell International - Rocky Flats

Dunn, D. A./Young, E. R./Ferris, Y. M.

Sandia Laboratories - Albuquerque

Tyler, R. P.

Sandia Laboratories - Livermore

Hennan, P. M.

Spencer, W. J.

Union Carbide Corporation - New York

Tinsley, S. W.

In addition, this report is distributed in accordance with the Category UC-15, Safeguards—Nuclear Materials Security, as given in the *Standard Distribution for Unclassified Scientific and Technical Reports*, DOE/TIC-4500.