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**DEMONSTRATION AND EVALUATION OF THE
20-TON-CAPACITY LOAD-CELL-BASED
WEIGHING SYSTEM,**

**~ELDORADO RESOURCES, LTD.
- PORT HOPE, ONTARIO,**

~ SEPTEMBER 3-4, 1986

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Operations Analysis and Planning Division

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✓ Prepared by the
OAK RIDGE GASEOUS DIFFUSION PLANT
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

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INTRODUCTION

On September 3 and 4, 1986, the prototype 20-ton-capacity load-cell-based weighing system (LCBWS) developed by the U.S. Enrichment Safeguards Program (ESP) at Martin Marietta Energy Systems, Inc., was field tested at the Eldorado Resources, Ltd., (ERL) facility in Port Hope, Ontario. The 20-ton-capacity LCBWS has been designed and fabricated for use by the International Atomic Energy Agency (IAEA) for verifying the masses of large-capacity UF_6 cylinders during IAEA safeguards inspections at UF_6 handling facilities. Funding for this equipment development is being provided by the U.S. Program for Technical Assistance to IAEA Safeguards (POTAS).

The purpose of the Canadian field test was to demonstrate and to evaluate with IAEA inspectorates and with UF_6 bulk handling facility operators at Eldorado the principles, procedures, and hardware associated with using the 20-ton-capacity LCBWS as a portable means for verifying the masses of 10- and 14-ton UF_6 cylinders. Session participants included representatives from the IAEA, Martin Marietta Energy Systems, Inc., Eldorado Resources, Ltd., the Atomic Energy Control Board (AECB), and the International Safeguards Project Office (ISPO) at Brookhaven National Laboratory (BNL). Appendix A presents the list of participants and their organization affiliation.

The two-day field test involved a formal briefing by ESP staff, two cylinder weighing sessions, IAEA critiques of the LCBWS hardware and software, and concluding discussions on the field performance of the system. Appendix B cites the meeting agenda. Summarized in this report are (1) the technical information presented by the system developers, (2) results from the weighing sessions, and (3) observations, suggestions, and concluding statements from meeting participants.

ORIENTATION SESSION

SYSTEM BRIEFING

The session began on Wednesday morning, September 3, in the main conference room of the ERL Administration Building in Port Hope. Following the welcome and introduction of session participants, chart books containing the presentation material for the briefing were distributed (Appendix C). In the session introduction, J. N. Cooley (Energy Systems) outlined the five objectives for the demonstration and evaluation session: (1) to demonstrate the equipment, procedures, and facility interfaces associated with weighing large cylinders using the prototype LCBWS, (2) to demonstrate the accuracy of the measurement system, (3) to demonstrate the user-friendliness of the measurement equipment, (4) to obtain feedback from the inspectors on operating procedures and equipment-handling requirements, and (5) to obtain feedback from the facility operator on facility interface requirements.

The LCBWS overview, presented by T. J. Huxford (Energy Systems), outlined a conceptual description of the LCBWS system, described the technical specifications of the hardware components comprising the

system, reviewed the operating procedures, and detailed Oak Ridge test data typifying the system's performance. The LCBWS is relatively portable and, in its current configuration, is crane or forklift compatible. The electronics of the LCBWS have been integrated with a computer control system to simplify field weighing of UF_6 cylinders. During routine operation of the LCBWS, the inspector is not required to record any data or to manually calculate cylinder weights. The prototype LCBWS is comprised of three subsystems: the mechanical assembly, the electronic console, and the computer control system.

The mechanical portion of the LCBWS consists of two parallel branches, each of which is comprised of one load cell, two flexures, and associated connecting hardware. Each branch of the 20-ton-capacity LCBWS is rated at 10 tons. Without shackles (i.e., the operating configuration for a forklift), each branch weighs 35 kg and is 131 cm long. Two 11.4-ton capacity precision load cells are used as the system's force transducers. Because of the parallel branch lifting configuration, each load cell measures the weight of approximately one-half the total cylinder weight. Each load cell has been calibrated at the U.S. National Bureau of Standards (NBS). Each branch of the LCBWS includes two flexures, one above and one below the load cell. The flexures act as universal joints to ensure that the load cell is measuring a uniaxial force.

The electronic console consists of two digital load-cell indicators, one standardizer, and two digital temperature indicators connected to resistance temperature detectors. The electronic console provides all interfaces with the control computer. The console can be manually controlled in the event of a computer malfunction. The two digital load-cell indicators provide a direct readout of the weight sensed by each load cell. Each indicator and its interconnecting 30-ft cable have been calibrated at the NBS. A standardizer is included to ensure that the electronics of the load cell indicators have not changed substantially since the NBS calibration of the load cells with the indicators. The standardizer simulates the electrical response of the load cell in order to compare the current indicator readings with the NBS-supplied readings. This operation allows for correction of load-cell meter drift in the field. A resistance temperature detector (RTD) is attached to each load cell during a cylinder weighing operation to measure the operating temperature of the load cells. These temperature data are used for correction of the load-cell calibration. The temperature sensitivity of each load cell was provided by the NBS. Panel-mounted temperature indicators provide a direct readout of each load cell's operating temperature. Each RTD and its associated temperature indicator have also been calibrated at the NBS.

The computer control system components include a Hewlett-Packard 75D computer with integral software and a printer. The computer system prompts the inspector with the operating procedures, prompts the electronic instruments for the data, corrects all field readings to calibrated standards, calculates cylinder weights, and provides the inspector with a printed copy of the results including a statistical analysis of the data.

During the summer of 1986, extensive prototypic field testing was conducted with the LCBWS at the Oak Ridge Gaseous Diffusion Plant (ORGDP).

Interfaced with a double-hook crane, the system was used for repeated weighings of seven 10- and seven 14-ton UF₆ cylinders. When compared to toll facility accountability scale readings, the results indicated a LCBWS accuracy of ± 2.6 kg (two standard deviations).

PRELIMINARY DISCUSSIONS

During the technical presentation, much discussion centered around the accuracy requirements for the LCBWS. The system was designed using an accuracy criteria of ± 1 to 2 kg. In order to achieve the stated accuracy, the LCBWS uses a computer program to correct field weighings based on various field-measured parameters (e.g., load-cell temperature, meter drift, and local gravitation field intensity). These corrections are applied to the direct readings displayed by the load-cell digital indicators. It was Barry Barnes' (IAEA) opinion that the prototype LCBWS was overdesigned relative to what is required by the IAEA.* The Agency desires a small, light system that is easy to use. Simplicity and transportability are the most important criteria. Barnes questioned the need for a separate indicator for each load cell and suggested that the load cells be paralleled, using a single indicator to display the sum of the two outputs. Barnes stated that an accuracy of ± 50 kg would probably be acceptable to the Agency because the enrichment measurement used in conjunction with the measurement of cylinder weights has an uncertainty of no better than $\pm 1\%$. (A total of 50 kg is 0.5% of the operational fill capacity of a 10-ton UF₆ cylinder.) John Skalyo (BNL) defended the design criteria for accuracy by stating that it is the overriding desire of system developers to provide the IAEA with the best possible instrument. If the Agency wants a less accurate system, it should be the Agency's decision to use the current system in that mode.

George Healey (AECB) suggested an operational approach whereby the existing LCBWS could be used in alternative modes (i.e., with or without the computer; with or without all the corrections). Without the computer, the inspectors could simply use the direct load-cell indicator readings instead of the computer-generated values. The LCBWS design team acknowledged that the difference between meter-indicated weight measurements and their corrected values, based on experience to date, has never exceeded 15 kg. (See hand calculation in Appendix D.) The design team expressed concern that some of the computer corrections could be much more significant in operational situations where winter ambient temperatures are experienced or at sites where the gravitational constant is significantly different. The design team recommended that a realistic sensitivity study be made in order to quantify a range of errors introduced by ignoring each individual correction. Healey stated

*After returning to Oak Ridge, the ESP staff learned that one reason for the accuracy requirements of $\sim \pm 2$ kg was that U.S. diffusion plant accountability scales have a stated accuracy of $\sim \pm 1$ kg. Since the LCBWS-determined weights are to be compared with facility accountability scale measurements, the same accuracy was chosen as a design requirement.

that based on his experience with IAEA inspections, some inspectors need step-by-step prompts to operate the inspection equipment because they lack familiarity with a system. Prompting software is desirable if the software is good. For the LCBWS operational mode that uses the computer, instructional prompts would be included along with options to apply the various corrections.

Another operational issue discussed was whether the LCBWS flexures are required. Analogous to IAEA issues regarding the computer system, the IAEA representatives are as concerned about transportability as they are about operational complexity. They view the flexures as extra weight and length in each load-cell branch. Barnes cited inspector experience with the smaller 5-ton system currently in use and indicated that only small accuracy differences are realized when the flexures are not used. It was agreed that during the field session, cylinders would be weighed with and without the flexures in the load-cell branches to compare the results.

Operational safety issues were also of concern. Barnes described the problem the Agency was currently experiencing with the use of the 5-ton load-cell system in British facilities. Apparently no uniform set of international standards for structural safety factors exists that applies to mechanical lifting hardware. The British have requested that the IAEA test each individual component of the single-branch 5-ton system to two times its safe load prior to its acceptability for use. The 5-ton system is currently certified at 1.5 times its rating. Huxford explained that the 20-ton LCBWS has a nominal safety factor of 3 relative to the rated capacity of each of its components. It was agreed that unambiguous documentation of each component's safe working load, ultimate load, breaking load, etc., should be provided with the completed system.

CYLINDER WEIGHING SESSIONS

For the demonstration of the 20-ton-capacity LCBWS, the session participants first assembled in a covered high-bay facility area. To maximize the available time for cylinder weighings, the equipment had already been assembled. The load-cell branches were attached to an Agency-owned cylinder lifting fixture that interfaces with the tongs of a forklift transporter;* the computer system and electronic console were arranged on a portable push cart. A single cylinder (Cog 5798) with a facility accountability weight of 14,764 kg was used for all the weighings. With the IAEA representatives operating the computer control system, the standardizer procedure was first conducted. As indicated by the standardizer results listed in Table 1, only a small correction for meter drift was required for the left load-cell indicator readings;

*The cylinder lifting fixture was originally designed to allow use of a portable Agency cylinder scale with a forklift truck. Modifications to this lifting fixture by ERL were required to interface the LCBWS with the facility forklift.

Table 1. Standardizer procedure results

The 16 left-load-cell standardizer readings taken in the field are as follows:

Standardizer Setting mV/V	NBS Reading Kgf	Site Reading Kgf
0	0	0
0.2	756	757
0.4	1513	1513
0.6	2270	2270
0.8	3026	3027
1.0	3783	3784
1.2	4540	4540
1.4	5296	5297
1.6	6053	6054
1.8	6810	6811
2.0	7567	7568
2.2	8324	8325
2.4	9081	9082
2.6	9838	9839
2.8	10595	10596
3.0	11352	11353

The 16 right-load-cell standardizer readings taken in the field are as follows:

Standardizer Setting mV/V	NBS Reading Kgf	Site Reading Kgf
0	0	0
0.2	756	756
0.4	1512	1512
0.6	2267	2268
0.8	3023	3024
1.0	3779	3780
1.2	4535	4535
1.4	5291	5291
1.6	6047	6047
1.8	6803	6803
2.0	7559	7559
2.2	8315	8315
2.4	9071	9071
2.6	9827	9827
2.8	10583	10583
3.0	11339	11339

DATE: 09/03/86

The time is 12:04 p.m.

no corrections were necessary for the right indicator readings. The 14-ton cylinder was initially weighed twice using the LCBWS with the computer. With all the corrections, the LCBWS measured the cylinder's weight as 14,771 and 14,770 kg. The corresponding direct indicator readings were 14,778 and 14,777 kg. Appendix E includes copies of the computer printouts for the first two cylinder weighings.

During this initial LCBWS demonstration, the computer software was judged cumbersome to use. It was slow and some of the prompts were redundant or unnecessary. Consequently during subsequent weighings, the participants preferred to make comparisons using only the indicator readings. Also included in this first weighing session was a test to check the repeatability of the LCBWS. The cylinder was weighed three times in succession with the last weighing done after the forklift tongs were repositioned to cause a different partitioning of the cylinder's weight between the two load cells. In each case, the cylinder's weight measurement repeated within 1 kg (14,777, 14,777, and 14,778 kg, respectively). At the conclusion of the first day's weighing session, it was suggested that a similar session be conducted outside the following day to observe the influences of wind and direct sunlight.

For the second day's demonstration session, the cathode ray tube (CRT) monitor being used to display the computer prompts malfunctioned causing the entire computer system to fail. Despite this, the demonstration continued using the uncorrected load-cell indicator readings. During this second field session there was light, intermittent rain with a 5 to 10 mph breeze and an ambient temperature of 19°C. (The previous day's ambient temperature was 24°C.) The first experiment was to reweigh the cylinder from the previous day. The result of 14,778 kg was repeated.

For the next experiment, the system's flexures were removed and the cylinder was weighed three times in succession. (Figure 1 shows the cylinder being weighed by the LCBWS configured without the flexures.) The resulting measurements of 14,774, 14,774, and 14,773 kg averaged 4 kg less than the measurements with the flexures (and consequently 4 kg closer to the facility-determined cylinder weight). For the last weighing experiment, Huxford suggested that the redundant bridge on each load cell be used (i.e., the uncalibrated bridge). The resultant measured weight was 14,775 kg.

CONCLUDING SESSION

On Thursday morning, a final wrap-up session, which followed the conclusion of the second weighing session, was held to solicit observations and comments from session participants. System accuracy demonstrated by the 20-ton-capacity LCBWS during the cylinder weighing demonstrations was judged excellent. All observers were notably impressed with the repeatability of the results. (Table 2 includes the demonstration results from both weighing sessions.) Comments by Eldorado facility personnel were limited to (1) making the LCBWS independent of facility on-site power so that all areas of a cylinder storage yard are accessible and (2) supplying extra sets of connecting cables. (During the outside weighing session, a forklift truck that was

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Fig. 1. IAEA field test of the LCBWS at Eldorado: outdoor cylinder weighing session. (LCBWS configured without the flexures.)

rearranging cylinders almost placed a 14-ton cylinder on top of the load-cell cables.)

The Agency participants conceded the need for development of a prototype load-cell system with a stringent accuracy requirement in order to illustrate the accuracies ultimately achievable by the system. However, for a rugged field system to be delivered for routine Agency use, the following modifications to the prototype LCBWS were suggested:

1. two load cells with one indicator that is not mounted in a console,
2. the standardizer as a separate unit,
3. no flexures,
4. battery operation to support 6 to 8 h of continuous use, and
5. an air transportable work table for packaging the system.

It was also suggested that NBS calibration of the load cells may not be necessary to achieve the less stringent accuracies; the manufacturer's stated accuracies for off-the-shelf load cells would probably suffice. In addition, the inspectors expressed interest in a single-branch system for application at several European facilities. For timely delivery of the LCBWS hardware to the Agency for field use, it was suggested that

Table 2. Cylinder weighing results
Test cylinder: COG 5798, facility-scale weight of 14,764 kg

Session 1: September 3, 1986

Location: Covered high-bay facility area
 Conditions: Sunny and dry, ambient temperature 24°C
 LCBWS configuration: Two load-cell branches with flexures

Weighing No.	Indicator readings		Total (kg·f)	Corrected mass (kg·m) ^a
	Left	Right		
1	7337	7441	14,778	14,771
2	7358	7419	14,777	14,770
3	7364	7413	14,777	
4	7364	7413	14,777	
5	7409	7369	14,778	

Session 2: September 4, 1986

Location: Cylinder storage yard
 Conditions: Light drizzle, ambient temperature 19°C
 LCBWS configuration: No. 1, load-cell branches with flexures
 No. 2-4, load-cell branches without flexures
 No. 5, load-cell branches without flexures,
 load-cell cables attached to uncalibrated
 load-cell bridges

Weighing No.	Indicator readings		Total (kg·f)
	Left	Right	
1	7347	7431	14,778
2	7464	7310	14,774
3	7304	7470	14,774
4	7282	7491	14,773
5	7323	7452	14,775

^aAs calculated by the computer program.

the 20-ton system be described as an upgraded 5-ton load-cell system so that extended field tests would not be required.

It was agreed that the field test of the LCBWS planned for late 1986 at a German facility would utilize the same mechanical hardware configurations as the system demonstrated at Eldorado. For the German demonstration, a new cart large enough to transport all the LCBWS components as a single unit would be obtained. To make the LCBWS independent of facility extension cords and possible problems associated with electrical voltage/frequency mismatches, a DC to AC inverter having a 12-V battery power source will be added. To the extent practical (realizing that any accompanying software will need to be rewritten for Agency field computers), the software will be modified to be more user friendly and faster during cylinder weighing operations. Hopefully, cleaning up the computer software will encourage its use.

Final action items agreed to by the system designers include (1) a documented safety analysis on LCBWS lifting hardware, (2) a sensitivity study on measurement errors corrected by the computer, and (3) a feasibility study for a simplified single-branch LCBWS incorporating the Agency-suggested modifications. Further discussions between the IAEA, ESP management, and ISPO will be required to determine the next steps for delivery of a 20-ton-capacity LCBWS for Agency field use.

ACKNOWLEDGMENTS

The demonstration of the 20-ton-capacity load-cell-based weighing system could not have been conducted without the support provided by the Eldorado Resources Ltd., facility, especially the dedicated efforts of Douglas Closs and Bev Rose.

Appendix A
LIST OF PARTICIPANTS

Appendix A

**DEMONSTRATION AND EVALUATION OF THE
20-TON-CAPACITY LOAD-CELL-BASED
WEIGHING SYSTEM****LIST OF PARTICIPANTS**

<u>Name</u>	<u>Organization</u>
B. Barnes	IAEA (DTS), Vienna, Austria
J. N. Cooley	Martin Marietta, Oak Ridge, Tennessee
D. Closs	Eldorado Resources Ltd., Port Hope, Ontario
G. J. Healey	Atomic Energy Control Board, Ottawa, Ontario
T. J. Huxford	Martin Marietta, Oak Ridge, Tennessee
B. Rose	Eldorado Resources Ltd., Port Hope, Ontario
W. Severe	IAEA (OCP), Vienna, Austria
J. Skalyo	Brookhaven National Laboratory (ISPO), Upton, New York

Appendix B

**LOAD-CELL-BASED WEIGHING SYSTEM DEMONSTRATION
AND EVALUATION SESSION (POTAS TASK A-137):
SCOPE, PURPOSE, OBJECTIVES, AND AGENDA**

Appendix B

LOAD-CELL-BASED WEIGHING SYSTEM DEMONSTRATION
AND EVALUATION SESSION (POTAS TASK A-137)ELDORADO RESOURCES, LTD.
PORT HOPE, ONTARIO

September 3-4, 1986

SCOPE, PURPOSE, AND OBJECTIVES

SCOPE: To demonstrate and to evaluate with IAEA inspectorates and with UF_6 bulk handling facility operators at the Eldorado Resources, Ltd., facility the principles, procedures, and hardware associated with using the 20-ton-capacity load-cell-based weighing system (LCBWS) being developed by Martin Marietta Energy Systems, Inc., as a portable means for verifying the mass of large-capacity UF_6 cylinders.

PURPOSE: To interact with IAEA inspectorates and with UF_6 bulk handling facility representatives on the transfer of technology for the 20-ton-capacity LCBWS being developed by Martin Marietta Energy Systems, Inc., for use by the IAEA in verifying the mass of large-capacity UF_6 cylinders.

- OBJECTIVES:
- (1) To demonstrate the equipment, procedures, and facility interfaces associated with verifying the mass of large-capacity UF_6 cylinders using the prototype LCBWS.
 - (2) To demonstrate the accuracy of the measurement system.
 - (3) To demonstrate the user friendliness of the measurement equipment.
 - (4) To obtain feedback from the inspectors on operating procedures and equipment handling requirements.
 - (5) To obtain feedback from the facility operator on facility interface requirements.

AGENDA

September 3, 1986

Location: Conference Room, Eldorado Resources, Ltd., Port Hope, Ontario

8:30 a.m. - 9:00 a.m. Arrive Eldorado Resources, Ltd., facility,
badge and pass at visitors' entrance

- ORIENTATION SESSION -

9:00 a.m. - 9:15 a.m. Welcome, introductions, and local arrangements

9:15 a.m. - 10:15 a.m. System overview, hardware description, and
evaluation plan

10:15 a.m. - 10:30 a.m. Break (assemble in West Bay area)

- DEMONSTRATION SESSION -

10:30 a.m. - 12:00 noon Equipment assembly and UF₆ cylinder weighing
demonstration

12:00 noon - 1:30 p.m. LUNCH

1:30 p.m. - 3:00 p.m. UF₆ cylinder weighings by inspectors and eva-
luation of operating procedures

3:00 p.m. - 3:15 p.m. BREAK (return to conference room)

3:15 p.m. - 4:15 p.m. Discussion and critique of demonstration
session, next day planning

4:15 p.m. ADJOURN

19/20

AGENDA (continued)

September 4, 1986

Location: Conference Room, Eldorado Resources, Ltd., Port Hope, Ontario

- 8:30 a.m. - 9:00 a.m. Arrive Eldorado Resources Ltd., facility,
badge and pass at visitors' entrance
- DEMONSTRATION SESSION (continued) -
- 9:00 a.m. - 9:15 a.m. Evaluation assignments
- 9:15 a.m. - 9:30 a.m. Reassemble in West Bay area
- 9:30 a.m. - 12:00 noon UF₆ cylinder weighings by inspectors
- 12:00 noon - 1:30 p.m. LUNCH
- CONCLUDING SESSION -
- 1:30 p.m. - 3:30 p.m. Review and discussion of conclusions, obser-
vations, and recommendations from LCBWS
demonstration and evaluation session
- 3:30 p.m. ADJOURN

Appendix C

**CHARTBOOK FROM THE DEMONSTRATION AND EVALUATION
OF THE 20-TON-CAPACITY LOAD-CELL-BASED WEIGHING SYSTEM
(K/OA-6026)**

MARTIN MARIETTA

K/OA-6026

DEMONSTRATION AND EVALUATION OF THE
20-TON-CAPACITY LOAD-CELL-BASED
WEIGHING SYSTEM

SEPTEMBER 3-4, 1986

ELDORADO RESOURCES LIMITED
PORT HOPE, ONTARIO

Prepared by the
Enrichment Safeguards Program Staff

UNITED STATES PROGRAM FOR TECHNICAL ASSISTANCE TO IAEA SAFEGUARDS

POTASDEPARTMENT OF STATE
DEPARTMENT OF ENERGY
ATOMIC ENERGY REGULATORY COMMISSION
NUCLEAR REGULATORY COMMISSION

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

AUGUST 13, 1986

K/OA-6026

DEMONSTRATION AND EVALUATION OF THE
20-TON-CAPACITY LOAD-CELL-BASED
WEIGHING SYSTEM

SEPTEMBER 3-4, 1986

ELDORADO RESOURCES LIMITED
PORT HOPE, ONTARIO

Prepared by the
Enrichment Safeguards Program Staff

UNITED STATES PROGRAM FOR TECHNICAL ASSISTANCE TO IAEA SAFEGUARDS

POTASDEPARTMENT OF STATE
DEPARTMENT OF ENERGY
ATOMIC ENERGY REGULATORY COMMISSION
NUCLEAR REGULATORY COMMISSION

OAK RIDGE GASEOUS DIFFUSION PLANT
Oak Ridge Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U S DEPARTMENT OF ENERGY
Under Contract No DE AC05 84OR21400

**20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM**

DWG. NO. M/G 88 2288

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UNITED STATES PROGRAM FOR TECHNICAL ASSISTANCE TO IAEA SAFEGUARDS

POTAS

 UNITED STATES
 DEPARTMENT OF ENERGY
 OFFICE OF INTERNATIONAL
 NUCLEAR SAFETY AND SECURITY

MARTIN MARIETTA

**20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM**

DWG. NO. M/G 88 2288

AGENDA**Wednesday, September 3, 1986**

8 30 a m	9 00 a m	Arrive Eldorado Resources Limited Facility
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ORIENTATION SESSION

9 00 a m	9 15 a m	Welcome, introductions, and local arrangements
9 15 a m	10 15 a m	System overview, hardware description, and evaluation plan
10 15 a m	— 10 30 a m	BREAK

DEMONSTRATION SESSION

10 30 a m	— 12 00 noon	Equipment assembly and UF ₆ cylinder-weighing demonstration
12 00 noon	1 30 p m	LUNCH
1 30 p m	3 00 p m	UF ₆ cylinder weighings and evaluation of operating procedures
3 00 p m	3 15 p m	BREAK
3 15 p m	— 4 15 p m	Discussion and critique of demonstration session

UNITED STATES PROGRAM FOR TECHNICAL ASSISTANCE TO IAEA SAFEGUARDS

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 NUCLEAR SAFETY AND SECURITY

MARTIN MARIETTA

20 TON CAPACITY
LOAD CELL BASED WEIGHING SYSTEM

DWG NO K/G 86 2280

AGENDA (CONTINUED)

Thursday September 4 1986

8 30 a m	9 00 a m	Arrive Eldorado Resources Limited Facility
9 00 a m	9 15 a m	Evaluation assignments
9 15 a m	9 30 a m	Travel to demonstration area
9 30 a m	12 00 noon	UF ₆ cylinder weighings by inspectors
12 00 noon	1 30 p m	LUNCH

CONCLUDING SESSION

1 30 p m	3 30 p m	Review and discussion of conclusions observations and recommendations
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UNITED STATES PROGRAM FOR TECHNICAL ASSISTANCE TO IAEA SAFEGUARDS

POTASDEPARTMENT OF STATE
DEPARTMENT OF ENERGY
ARMY, NAVY AND AIR FORCE
NUCLEAR REGULATORY COMMISSION**MARTIN MARIETTA**

20 TON CAPACITY
LOAD CELL BASED WEIGHING SYSTEM

INTRODUCTION

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Safeguards Program
Martin Marietta Energy Systems, Inc

UNITED STATES PROGRAM FOR TECHNICAL ASSISTANCE TO IAEA SAFEGUARDS

POTASDEPARTMENT OF STATE
DEPARTMENT OF ENERGY
ARMY, NAVY AND AIR FORCE
NUCLEAR REGULATORY COMMISSION**MARTIN MARIETTA**

20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DMC NO. M/C 88 2296

INTRODUCTION

LCBWS DEVELOPMENT AND SUPPORT

- DEVELOPED BY THE ENRICHMENT SAFEGUARDS PROGRAM
AT MARTIN MARIETTA ENERGY SYSTEMS, INC.
- SUPPORTED BY THE U.S. PROGRAM FOR TECHNICAL
ASSISTANCE TO IAEA SAFEGUARDS (POTAS)

UNITED STATES PROGRAM FOR TECHNICAL ASSISTANCE TO IAEA SAFEGUARDS

POTAS

ENRICHMENT SAFEGUARDS
PROGRAM
MARTIN MARIETTA ENERGY SYSTEMS, INC.
P.O. BOX 1000, ANDERSON, SC 29621-1000

MARTIN MARIETTA

20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DMC NO. M/C 88 2296

INTRODUCTION

POTAS TASK A-137: LCBWS

TASK SCOPE

- TO PROVIDE THE INTERNATIONAL ATOMIC ENERGY
AGENCY (IAEA) WITH A 20-TON-CAPACITY LCBWS
ENGINEERED FOR IAEA APPLICATION

TASK OBJECTIVE

- TO PROVIDE THE IAEA WITH A PORTABLE MEANS
FOR VERIFYING THE MASSES OF LARGE CAPACITY
UF₆ CYLINDERS AT UF₆-HANDLING FACILITIES

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INTRODUCTION

POTAS TASK A-137: LCBWS

TASK STATUS

- PROTOTYPE FIELD-TESTED IN OAK RIDGE SINCE JUNE
- SUCCESSFUL DEMONSTRATION OF PROTOTYPE TO IAEA POTAS TASK COORDINATOR CONDUCTED JULY 2 IN OAK RIDGE
- FIELD TESTING OF PROTOTYPE BY IAEA AT ELDORADO RESOURCES LIMITED ON SEPTEMBER 3 AND 4
- FIELD TESTING OF PROTOTYPE BY IAEA AT GERMAN FACILITY PLANNED FOR LATE 1986

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NUCLEAR REGULATORY COMMISSION**MARTIN MARIETTA**

INTRODUCTION

LCBWS DEMONSTRATION AND EVALUATION

SCOPE

- DEMONSTRATION AND EVALUATION OF THE PRINCIPLES, PROCEDURES, AND HARDWARE ASSOCIATED WITH WEIGHING LARGE CAPACITY UF_6 CYLINDERS USING THE 20-TON-CAPACITY LCBWS BEING DEVELOPED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.

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20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

INTRODUCTION

LCBWS DEMONSTRATION AND EVALUATION

OBJECTIVES

- TO DEMONSTRATE THE EQUIPMENT, PROCEDURES, AND FACILITY INTERFACES ASSOCIATED WITH VERIFYING THE MASSES OF LARGE CAPACITY UF₆ CYLINDERS USING THE LCBWS PROTOTYPE
- TO DEMONSTRATE THE ACCURACY OF THE MEASUREMENT SYSTEM
- TO DEMONSTRATE THE USER-FRIENDLINESS OF THE MEASUREMENT EQUIPMENT
- TO OBTAIN FEEDBACK FROM THE INSPECTORS ON OPERATING PROCEDURES AND EQUIPMENT-HANDLING REQUIREMENTS
- TO OBTAIN FEEDBACK FROM THE FACILITY OPERATOR ON FACILITY INTERFACE REQUIREMENTS

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DWG NO. K/G-88-2291

20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

INTRODUCTION

LCBWS DEMONSTRATION AND EVALUATION

SYSTEM OVERVIEW

- COMPONENT DESCRIPTION
- OPERATING PROCEDURES
- FIELD TEST RESULTS
- EVALUATION PLAN

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20 TON CAPACITY
LOAD-CELL BASED WEIGHING SYSTEM

SYSTEM OVERVIEW

T J Huxford, Engineer
Martin Marietta Energy Systems, Inc

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WASHINGTON, DC 20545

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20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

SYSTEM OVERVIEW

BACKGROUND

- 5-TON-CAPACITY LCBWS SYSTEM IS NOW IN USE BY THE IAEA FOR WEIGHING 30-in. UF₆ CYLINDERS
- 20-TON-CAPACITY LCBWS PROTOTYPE IS UPGRADED VERSION OF 5-TON-CAPACITY SYSTEM
- 20-TON-CAPACITY SYSTEM FOR WEIGHING 10- AND 14-TON UF₆ CYLINDERS

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5-TON-CAPACITY LCBWS

20 TON CAPACITY
LOAD CELL BASED WEIGHING SYSTEM

DWG NO. N/C 83 1148 R1

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20-TON-CAPACITY LCBWS

20 TON CAPACITY
LOAD CELL BASED WEIGHING SYSTEM

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20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DWG NO. K/C-8-2288

SYSTEM OVERVIEW**DESIGN FEATURES**

- TWO LOAD CELL BRANCHES
- 20-TON CAPACITY
- INTEGRAL COMPUTER SYSTEM
- CRANE OR FORKLIFT COMPATIBLE
- RELATIVELY PORTABLE

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K/M-1-25**MARTIN MARIETTA**

20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DWG NO. K/C-8-2288

SYSTEM OVERVIEW**LCBWS SUBSYSTEMS**

- MECHANICAL ASSEMBLY
- ELECTRONIC CONSOLE
- COMPUTER CONTROL SYSTEM

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20-TON-CAPACITY LCBWS SUBSYSTEMS

20-TON-CAPACITY LOAD-CELL-BASED WEIGHING SYSTEM

DWG NO. M/G-84-1023 R2

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COMPUTER CONTROL
SYSTEM

ELECTRONIC CONSOLE

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20-TON-CAPACITY LOAD-CELL-BASED WEIGHING SYSTEM

DWG NO. M/G-84-2384

SYSTEM OVERVIEW

MECHANICAL ASSEMBLY

COMPONENTS OF A SINGLE BRANCH

- ONE LOAD CELL
- TWO FLEXURES
- INTERCONNECTING HARDWARE

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20 TON CAPACITY
LOAD-CELL BASED WEIGHING SYSTEM

ONE BRANCH OF THE 20-TON-CAPACITY LCBWS

DWG NO K/G-86 2260

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20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

SYSTEM OVERVIEW

MECHANICAL ASSEMBLY COMPONENTS

PRECISION LOAD CELLS

- PROVIDES ELECTRICAL SIGNAL TO MEASURE WEIGHT OF LOAD
- COMMERCIALY AVAILABLE
- 11.4-TON CAPACITY
- CALIBRATED AT U. S. NATIONAL BUREAU OF STANDARDS (NBS)

DWG NO K/G-86 2263

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20 TON CAPACITY
LOAD-CELL BASED WEIGHING SYSTEM

DMG NO. H/G 86 2282

SYSTEM OVERVIEW

MECHANICAL ASSEMBLY COMPONENTS

FLEXURES

- ACTS AS UNIVERSAL JOINT
- ENSURES LOAD CELL IS MEASURING UNIAXIAL FORCE
- TWO PER BRANCH (ABOVE AND BELOW LOAD CELL)

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20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DMG NO. H/G 86 2281

SYSTEM OVERVIEW

MECHANICAL ASSEMBLY COMPONENTS

INTERCONNECTING HARDWARE

- INTERFACES LOAD CELL AND FLEXURES WITH FACILITY LIFTING EQUIPMENT
- MAY VARY WITH FACILITY

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20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DWG. NO. 14-86-2279

SYSTEM OVERVIEW

MECHANICAL ASSEMBLY COMPONENTS

BRANCH OF 20-TON-CAPACITY LCBWS

- RATED AT 10 TONS
- BRANCH LENGTH
 - WITHOUT SHACKLES 131 cm
 - WITH SHACKLES 163 cm
- BRANCH WEIGHT
 - WITHOUT SHACKLES 35 kg
 - WITH SHACKLES 70 kg

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20 TON-CAPACITY
LOAD CELL BASED WEIGHING SYSTEM

DWG. NO. 14-86-2279

SYSTEM OVERVIEW

ELECTRONIC CONSOLE

COMPONENTS

- TWO DIGITAL LOAD CELL INDICATORS
- ONE STANDARDIZER
- TWO RESISTANCE TEMPERATURE DETECTORS
(RTDs) AND DIGITAL TEMPERATURE INDICATORS

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LCBWS ELECTRONIC CONSOLE AND COMPUTER CONTROL SYSTEM

20 TON CAPACITY
LOAD CELL BASED WEIGHING SYSTEM

DWG. NO. M/G 86233

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20 TON CAPACITY
LOAD CELL BASED WEIGHING SYSTEM

SYSTEM OVERVIEW

ELECTRONIC CONSOLE COMPONENTS

DIGITAL LOAD CELL INDICATOR

- PROVIDES DIRECT READOUT OF WEIGHT SENSED BY LOAD CELL (IN KILOGRAMS OR POUNDS)
- ONE FOR EACH LOAD CELL
- HAS INTEGRAL STABILITY SENSOR AND PUSHBUTTON ZERO

DWG. NO. M/G 86228

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20-TON-CAPACITY
LOAD CELL BASED WEIGHING SYSTEM

DWG. NO. K/G-16-2277

SYSTEM OVERVIEW

ELECTRONIC CONSOLE COMPONENTS

STANDARDIZER

- SIMULATES ELECTRICAL RESPONSE OF LOAD CELL TO CALIBRATE LOAD CELL INDICATORS
- ALLOWS FOR CORRECTION OF LOAD CELL METER DRIFT IN THE FIELD
- CALIBRATED AT U.S. NBS

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20 TON-CAPACITY
LOAD CELL BASED WEIGHING SYSTEM

DWG. NO. K/G-16-2276

SYSTEM OVERVIEW

ELECTRONIC CONSOLE COMPONENTS

RESISTANCE TEMPERATURE DETECTORS AND TEMPERATURE INDICATORS

- MEASURES OPERATING TEMPERATURE OF LOAD CELLS
- ALLOWS FOR TEMPERATURE CORRECTION OF LOAD CELL CALIBRATION
- ONE RTD AND INDICATOR FOR EACH LOAD CELL
- CALIBRATED AT U.S. NBS

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20 TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DWG. NO. N/G 86 2278

SYSTEM OVERVIEW

ELECTRONIC CONSOLEOPERATING FEATURES

- PROVIDES ALL INTERFACES WITH CONTROL COMPUTER
- CAN BE MANUALLY CONTROLLED

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20-TON-CAPACITY
LOAD-CELL BASED WEIGHING SYSTEM

DWG. NO. N/G 86 2274

SYSTEM OVERVIEW

COMPUTER CONTROL SYSTEMCOMPONENTS

- HEWLETT-PACKARD 75D COMPUTER WITH INTEGRAL SOFTWARE
- PRINTER

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20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DWG NO. N/G-88-2273

SYSTEM OVERVIEW

COMPUTER CONTROL SYSTEM COMPONENTS

COMPUTER WITH SOFTWARE

- PROMPTS THE INSPECTOR WITH THE OPERATING PROCEDURES
- CORRECTS ALL FIELD READINGS TO NBS STANDARDS AND CALCULATES CYLINDER WEIGHT

PRINTER

- PROVIDES HARD COPY OF RESULTS

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20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DWG NO. N/G-88-2272

SYSTEM OVERVIEW

COMPUTER CONTROL SYSTEM COMPONENTS

COMPUTER SOFTWARE

- CORRECTS FOR CYLINDER BUOYANCY EFFECTS
- CORRECTS FOR LOCAL GRAVITATIONAL CONSTANT
- CORRELATES NBS CALIBRATIONS FOR TEMPERATURE, METER DRIFT, AND LOAD CELL FORCE MEASUREMENT

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LCBWS OPERATIONAL LOGIC

DWG. NO. K/G-88-2837

SYSTEM OVERVIEW

20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEMFIELD OPERATIONS PROCEDURESINSPECTOR ACTIVITIES

- TRANSPORT LCBWS HARDWARE TO SITE
- ASSEMBLE LOAD CELL BRANCHES
- ASSIST OPERATOR IN INTERFACING HARDWARE TO FACILITY LIFTING DEVICE
- CONNECT COMPUTER AND ELECTRONIC CABLING
- INITIALIZE COMPUTER SOFTWARE
- RESPOND TO SOFTWARE PROMPTS FOR CALIBRATION AND CYLINDER WEIGHING
- DIRECT OPERATOR TO LIFT CYLINDERS
- OBTAIN RECORD OF CYLINDER WEIGHING DATA
- DISASSEMBLE EQUIPMENT

DWG. NO. K/G-88-2871

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SYSTEM OVERVIEW

FIELD OPERATIONS PROCEDURES

FACILITY OPERATOR ACTIVITIES

- PRIOR TO ROUTINE USE OF LCBWS AT FACILITY
 - ENSURE COMPATIBILITY OF LCBWS HARDWARE WITH FACILITY LIFTING EQUIPMENT
 - FURNISH CALIBRATION PROCEDURES AND DATA FOR FACILITY ACCOUNTABILITY SCALE
- ROUTINE
 - PROVIDE MANPOWER SUPPORT (e. g., CRANE OR FORKLIFT OPERATOR)
 - SUPPLY CYLINDER NUMBERS AND DECLARE ACCOUNTABILITY WEIGHTS

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SYSTEM OVERVIEW

OAK RIDGE FIELD TESTS

TEST DESCRIPTION

- SYSTEM TESTED UNDER PROTOTYPIC CONDITIONS
(e.g., INSIDE, AMBIENT TEMPERATURE 25-30°C)
- SYSTEM INTERFACED WITH DOUBLE HOOK CRANE
- INVOLVED REPEATED WEIGHINGS OF SEVEN 10- AND SEVEN 14-TON UF₆ CYLINDERS
- RESULTS COMPARED TO TOLL FACILITY ACCOUNTABILITY WEIGHTS

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SYSTEM OVERVIEW

20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

OAK RIDGE FIELD TESTSTEST RESULTS

- RANGE 5.0 kg
- MEAN DIFFERENCE 1.6 kg
- STANDARD DEVIATION ± 1.3 kg
- DATA ANALYSIS INDICATES:
 - NORMALITY
 - RANDOMNESS
 - NO OUTLIERS IN SAMPLE POPULATION

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DWG NO. K/G-86-2302

SYSTEM OVERVIEW

OAK RIDGE FIELD TESTS

20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

TEST DATA

NUMBER	LCBWS (kg)	TOLL FACILITY (kg)	DIFFERENCE (kg) (LCBWS — TOLL)	
<u>10-TON CYLINDERS</u>				
1	11,558.2	11,555.7	2.5	RANGE 3.2
2	11,093.2	11,091.3	1.9	
3	11,553.2	11,552.1	1.1	
4	11,239.1	11,237.3	1.8	
5	11,124.1	11,124.8	-0.7	
6	10,399.5	10,397.3	2.2	
7	11,501.1	11,500.9	0.2	
<u>14-TON CYLINDERS</u>				
1	13,467.0	13,463.1	3.9	RANGE 5.0
2	13,325.0	13,320.7	4.3	
3	13,484.0	13,482.6	1.4	
4	13,346.0	13,344.3	1.7	
5	12,878.0	12,877.0	1.0	
6	13,063.0	13,061.7	1.3	
7	13,375.9	13,375.5	0.4	

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43/44

20-TON-CAPACITY
LOAD-CELL-BASED WEIGHING SYSTEM

DWG NO K/G-86-2303

SYSTEM OVERVIEW

EVALUATION PLAN

DEMONSTRATION AND CRITIQUE OF OPERATING SYSTEM IN PROTOTYPIC FIELD CONDITIONS

- HARDWARE ASSEMBLY/DISASSEMBLY
- PERFORMANCE OF SYSTEM (FACILITY vs LCBWS)
- USER FRIENDLINESS OF CONTROL COMPUTER
- EVALUATION OF OPERATING PROCEDURES
- EVALUATION OF SYSTEM TRANSPORTABILITY

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Appendix D

HAND CALCULATION OF CYLINDER MASS

Appendix D

HAND CALCULATION OF CYLINDER MASS

Oak Ridge Gaseous Diffusion Plant Check Weight 25,900 lbm

Meter readings

	<u>Left</u>	<u>Right</u>
Load-cell indicators (R)	5521 kgf	6217 kgf
Temperature indicators (T)	24.6°C	24.3°C

- (1) Calculate operating temperature of load cells

$$T_o = T + \Delta T$$

$$\Delta T_{\text{left}} = (7.615 \times 10^{-9})T^3 - (9.964 \times 10^{-6})T^2 - (1.100 \times 10^{-3})T + 0.6532$$

$$\Delta T_{\text{right}} = -(3.246 \times 10^{-8})T^3 - (1.175 \times 10^{-5})T^2 + (1.277 \times 10^{-3})T + 0.7088$$

$$T_o(\text{left}) = 25.22^\circ\text{C}$$

$$T_o(\text{right}) = 25.03^\circ\text{C}$$

- (2) Correct load-cell indicator readings (R_c) for meter drift

	<u>NBS</u>	<u>Standardizer</u>	<u>Indicator</u>
Left	5296 6053	5297 6054	5521
Right	6047 6803	6047 6803	6217

$$R_c(\text{left}) = 5520 \text{ kgf}$$

$$R_c(\text{right}) = 6217 \text{ kgf}$$

- (3) Correct for load-cell temperature effects

$$R_{TC}(\text{left}) = R_c \left[1 + \frac{(9.5 \times 10^{-6})}{^\circ\text{C}} (23^\circ\text{C} - T_o) \right]$$

$$R_{TC}(\text{right}) = R_c \left[1 + \frac{(9.4 \times 10^{-6})}{^\circ\text{C}} (23^\circ\text{C} - T_o) \right]$$

$$R_{TC}(\text{left}) = 5519.88 \text{ kgf}$$

$$R_{TC}(\text{right}) = 6216.88 \text{ kgf}$$

(4) Calculate load using NBS correlations

$$R_{TC}(\text{left}) = 0.117315 + 0.453541 L + (0.227887 \times 10^{-7}) L^2$$

$$R_{TC}(\text{right}) = 0.758459 + 0.453622 L + (0.162211 \times 10^{-7}) L^2$$

(R_{TC} in kgf; L in lbf)

$$L_{\text{left}} = 12,162.94 \text{ lbf} (5517.07 \text{ kgf})$$

$$L_{\text{right}} = 13,696.60 \text{ lbf} (6212.74 \text{ kgf})$$

(5) Cylinder's apparent weight

$$L_{\text{left}} + L_{\text{right}} = 25,859.54 \text{ lbf} (11,729.81 \text{ kgf})$$

(6) Cylinder's total apparent mass

$$\frac{(25,859.54 \text{ lbf})}{(9.797073 \text{ m/sec}^2)} = 25,884.5 \text{ lbm}$$

(7) Mass vs brass correction

$$1 \text{ lbm} \times 1.000143 = 25,888.20 \text{ lbm}$$

compared to 25,900.00 lbm facility reading

Correction summary

	<u>Left</u>	<u>Right</u>	
Meter readings	5521 kgf	6217 kgf	(uncorrected sum = 11,738 kgf)
Meter drift correction	5520	6217	
Temperature correction	5519.88	6216.88	
NBS correction	5517.07	6212.74

	11,729.81 kgf	(25,859.54 lbf)	
g correction	11,741.15 kgm	(25,884.50 lbf)	
buoyancy correction	11,742.83 kgm	(25,888.20 lbf)	

Appendix E

COMPUTER PRINTOUTS FROM CYCLINDER WEIGHING DEMONSTRATIONS

Appendix E

COMPUTER PRINTOUTS FROM CYLINDER WEIGHING DEMONSTRATIONS

Results from Weighing No. 1

 WEIGHING NO. 3

CYLINDER NO. QWERTYUIOP1234567890-ASDFGHIJKL;
 DATE: 09/03/86
 The time is 12:11 p.m.

The transducer-indicator reading of the left load cell is 7337 kgf.

Alpha (z) = .99986340263
 N1 = 10

The temperature of the left load cell is 23.5226430176 °C.
 The serial number of the left load cell is 22128.

Rtc = 7335.96136106 kgf

R1 = 16161.4755778 lbf

D1(1) = .00000456
 D1(2) = .00000003
 D1(3) = -.00000002
 D1(4) = -.00000002
 D1(5) = -.00000002
 D1 is repeating.
 R1 = 16161.4755677

The roots of the left load cell's calibration equation are as follows:

R1 = 16161.4755677 lbf

R2 = -19918174.3153 lbf

The force detected by the left load cell (S/N 22128) after
 lifting the cylinder is 71889.8126238 newtons.
 This force represents the portion of the cylinder's
 apparent weight detected by the left load cell.

The transducer-indicator reading of the right load cell is 7441 kgf.

Alpha (z) = 1.000000000000
 N2 = 26

Results from Weighing No. 1 (continued)

The temperature reading of the right load cell is 24.1317983389 deg C.

The serial number of the right load cell is 22104.

$R_{tc} = 7440.92083592 \text{ kgf}$

The root obtained before substituting it back into the equation is $R1 = 16392.0704206 \text{ lbf}$.

$D2 > -.01$ and $D2 < .01$ and $R1 = 16392.0704206$

The root obtained before substituting it back into the equation is $R2 = -27981326.631 \text{ lbf}$.

$D3(1) = .00002308$

$D3(1) > -.01$ AND $D3(1) < .01$. $R2 = -27981326.631$

The roots of the right load cell's calibration equation are as follows:

$R1 = 16392.0704206 \text{ lbf}$

$R2 = -27981326.631 \text{ lbf}$

The portion of the cylinder's apparent weight detected by the right load cell (SN 22104) after the cylinder is lifted is 72915.5494568 newtons.

The cylinder's total apparent weight = 144805.362081 newtons.

The cylinder's total apparent mass (M_{lc}) = 14769.2836794 kg
or 32560.7024931 lbm.

The cylinder's LCBWS apparent mass versus brass (M_c) = 32565.3597328 lbm
or 14771.3961674 kg.

The cylinder's apparent mass versus brass determined on the facility's accountability scale (M_f) is 14764 lbm or 6696.83660199 kg.

The difference between the LCBWS apparent mass versus brass and that of the accountability scale's ($M_c - M_f$) is 17801.3597328 lbm or 8074.55956542 kg.

Note: The cylinder's facility-determined mass (M_f) was erroneously entered as 14,764 lbm.

Results from Weighing No. 2

 WEIGHING NO. 4

CYLINDER NO. 123
 DATE: 09/03/86
 The time is 12:29 p.m.

The transducer-indicator reading of the left load cell is 7358 kgf.

Alpha (α) = .99986381004
 N1 = 10

The temperature of the left load cell is 23.722331797 °C.
 The serial number of the left load cell is 22128.

Rtc = 7356.9474294 kgf

R1 = 16207.672048 lbf

D1(1) = .00000638
 D1(2) = .00000002
 D1(3) = .00000002
 D1(4) = .00000002
 D1 is repeating.
 R1 = 16207.672034

The roots of the left load cell's calibration equation are as follows:

R1 = 16207.672034 lbf

R2 = -19918220.5117 lbf

The force detected by the left load cell (S/N 22128) after
 lifting the cylinder is 72095.3047085 newtons.
 This force represents the portion of the cylinder's
 apparent weight detected by the left load cell.

The transducer-indicator reading of the right load cell is 7419 kgf.

Alpha (α) = 1.00000000000
 N2 = 26

Results from Weighing No. 2 (continued)

The temperature reading of the right load cell is 24.732197604 deg C.

The serial number of the right load cell is 22104.

$R_{tc} = 7418.87919897 \text{ kgf}$

The root obtained before substituting it back into the equation is $R1 = 16343.5369056 \text{ lbf}$.

$D2 > -.01$ and $D2 < .01$ and $R1 = 16343.5369056$

The root obtained before substituting it back into the equation is $R2 = -27981278.0974 \text{ lbf}$.

$D3(1) = -.00003997$

$D3(1) > -.01$ AND $D3(1) < .01$. $R2 = -27981278.0974$

The roots of the right load cell's calibration equation are as follows:

$R1 = 16343.5369056 \text{ lbf}$

$R2 = -27981278.0974 \text{ lbf}$

The portion of the cylinder's apparent weight detected by the right load cell (SN 22104) after the cylinder is lifted is 72699.6616634 newtons.

The cylinder's total apparent weight = 144794.966372 newtons.

The cylinder's total apparent mass (M_{lc}) = 14768.2233791 kg
or 32558.3649307 lbm.

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|The cylinder's LCBWS apparent mass versus brass ( $M_c$ ) = 32563.021836 lbm |
|or 14770.3357155 kg. |
| |
|The cylinder's apparent mass versus brass determined on the |
|facility's accountability scale ( $M_f$ ) is 32548.7 lbm or 14763.839441 kg. |
| |
|The difference between the LCBWS apparent mass versus brass |
|and that of the accountability scale's ( $M_c - M_f$ ) is 14.321836 lbm or |
| 6.49627441971 kg. |
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ACRONYMS AND INITIALISMS

AECB	Atomic Energy Control Board
BNL	Brookhaven National Laboratory
ERL	Eldorado Resources Ltd.
ESP	U.S. Enrichment Safeguards Program
IAEA	International Atomic Energy Agency
ISPO	International Safeguards Project Office
LCBWS	load-cell-based weighing system
NBS	U.S. National Bureau of Standards
ORGDP	Oak Ridge Gaseous Diffusion Plant
POTAS	U.S. Program for Technical Assistance to IAEA Safeguards
RTD	resistance temperature detector

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