27
4-11-77
2580 UT-15

UCID- 17398

Lawrence Livermore Laboratory

MECHANICAL DESIGN AND ENVIRONMENTAL TESTING
OF A COMPUTING GAMMA SPECTROMETER

K. L. Steffan

February 17, 1977

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the laboratory.

Prepared for U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
MASTER

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.

The following pages are an exact
representation of what is in the original
document folder.

LAWRENCE LIVERMORE LABORATORY

TO: All holders of UCID-17398 Mechanical Design and Environmental Testing
of a Computing Gamma Spectrometer
FROM: Technical Information Department, L-9

ERRATA

Please make the following corrections to your copy of UCID-17398:

Page 4

Last line on page should read: ". . . . 15 K per h."

Page 23

Caption for Fig. A-22 (b) should read: "rubber snubber."

Caption for Fig. A-22 (d) should read: "captive screw (two per clamp)."

Page 25

Eighth line from bottom should read: ". . . . 268 K."

B.H. Kamegai

Technical Information Department

CONTENTS

Abstract	1
Introduction	1
Results	2
Recommendations and Conclusions	4
Appendix A. Details of the Mechanical Design and Environmental Tests	5

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research and Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or 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.

MASTER

MECHANICAL DESIGN AND ENVIRONMENTAL TESTING OF A COMPUTING GAMMA SPECTROMETER

ABSTRACT

A portable computing gamma spectrometer has been constructed and environmentally tested. It functions properly after undergoing both a 150 mm drop test and a 1.5 g vibratory sweep test at 263 K. The drop height represents the level beyond which at least partial failure results. The unit is unaffected by thermal cycling but is somewhat sensitive to thermal shock. It is mounted in a waterproof container.

INTRODUCTION

A portable computing gamma spectrometer has been developed to provide a means of identifying radioactive materials under field conditions. This unique instrument was designed with special capabilities that make it particularly useful in a variety of emergency situations. After 2 to 3 years of developmental activity, we are nearing completion of the first 13 spectrometers. This report summarizes the mechanical design, assembly, and environmental testing of them. A discussion of the electronic design and capability of this instrument has been published.¹

Although the mechanical design effort began in January 1975, this report centers upon activity from May 1976 when I joined the program until its completion in February 1977.

The intended use of the spectrometer required that it be housed in a case that appears as a piece of luggage. For this reason a standard suitcase was modified and strengthened to withstand moderate handling and weather conditions as well as to house and protect the instrument. It is now a stronger piece of luggage, but as an instrument case, it is still relatively fragile.

Twelve units have been completed and delivered thus far. The remaining unit will be ready for delivery by the end of March 1977. Details of the mechanical design and environmental testing effort may be found in Appendix A.

RESULTS

Each spectrometer undergoes the set of five environmental tests described below. Although these tests appear minimal, they approach the limit tolerable by the unit, which was initially designed to meet other criteria.

The test description applies to the first unit. It was instrumented for these tests and successfully passed them. We did not operate the spectrometer during any of these tests. Rather, it was considered to have passed each test if it functioned normally afterward.

1. Mechanical Vibration

This test consisted of a 1.5-g, 12-min, vibratory sweep from 5-200-5 Hz. The test was performed at ambient temperature and also at 263 K in a manner consistent with MIL-STD-810C.* Test results were temperature independent.

- a. With the spectrometer installed, the suitcase was first mounted with its canisters on the shaker table and driven in a vertical direction (Fig. 1). Resonance occurred at 50 to 60 Hz; amplification at that point was about 8:1.
- b. It was next laid on its side upon the shaker table and driven in a vertical direction (Fig. 2). Resonance was at 80 Hz with amplification at that point about 8:1. The same results were obtained with either side of the suitcase upon the shaker table.
- c. Vibration performance along the ends of the suitcase was of secondary interest compared to its sides. Therefore, because time did not permit it, the unit was not vibrated through its ends.

2. Mechanical Shock

The suitcase, with the spectrometer installed, was dropped once from a height of 150 mm onto a 50-mm-thick surface of plywood over concrete (Fig. 3). Impact was against a bottom corner of the suitcase. Temperature of the unit was 263 K. The unit functioned normally afterward. No adverse effects were detected.

*MIL-STD-810C is a compilation of military specifications governing environmental tests for electronic instruments.

Figure 1. Shake test.

Figure 3. Mechanical shock test.
Suitcase 150 mm above plywood
surface.

Figure 2. Shake test.

Figure 4. Computing gamma spectrom-
eter with lid removed.

3. Humidity

The humidity test was a greatly abbreviated version of the test specified in MIL-STD-810C. A humidity chamber environment of 311 K and 95 to 98% relative humidity was maintained for 17 h. During this period, the lid was removed and the front panel of the spectrometer exposed to the chamber environment (Fig. 4). Initially, the suitcase interior was at 298 K and 10% relative humidity. After 17 h, it was at 308 K and 16% relative humidity.

4. Thermal Shock

During tests of the production unit, thermal shock occurred when the unit was exposed to room temperature after being tested at 263 K. In preliminary tests, however, the suitcase and, independently, the spectrometer with its sodium-iodide detector were thermally shocked to 325 K and 263 K from an ambient temperature of 299 K and functioned normally afterward. In addition, the spectrometer without its detector successfully withstood thermal shock to 343 K and 243 K. It is suspected that the detector is somewhat thermally shock sensitive but the degree of sensitivity is not known.

5. Immersion

The immersion test was a modified version of that specified in MIL-STD-810C. After being immersed for 1 h under a minimum head of 300 mm of water, the closed and empty suitcase was found to be essentially watertight. This test was conducted after all of the above tests were completed.

The 12 spectrometers to follow will be subjected to abbreviated proof tests, i.e., uninstrumented versions of the above tests. Specifically, they will undergo: Test 1b - Mechanical Vibration, Test 2 - Mechanical Shock, and Test 5 - Immersion. In addition, they will undergo a Thermal Cycle Test:

299 K → 325 K → 263 K → 299 K

There is a minimum 12-h hold at both the high and low temperatures. The rate of temperature change is limited to 287 K per h.

RECOMMENDATIONS AND CONCLUSIONS

The 13 spectrometers developed and built went to six scientific organizations throughout the country. Their respective responses indicate a possible commercial market for instruments of this type. If so, future units would be significantly improved by mechanical redesign. The present units are sensitive to thermal and mechanical shock. Their tolerance to dust is unknown and tolerance to humidity, while encouraging, has not been fully verified. In general, standards should be selected for the desired level of environmental performance and the units redesigned to meet them.

One requirement was that the spectrometer be housed in a case that appears as luggage. However, if that requirement is not necessary, one can reduce the cost of the case considerably by using a commercially available instrument case.

ACKNOWLEDGMENTS

I would like to thank John W. Federline, Mechanical Designer and Thomas H. Smith, Mechanical Technician whose efforts improved the performance of these units.

REFERENCE

1. McGibbon, Alan L., *A Second-Generation 1024-Channel Portable Gamma-Ray Spectrometer*, Lawrence Livermore Laboratory, Livermore, Report UCRL-78250 (1976).

APPENDIX A
DETAILS OF MECHANICAL DESIGN AND ENVIRONMENTAL TESTS

Mechanical Design - Suitcase

In this section, I discuss the mechanical design of the suitcase and the spectrometer. The suitcase was originally Samsonite luggage, Type: Royal Traveller, Model: Montbello II, Color: Black (Fig. A-1). It is an inexpensive, one-suit luggage made of polypropylene.

The design required the suitcase be disassembled, modified, and reassembled as described below. The suitcase was first disassembled and the resulting suitcase halves were cut to accommodate the electronics contents. These modified pieces were then attached to specially fabricated, aluminum strips to form a lid section and a bottom section. A pair of specially fabricated, black-anodized aluminum frames were installed (one in each section) to form a watertight interface between lid and bottom. To fit the contour of the suitcase, these frames were fabricated in our shops on a numerically controlled, 5-axis mill. The plastic pieces, trim strips, and sealing frames were held together by adhesive and rivets (Figs. A-2 and A-3).

In preparation for assembly, the polypropylene is first primed to better accept the structural epoxy adhesive. Although we used "Scotch-Weld," a 3-M product, in our assembly operations, any comparable adhesive may be used. The adhesive is applied to the components comprising the lid section and these parts are then assembled with screws. This assembly is mounted in a special fixture which provides proper positioning and sufficient clamping force while the adhesive is drying (Figs. A-4 and A-5). After the adhesive has cured for 24 h at room temperature, the screws are replaced by rivets. The bottom section is assembled in a similar fashion except that no fixture is used. The work just described was done by Coleman Precision Manufacturing in Campbell, CA. A Laboratory mechanical technician completed the assembly with the installation of casters (Fig. A-6), latches (Fig. A-7), handle, automatic pressure-equalizer valve, microswitch (Fig. A-3) and plastic foam support cushions (Fig. A-8).

A watertight suitcase assembly, necessary to protect the spectrometer electronics from moisture, was constructed by the following assembly technique. First, the entire interior surface of the suitcase assembly was coated with Flexane 60, a Devcon Corporation product (Figs. A-9 and A-10). To act

Figure A-1. Original Samsonite luggage, left, and reworked suitcase, right.

Figure A-2. Suitcase bottom section showing (a) clear-anodized aluminum strip, (b) black-anodized aluminum frame, (c) polypropylene surfaces, (d) rivets: MS2042AD4-8 and (e) rivets: MS20470AD4-8.

Figure A-3. Suitcase, lid section showing (a) black-anodized aluminum frame, (b) polypropylene surface, (c) handle, (d) clear, anodized aluminum trim strip, (e) automatic pressure-equalizer valve, (f) micro-switch, (g) rivets: MS20470AD4-8, and (h) rivets MS20426AD4-8.

Figure A-4. Lid assembly fixture showing (a) lid frame, (b) bicycle inner tube: 20 x 1 5/8, (c) rim, and (d) fixture base.

Figure A-5. Lid assembly fixture.

Figure A-6. Casters, comprised of a steel ball bearing and a teflon holder.

Figure A-7. Suitcase bottom (exterior view) with four casters. Protruding latch on left.

Figure A-8. Suitcase bottom (interior view). Foam support cushions.

Figure A-9. Flexane-coated interior surface of suitcase lid. Micro-switch on right and automatic pressure-equalizer valve on left.

Figure A-10. Exterior suitcase lid.

as a sealant, Flexane must be properly cured for either 7 da at room temperature or 16 h at 338 K. Here again, any comparable material would have been as effective in caulking the suitcase. Second, an "O"-ring groove was cut in the lid frame. This frame holds a 3-mm diameter "O" ring which is seated against a flat, smooth surface in the bottom frame. Third, latches must be capable of exerting sufficient force to effect a seal between the "O" ring and the frames. The first unit delivered had suitcase latches which possessed sufficient force to seal the "O" ring when new, but which loosened after a little use. The "O"-ring seal was then not watertight and there was no provision for adjustment. In view of this, subsequent suitcases have latches from a different manufacturer which possess sufficient clamping force and are adjustable (Fig. A-11).

While it is important that the suitcase be watertight, it is also necessary for external and internal air pressure to be equalized so that the suitcase may be opened after an airline flight. This was done using an 0.4- μ Nucleopore filter mounted and supported in a suitable holder. The resulting breather assembly would readily pass air yet would not pass moisture unless a differential pressure of 34.5 KPa or more developed (Fig. A-12).

The exterior appearance of the case as luggage was maintained by mounting the breather inside the lid under one of the mounting posts of the handle. This post had its center drilled. External air gets inside the unit by passing into one end of the handle. This end houses foam and the mounting post. The foam acts as a dust filter. Air passes through it, into the post, then along the post axis (the drilled center portion) until it encounters the breather assembly. After passing through the breather it is inside the unit. Air within leaves by moving in the reverse direction along the same path (Fig. A-13).

The plastic parts comprising the suitcase are low in density, present a good appearance, and are abrasion resistant. However, the plastic, polypropylene, has a few characteristics which I consider detrimental to its use in this project. One of these is that the brittle transition range for this material is 273 K to 253 K. Below this temperature, the material is brittle, meaning it can fracture with no plastic deformation. Also, the thermal expansion coefficient is 3 to 5 times that of aluminum. In the current configuration, the polypropylene is put into tension upon cooling. At temperatures of 238 K, the tensile stress in the polypropylene is about 1/10 yield strength.

Figure A-11. Latches. Top: original latch, type 4443N, from vendor: Excelsior, Inc. Center and bottom: later, improved latches, type H462-1 from vendor: Hartwell.

Figure A-12. Breather (automatic pressure-equalizer valve).

Figure A-13. Breather installation showing (a) handle, (b) drilled post, (c) foam filter, (d) breather, (e) trim strip.

Figure A-14. Chassis and front panel showing (a) hydrogen getter, (b) chassis, (c) detector well, (d) spacer, (e) front panel seal, (f) subpanel, (g) keyboard panel, (h) polarizing filter, (i) bezel, and (j) front panel.

During preliminary environmental tests, the lid cracked when the suitcase was dropped onto a bottom corner from a height of 300 mm at a temperature of 238 K.

A second characteristic is that there are few adhesives that will bond well to polypropylene. In the present case "Scotch-Weld" structural epoxy was used. It attains a fair to good bond but is not consistent. At room temperature, the bond usually broke first. However, occasionally the bond was stronger than the polypropylene. At temperatures of 358 K the bond is quite weak and breaks readily.

Mechanical Design - Electronic Chassis

The two main mechanical components of the spectrometer are the front panel and the chassis (Fig. A-14). The front panel is a modified version of a standard 475 mm panel. It fits into the bottom frame and seals it by means of a split "O" ring placed around the perimeter of the panel. The split "O" ring is fabricated by the Laboratory's Plastics Group using a specially made mold (Fig. A-15). The panel itself is gold-anodized, painted, and silk screened. Keyboard and subpanel pieces fit into it. Originally they were held in place only by adhesive, but this was ineffective because the glue bond would easily break and the pieces would pull out. The problem was solved by the addition of reinforcing strips, riveted and glued to these pieces. The strips were installed behind the front panel and strengthened it significantly while also holding the panel pieces securely in place (Fig. A-16). The rivets are of aircraft structural quality while the adhesive consists of a general purpose epoxy resin (EPON828) and a polyamide curing agent (VERSAMIDE). Additional hardware includes a black-anodized aluminum detector well, glued into the subpanel and an assembly consisting of a black-anodized aluminum bezel, a polarizing filter and a lens all held in place by screws (Fig. A-17). The latter assembly frames a section of the front panel where data is displayed. A camera (Polaroid SX-70) can be used to record this data. Camera attachment is facilitated by the fabrication of a camera mount and camera bellows (Fig. A-18). The length of the bellows is compatible with the focal length of the camera. The camera, mount, bellows, and film are stored in the suitcase lid (Fig. A-19).

The chassis consists of alodined, aluminum sheet metal stampings held together by rivets, screws, and locking, press-in nuts. Examples of typical stampings and fixtures are found in Figs. A-20 and A-21. The chassis is attached to the front panel but the coupling is relatively weak and cannot

Figure A-15. Mold for the panel seal showing
(a) components of seal mold, (b) rubber seal,
and (c) front panel.

Figure A-16. Complete chassis consisting of (a) hydrogen getter, (b) rubber snubber and mounting lug, (c) batteries, (d) breather, (e) detector well, (f) spacer, (g) rivets: MS20426AD4-6, and (h) reinforcing strips.

Figure A-17. CRT display frame showing (a) "O" rings, (b) polarizing filters, (c) lens, and (d) black-anodized aluminum bezel.

Figure A-18. Camera accessories: (a) Polaroid SX-70 camera, (b) camera mount, and (c) camera bellows.

Figure A-19. Suitcase lid cushion:
 (a) lid cushion, (b) camera mount,
 (c) camera, (d) bellows, (e)
 charging cord, (f) microphone, and
 (g) film.

Figure A-20. Hydroformed part and
 die.

take high acceleration loads without gross deformation of certain chassis components. The chassis is held in the suitcase by a bolt through the suitcase bottom. The bolt threads into a rubber snubber attached to battery clamps on the chassis (Figs. A-16 and A-22).

Environmental Tests

The basic assumption of the environmental test was that the suitcases would encounter moderate rather than extreme weather conditions. Environmental tests were broken into two groups: a preliminary test sequence, using a suitcase and an empty chassis (no electronics), and a prototype sequence, wherein the complete unit (suitcase, electronics, and accessories) was tested. The preliminary test took place during the last part of August and the beginning of September. In this series, two suitcases were tested under three different conditions: thermal cycle, thermal shock, and mechanical shock.

The thermal cycle test began with the suitcase in thermal equilibrium at 300 K (ambient temperature). The temperature was raised to 325 K at 12 K/h and held for 24 h. Relative humidity at that temperature was 15%. The temperature was then returned to ambient at 12 K/h. Another thermal cycle began with the suitcase in thermal equilibrium at ambient temperature. The temperature was then lowered to 238 K at 12 K/h and maintained there. Relative humidity was about 30%. After 24 h, it was returned to 300 K at 12 K/h.

In the second environmental test of this sequence, the suitcase, again in thermal equilibrium at 300 K, was thermally shocked by quickly placing it into a chamber at 325 K. After 1 1/2 h it was promptly removed and exposed to ambient environment. In the second part of this test, the suitcase, initially at ambient temperature, was again quickly placed into a chamber at 238 K. After 1 1/2 to 2 h it was again promptly removed and exposed to ambient temperature. The suitcase was immersed in water after each of these tests to check for leaks. One conclusion from these tests was that the thermal shock test appears to be a more severe and less time-consuming test. It was also more consistent with the treatment the unit would receive in actual use.

The mechanical shock test consisted of dropping the suitcase from various heights onto 50 mm of plywood backed by concrete (Fig. 3). In order to simplify the number of drops, it was decided to drop the suitcase onto one of its bottom corners. This was believed to be the most severe test. For this sequence, the chassis was weighted with 9 kg of lead to approximate the mass of the electronics components. Three accelerometers were installed. One was

Figure A-21. Hydroformed part and die.

Figure A-22. Battery clamp assembly consisting of (a) battery clamp, (b) rubber scrubber, (c) metal locating block, and (d) (2 in. clamp) captive screw typical.

located inside the suitcase at the impact corner. The second was mounted on the chassis. Both were aligned with the direction of fall. The third accelerometer, a tri-axial type, was mounted on the chassis and aligned with its length, width, and height.

Initial drop tests were done at ambient temperature from drop heights of 150 mm and 300 mm. Three or four drop tests from a 150 mm height were done first in order to check the test procedure, the TDAC data-recording system, and the test repeatability. Two drop tests from a 300 mm height were conducted next to check test repeatability. Subsequently, a drop test from a height of 150 mm at a temperature of 238 K was performed. After that, a drop test at the same temperature and a 300 mm drop height cracked the suitcase lid. This was the first such test at this height and temperature and it was only afterward that we learned of the relatively high, brittle transition temperature of polypropylene.

Data recorded by the suitcase accelerometer from all tests involving a 150 mm drop was in the range of 20 to 30 g, while the data from all 300-mm drop tests was in the range of 40 to 60 g. The recorded pulse width was 10 to 15 ms and was essentially independent of drop height. These data indicate the shock level the suitcase itself experienced during the drop test. Accelerometers mounted on the chassis indicated shock levels 10 to 100 times higher. This is a high degree of amplification. You will recall that the chassis was loaded with 9 Kg of lead to approximate the mass of the electronic components. It is believed that a substantial amount of the amplification derived from this lead weight shifting upon impact and acting as a shock amplifier. The 300 mm drop tests did produce some permanent deformation in the chassis. From these preliminary tests, it was concluded that future units would be dropped from a height no greater than 150 mm at a temperature of 263 K to avoid the possibility of either chassis deformation or fracture of the suitcase.

Immersion tests were conducted after each drop. Initially, suitcases leaked after some of the tests, but after being caulked inside and out with Flexane 60 the suitcases no longer leaked.

The second sequence of tests (prototype) was done under moderate to severe time constraints due to a delivery deadline. The following tests were conducted between the 21st and the 29th of September: water immersion, vibration, shock, and humidity.

The first test of this sequence was a water-immersion test with the suitcase closed and weighted with 27 to 32 Kg of lead. The suitcase was found

watertight after being submerged under a minimum of 150 mm of water for half an hour.

Vibration tests were conducted in accordance with MIL-STD-801C. A performance check of the electronics was pursued after each step of the test sequence or as deemed necessary. The suitcase, with spectrometer installed, was vibrated independently in each of two directions. In the first of these, it was mounted with its casters on the shake table and firmly clamped thereto (Fig. 1). The initial sweep of from 5-200-5 Hz was of 12 min duration, 0.5 g input, and was conducted at ambient temperature. The intent was to look for resonance points and amplification factors. Subsequent sweeps were made at 1.0 g and 1.5 g input. As a result of information gained from these tests, additional support blocks of plastic foam (Ethafoam) were added in the suitcase bottom to reduce amplification. In the final configuration, peak resonance was at 50 to 60 Hz and amplification at that point was about 8:1. The test was repeated at 263 K and 1.5 g input. No change in resonance peak or amplification was found.

The suitcase was then mounted on its side on the shake table (Fig. 2). A special mold was made to fit the suitcase contour. Again, the initial sweep of from 5-200-5 Hz was 12 min long at 0.5 g input, and ambient temperature. Subsequent passes were made at 1.0 g and 1.5 g input. As a result of these tests, the support of the plastic foam was increased so as to extend over the entire interior side surfaces of the suitcase. In this final configuration, peak resonance was at about 80 Hz, and amplification at that point was about 8:1. The suitcase was then turned over and mounted with its other side on the shake table. A single sweep from 5-200-5 Hz of 12 min at 1.5 g and ambient temperature was performed. Peak resonance and amplification were unchanged. The suitcase was then turned over, mounted on its first side again and cooled to 263 K in preparation for a cold temperature vibration test. The interior suitcase temperature at the time of the test was -5°C . This sweep of 5-200-5 Hz was 12 min long with an input g-level of 1.5. The peak resonance and amplification were unchanged. The electronics unit passed performance tests conducted throughout this sequence.

Parameters for the mechanical shock test were determined previously during the preliminary test sequence. This simplified the current mechanical shock test to a single drop at 263 K. In preparation for this test, the unit was suspended in a cooling chamber and chilled to 263 K. It was then dropped

from a height of 150 mm onto a floor of 50 mm plywood over concrete. At the time of the test, the suitcase interior was 264 K. The electronics unit passed a performance check after this test; however, instrumentation data was lost when the triggering set-up malfunctioned.

Because of time constraints, the unit then underwent a greatly abbreviated version of the humidity test specified in MIL-STD-810C. Preparations for it were made in the Low Humidity Room of 131 High Bay where the ambient relative humidity was about 10%. A humidity sensor was placed in the suitcase and a thermocouple was positioned in the annulus between the detector and detector well. For this test, the lid was removed and the front panel exposed to the humidity chamber environment. The chamber was initially at 299 K and 55% relative humidity while the suitcase interior (the electronics environment) was at 297 K and 10% relative humidity. The chamber temperature was raised to 311 K in about an hour, then the humidity was promptly raised to 95 to 98% relative humidity. These conditions were maintained for 17 h. During this period, the suitcase interior reached 311 K and 16% relative humidity. After 17 h, the chamber humidity was lowered to about 20% to begin a 1 to 2 h drying period. The test was then terminated. Subsequently, the electronics unit successfully passed a performance check.

The maximum humidity tolerated by the electronics before high-voltage arcing occurs is not known. It was not the purpose of this test to determine that level. If it were known or determined, it could be expressed in terms of specific humidity, a quantity independent of temperature. For example, the unit functions in an atmosphere of 299 K and 55% relative humidity. This corresponds to 311 K and 25% relative humidity, both of which correspond to a specific humidity of 70 grains moisture per pound of dry air.

The final test was a repeat of an earlier immersion test. The suitcase, closed and empty, was fitted with new latches of the same type as the originals, weighted with 27 to 32 Kg of lead, and immersed in water to a depth 300 mm below the surface. After 1 h, the suitcase was removed, dried, and opened. The "O"-ring seal was watertight but a small leak had developed along a bottom edge. It was patched and delivered to electronics personnel in preparation for shipment.

BIBLIOGRAPHY

1. Holmes & Narver, Inc., Mercury, Nevada - personal communication.
2. CFR Title 10, Part 20, Paragraph 20.4, "Radiation Units."
3. ICRU Handbook 85. U.S. National Bureau of Standards, 1964.
4. Environmental Sciences Department Final Radiological Survey of U20aa. Reynolds Electrical & Engineering Co., Inc., Mercury, Nevada.
5. "Vac-All" Street & Catch Basin Cleaner. Central Engineering Inc., Milwaukee, Wisconsin.
6. "In-house" portal monitor. Reynolds Electrical & Engineering Co., Inc., Mercury, Nevada.
7. Author's personal observation.
8. ERDA Manual Chapter 0524, Appendix A, "Concentrations in Air and Water Above Natural Background."
9. "In-house" model air sampler. Reynolds Electrical & Engineering Co., Inc., Mercury, Nevada.
10. U.S. EPA, Las Vegas, Nevada. "Interim Report for the Nevada Test Site, Third Quarter, 1976." December 1976. Informal Report.
11. NIOSH approved permissible air sampling pump, Model C-115. Bendix Corporation, Baltimore, Maryland.

NOTICE

"This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research & Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or 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."

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research & Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or 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.

NOTICE

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Energy Research & Development Administration to the exclusion of others that may be suitable.

Printed in the United States of America

Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy \$; Microfiche \$3.00

<u>Page Range</u>	<u>Domestic Price</u>	<u>Page Range</u>	<u>Domestic Price</u>
001-025	\$ 3.50	326-350	10.00
026-050	4.00	351-375	10.50
051-075	4.50	376-400	10.75
076-100	5.00	401-425	11.00
101-125	5.50	426-450	11.75
126-150	6.00	451-475	12.00
151-175	6.75	476-500	12.50
176-200	7.50	501-525	12.75
201-225	7.75	526-550	13.00
226-250	8.00	551-575	13.50
251-275	9.00	576-600	13.75
276-300	9.25	601-up	*
301-325	9.75		

*Add \$2.50 for each additional 100 page increment from 601 to 1,000 pages;
add \$4.50 for each additional 100 page increment over 1,000 pages.

Technical Information Department

LAWRENCE LIVERMORE LABORATORY

University of California | Livermore, California | 94550