

7007
LA-UR-08-TBD

*Approved for public release;
distribution is unlimited.*

Title:

**Dexterity Tests Data Contribute to Reduction in Leaded
Glovebox Gloves Use**

Authors:

**Michael E. Cournoyer, Cindy M. Lawton, Amanda M.
Castro, Steve Costigan, and Stephen Schreiber**

Submitted to:

**Journal of the American Society of Mechanical Engineers,
Proceedings from Waste Management 2009 Symposium,
Phoenix, Arizona, March 1-5, 2008.**

Dexterity Tests Data Contribute to Reduction in Leaded Glovebox Gloves Use

Michael E. Cournoyer, Cindy M. Lawton, Amanda M. Castro, Steve Costigan, and
Stephen Schreiber

Los Alamos National Laboratory,
Los Alamos, NM 87545
(505) 665-7616

ABSTRACT

Programmatic operations at the Los Alamos National Laboratory Plutonium Facility (TA-55) involve working with various amounts of plutonium and other highly toxic, alpha-emitting materials. The spread of radiological contamination on surfaces and airborne contamination and excursions of contaminants into the operator's breathing zone are prevented through the use of a variety of gloveboxes. Through an integrated approach, controls have been developed and implemented through an efficient Glovebox Glove Integrity Program (GGIP). A key element of this program is to consider measures that lower the overall risk of glovebox operations. Line management owning glovebox processes through this program make decisions on which type of glovebox gloves (the weakest component of this safety significant system) would perform in these aggressive environments. As Low As Reasonably Achievable (ALARA) considerations must be balanced with glove durability and worker dexterity, both of which affect the final overall risk of the operation. In the past, lead-loaded (leaded) glovebox gloves made from Hypalon® had been the workhorse of programmatic operations at TA-55. Replacing leaded gloves with unleaded gloves for certain operations would lower the overall risk as well as reduced the amount of mixed TRU waste. This effort contributes to Los Alamos National Laboratory Continuous Improvement Program by improving the efficiency, cost effectiveness, and formality of glovebox operations. In the following report, the pros and cons of wearing leaded glovebox gloves, the effect of leaded gloves versus unleaded gloves on task performance using standard dexterity tests, the justification for switching from leaded to unleaded gloves, and pollution prevention benefits of this dramatic change in the glovebox system are presented.

Introduction

Plutonium requires a high degree of confinement and continuous control measures in nuclear research laboratories because of its extremely low permissible body burden [Ref. 1]. Methods and equipment must be designed toward the ultimate accomplishment of preventing any internal deposition of plutonium even though such a degree of control may often seem extreme. Uncontrolled releases of plutonium usually result in some contamination of the atmosphere near the site of release, whether the plutonium is in a liquid, solid, or gaseous state. To preclude uncontrolled release, gloveboxes are used to confine plutonium during laboratory work. The glovebox is an “absolute barrier”, *i.e.*, a sealed enclosure. A typical glovebox train is shown in Figure 1.

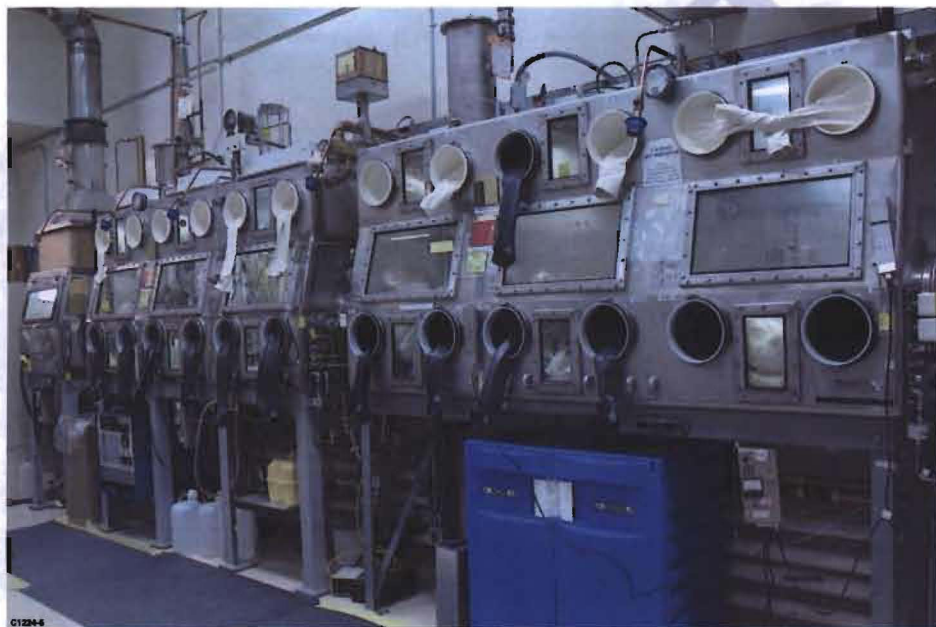


Figure 1. Typical Glovebox Train

The weakest link of this system is the glovebox gloves (hereafter referred to as gloves) themselves. They are easily punctured, torn, cracked, will deteriorate, and have selective permeability for various chemicals. As a matter of good business practices, a team of glovebox experts from Los Alamos National Laboratory (LANL) has been assembled to proactively investigate processes and procedures that minimize unplanned openings in the gloves, *i.e.*, breaches and failures. Working together, they have developed the key elements of an efficient Glovebox Glove Integrity Program (GGIP). Recent accomplishments of this team have been previously reported [Ref. 2]. A key element of this program is to consider measures that lower the overall risk of glovebox operations. The proper selection of gloves is one of these measures.

The lead-loaded (leaded) glove made from Hypalon® was for many decades the workhorse of LANL Plutonium Facility (TA-55) programmatic operations and represents over 75% of the gloves used (6000). Thus, studies to determine exactly how leaded versus Hypalon® (unleaded) gloves may affect the outcome of any dexterity task would be fundamental. Line managers and Health Physics Operations could make better

decisions on which glove is better suited for an operation if they knew how much longer a task takes in a leaded glove versus an unleaded glove. This data can be obtained by having glove workers perform the following acceptable dexterity tests: Purdue Pegboard, and the Minnesota Dexterity Test. In the following report, the pros and cons of wearing leaded gloves are expanded on, the effect of leaded gloves versus unleaded gloves on task performance using standard dexterity tests are examined, and pollution prevention benefits of this dramatic change in the glovebox system are presented.

Glove Features

Gloves used at TA-55 are made from four types of formulations: Hypalon, Hypalon with an inner lead oxide layer, Butasol,[®] and Viton.[®] Finding the most compatible glove for the glovebox environment is the key to minimizing unplanned glove openings and is the responsibility of line management. In terms of chemical compatibility, hypalon is the material of choice for most glovebox operations because it is resistant to interactions with strong acids and bases. Lead-lined Hypalon gloves have added radiological shielding. For gas permeability applications, Butasol is the material of choice. At this time hypalon glove are used for tritium operation because hazards from a breach present a greater risk than the permeation issue with tritium. For operations involving bromobenzene, gloves made from Viton are selected.

The physical and mechanical properties of the hypalon gloves used at TA-55 are compiled in Table 1.

Table 1. Glove Physical and Mechanical Properties.

Properties	North Catalog No.		
	8Y1530	8Y3030	8YLY3030
Material	Hypalon	Hypalon	Hypalon/ Lead Oxide-Neoprene/ Hypalon
Thickness	15 mil	30 mil	30 mil
Tensile Strength	1900 psi	1900 psi	1200 psi
Elongation	500%	500%	300%
Abrasion (cycles)*	1	4	4
Cut (number)*	1	1	1
Tear (newton)*	1	1	2
Puncture (newton)*	1	2	1

*EN 388 mechanical ratings for each glove

Thicker gloves of the same material provide better protection against puncture, cut, sharps, and abrasive hazards. Thinner gloves are preferred for tasks that require more dexterity. Tensile strength and elongation values are independent of thickness. In general, the higher the tensile strength and elongation values, the more resistant the glove is against physical hazards. The EN 388 mechanical ratings for abrasion, cut, tear and puncture, take into account the thickness of the glove [Ref. 3]. The higher the EN 388 rating, the more resistant to these hazards the gloves are.

The lead in gloves is used to shield against low energy and moderately penetrating gamma rays and x-rays (less than 50-keV) and this results in a reduction of the radiation dose to the hands. The disadvantage of leaded gloves versus unleaded glove is that a task takes longer to complete secondary to reduction of dexterity, and weighs more producing excessive force to be utilized by the body. Furthermore, leaded gloves do little to shield against neutrons and more penetrating gamma rays (more than 50-keV). While, leaded gloves may increase the protection against external radiation doses, the lower flexibility of the leaded gloves may introduce problems for those who perform task requiring fine or gross manual dexterity. Additionally, prolonging the time required to perform a task may increase the collective dose a worker receives. There are opportunities at TA-55 to improve overall safety for glovebox workers through improved selection of gloves. Specifically, there are situations where use of unleaded rather than leaded gloves is preferable when all factors are considered. Reasons that unleaded gloves should be selected over layered hypalon-lead when possible include the following [Ref. 4]:

- **Mechanical Properties:** There are *significantly* better mechanical properties of the unleaded gloves over leaded gloves, as shown in Table 1. The unleaded gloves provide better protection from glove punctures. The unleaded glove does have a lower tear rating. Since many of the activities at TA-55 involve rotating equipment, the lower tear rating of unleaded gloves versus leaded glove is considered an advantage.
- **Dexterity:** Unleaded gloves are more flexible therefore provide greater dexterity than leaded gloves. The use of unleaded instead of leaded gloves is likely to result in overall greater safety from mechanical hazards. This would be particularly true and important for operations where better dexterity could provide improved safety around equipment and or machinery that could cause injury or penetration of the gloves (for example around rotating parts, sharps, or operations that require fine motor control). It would also be useful, for situations in which the use of protective gloves over glove box gloves is called for in operations that involve sharps; the loss of dexterity that results when the protective gloves are used is lessened because gloves without lead are more flexible. Like EN 388, there is European Standard for Dexterity: EN 420 [Ref. 5]. In this test, a subject wearing the test glove is instructed to pick a series of pins of similar length but differing diameters. The dexterity is rated according to the smallest pin diameter that the subject wearing the glove can pick up; the smaller the pin diameter, the higher the rating. EN 420 results for the gloves used in this study were not available at the time publication.

- **Ergonomic Considerations:** Hypalon gloves are thought to be a better option from an ergonomic perspective as they allow for more flexibility and less strain on the upper extremity. This decrease in strain to the upper extremity and back is thought to correlate with a decrease in injury; particularly injuries resulting from overuse.
- **Radiation Epidemiology:** Penetrating radiation passes through tissue in a well-known manner. An uptake of plutonium into the lungs is more unpredictable. Externally penetrating radiation affects cells directly, whereas “internally deposited” radionuclides must be transported through the body. Consequently, dosimetry is generally more uncertain with internal doses than with extremity doses.

Experimental Design

The purpose of this study was to examine the effects of leaded gloves on both gross and fine motor dexterity with consideration of gender and experience as glovebox worker. To this end, a laboratory experimental design was developed.

- **Participants** In accordance with 45 CFR 46, Protection of Human Subjects and LANL’s Federal Wide Assurance with the Office for Human Research Protection, Department of Health and Human Services FWA#00000362, 40 participants volunteered to participate in this study. No tracking or numbering system links the participant to the raw data that we collect. The researchers distributing test are the only ones that have access to the raw data.
- **Dexterity Test Platforms** Two platforms were used to simulate finger dexterity and hand motions, the Minnesota Dexterity Test and the Purdue Pegboard Test. Each platform included different tasks that used the dominant hand or both hands together.

Minnesota Dexterity Test This widely used test measures capacity for simple but rapid eye-hand-finger movement and gross motor dexterity. This is particularly applicable in shop occupations requiring quick movement in handling simple tools and production materials without differentiating size and shape. The complete test consists of 5 different tests, however, in our study we felt that Turning and One-handed Turning tests best suited what we were looking for. The scores are based on the total time required to complete an entire task.

Purdue Pegboard Test The Purdue Pegboard Test was first developed by Joseph Tiffin, Ph.D., an Industrial Psychologist at Purdue University in 1948. Since that time, this device has been used extensively to aid in the selection of employees for jobs that require fine motor dexterity and coordination as well as in physical therapy both as a measuring and conditioning device. The Purdue Pegboard measures the fine motor skill of an individual taking into account single handed dexterity as well as the use of both hands. The single handed test, we used the dominant hand for our study, consists of a test that last for 30 seconds where the individual picks up the pins and

places them one by one in the row of holes provided. To measure the dexterity of both hands the assembly test is given.

- **Glovebox Gloves** Glovebox gloves tested were North Hypalon 15 Mil (8Y1532), North Hypalon 30 Mil (8Y3032), and North Hypalon Lead Lined, 30 Mil (8YLY3032). All gloves were used as received from North Safety (Clover, SC).
- **TA-55 Cold Laboratory** The TA-55 Cold Laboratory is a fully functional glovebox train with several types of gloveboxes including a trolley line in a nonradiological environment. Gloves were assembled on a rigid glovebox.
- **Experimental Sessions** One practice run with the 15 mil gloves were conducted before recording the results of the Minnesota Dexterity Test and the Purdue Pegboard Test. All tests were performed with a random sequence to minimize the effect of learning which could affect the results.

Results

Laboratory test were performed to examine the effects of dexterity on three different types of gloves. During the individual sessions, data were recorded manually on a worksheets designed for data collection. In all, 62 TA-55 residents participated in the study. The anthropometric data for the study is compiled in Table 2.

Table 2. Anthropometric Data.

Anthropometric Measurement	Mean	Standard Deviation	Minimum Value	Maximum Value
Worker Height (in)	68.2	3.8	59.8	76.0
Elbow Height (in)	42.0	2.5	35.5	45.5
Shoulder Height (in)	55.8	3.3	49.5	64.3
Shoulder Reach (in)	25.4	1.8	21.0	27.5
Shoulder Angle (degree)	63.5	18.9	25.0	95.0
Shoulder Angle w/ step stool (degree)	50.5	9.4	45.0	70.0
Hand Breadth (in)	3.4	0.4	2.8	4.0
Hand Circumference (in)	9.9	0.9	8.1	11.3
Hand Length (in)	7.3	0.5	6.5	8.5
Finger Length (in)	3.1	0.3	2.8	4.0

The results of the dexterity tests are shown in Tables 3 and 4.

Table 3. Results of Minnesota Dexterity Test.

	One-handed Turning Test (sec)	Turning Test (sec)	Pincer Test (lbs)	Grip Test (lbs)
Statistics	Hypalon 15 mil. Thickness, 30 in. Glove			
Mean	95.8	88.4	13.3	93
Standard Deviation	19.1	20.8	4.2	22
Minimum Value	68.4	59.5	7.0	42
Maximum Value	137.1	123.0	22.0	125
	Hypalon 30 mil. Thickness, 30 in. Glove			
Mean	119.6	111.0	13.7	87
Standard Deviation	18.8	37.5	4.9	19
Minimum Value	82.2	72.2	6.8	45
Maximum Value	136.8	193.3	25.0	113
	Hypalon 30 mil. Thickness, 30 in. Lead-Loaded Glove			
Mean	152.5	123.4	13.0	80
Standard Deviation	35.9	28.7	4.5	17
Minimum Value	102.7	80.2	7.0	46
Maximum Value	242.0	166.2	25.0	110

Table 4. Results of Purdue Pegboard Dexterity Test.

	Dominant Hand Test	Assembly Test	Pincer Test (lbs)	Grip Test (lbs)
Statistics	Hypalon 15 mil. Thickness, 30 in. Glove			
Mean	8.1	9.2	12.9	85
Standard Deviation	1.7	2.7	2.9	21
Minimum Value	5.0	3.0	8.2	42
Maximum Value	11.0	14.0	20.0	120
	Hypalon 30 mil. Thickness, 30 in. Glove			
Mean	5.2	4.3	12.4	85
Standard Deviation	2.4	2.4	3.7	22
Minimum Value	1.0	1.0	7.0	40
Maximum Value	9.0	10.0	22.0	135
	Hypalon 30 mil. Thickness, 30 in. Lead-Loaded Glove			
Mean	4.5	4.3	12.2	85
Standard Deviation	1.9	2.4	3.3	22
Minimum Value	2.0	1.0	6.0	40
Maximum Value	9.0	10.0	20.0	135

Analysis

The analysis of the anthropometric data and correlating it to the performance data is beyond the scope of this paper and will be reported at a later date. The results of the Minnesota Dexterity Test are compared in Figure 2. Doubling the thickness of the hypalon gloves (15 mil $\rightarrow$ 30 mil) increased the task time by one-fourth for both the one-handed and two handed tasks. As expected, tasks with the leaded gloves take significantly longer than nonleaded gloves of the same thickness (30 mil). For the one-handed task, the leaded gloves take about one-fourth longer. The difference is cut by half for the two handed task.

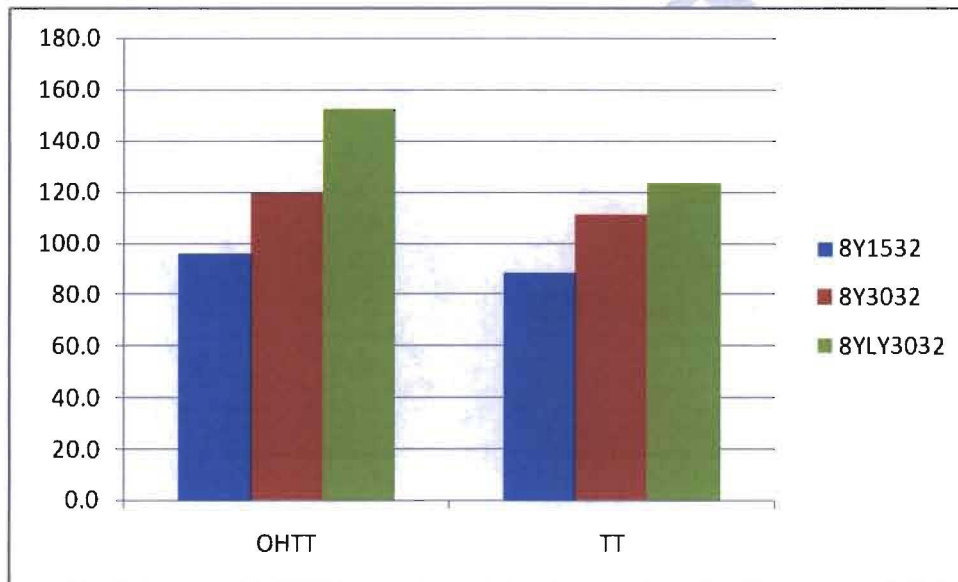


Figure 2. Results of the Minnesota Dexterity Test.

The results of the Purdue Pegboard Dexterity Test are compared in Figure 3. Performance decreases by about 40% for both the leaded and unleaded gloves for Dominant Hand Test (DHT), when the thickness of the hypalon glove is doubled (15 mil $\rightarrow$ 30 mil). This increases to 50% for the Assembly Test (AT). The performance of the unleaded was observed to be about 10% better than leaded glove of the same thickness in the Dominant Hand Test.

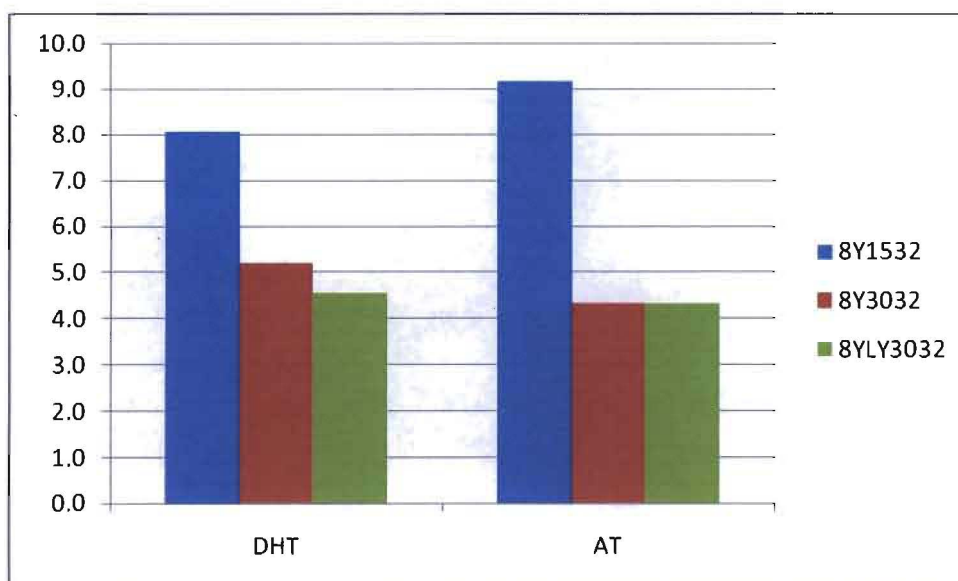


Figure 3. Results of the Purdue Pegboard Dexterity Test.

The results of the Pincer Test (PT) and Grip Test (GT) are compared in Figure 4. No difference in the pincer test was observed. A slight decrease in grip strength was observed as the thickness of the glove was increased and then again when lead is added to the formulation.

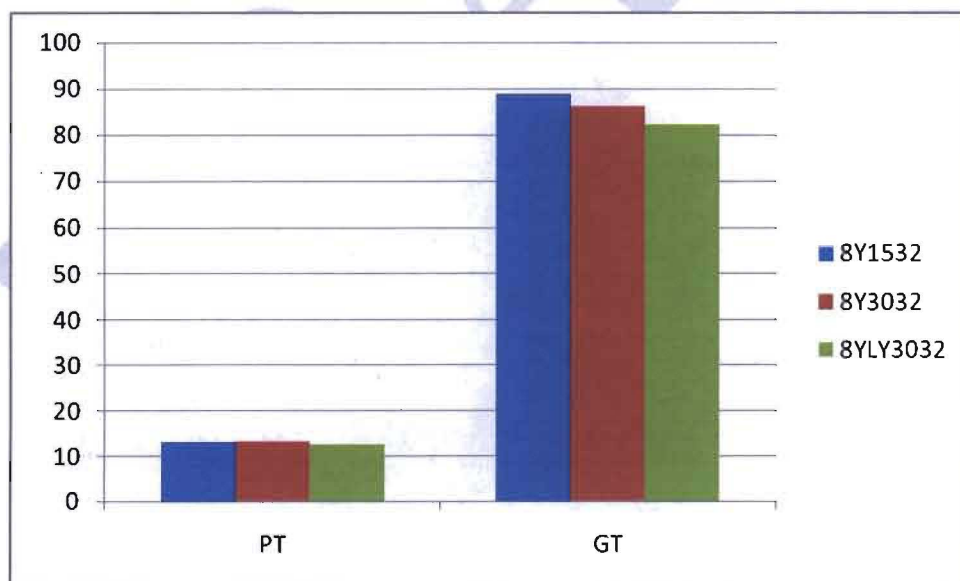


Figure 4. Results of the Pincer Test (PT) and Grip Test (GT).

Discussion

The increase in difficulty when increasing the thickness of a glove or adding lead to the formulation has been known qualitatively. The results of this study have quantified the results. The Dominant Hand Test most simulates the type tasks conducted at TA-55. For operations that require fine motor skills, the thickness of the glove is more important than whether it is leaded or unleaded. The thickness and formulation of the glove have little effect on pincer and grip tests. These test will be not be included in future studies. EN 420 dexterity results will be obtained for future glove studies and compared against the results of the Purdue Pegboard Dexterity Test. In addition to dexterity test, anthropometric data were also collected. The correlation of anthropometric data to performance data will be reported at a later date.

A main objective of an effective GGIP is to maintain the risk of an unplanned glove opening to an acceptable level. From a business viewpoint, the acceptable level is reached when the costs of decreasing a given risk further are greater than the costs realized from radiation exposure to the operator and the spread of radioactive contamination. Because the magnitude of a risk involves both likelihood and severity of the associated harm, continuous improvement of a GGIP can be reasonably based on reducing severity, likelihood, or both. Switching from leaded gloves to unleaded gloves should increase production by one-fourth for most Pu-239 operations. As discussed in the Glove Feature section, less glove breaches due to punctures should be observed. LANL has a Continuous Improvement Program in which efficiency, cost effectiveness and formality of operations are constantly being improved and is supported by "Lean Six Sigma" activities using Lean Manufacturing and Six Sigma business practices.¹ Improvements of this nature contribute to this effort as well.

1300 pairs of gloves are replaced each year at TA-55, generating approximately 500 m³/yr of transuranic (TRU) waste and Low Level Waste (LLW) waste that represents an annual disposal cost of about 4 million dollars. More waste is generated when a glove breach produces a contamination incident. In addition to waste generation, significant costs are incurred from a contamination incident due to the loss in production, cost of the cleanup, and preparation of incident documentation. By replacing leaded gloves with unleaded ones, a dramatic reduction in waste will be realized; exposure of the worker to residual contamination reduced, and the number of breaches would be reduced.

Leaded gloves provide greater protection against external radiation doses to the extremities (and to some degree to the whole body doses but the primary effect are in extremity dose reduction). There are some situations in which leaded gloves are needed. For example, leaded gloves should be used for operations that involve routine hands-on work with Pu-238 or containers with significant quantities of Pu-238. Other gloves in Pu-238 work areas that are not routinely used for handling of Pu-238 do not need to be leaded (for example, upper level gloves).

¹ Named after the number of standard deviations around the mean (6σ),

However, in making As Reasonably Achievable (ALARA) decisions, all factors are looked at including the greater protection that is provided against accidental large internal doses that could result from a breach in a glove box glove. With most Pu-239 operations this is the case. Leaded gloves are typically *less effective* against Pu-239, particularly when there is a significant amount of Am-241 present. Unleaded gloves are preferable in these operations because of their better overall characteristics. The default for Pu-239 operations should be unleaded gloves unless it has been shown that there is a need to reduce extremity exposures for certain very "hot" operations where the annual extremity dose limit of 50 Roentgen Equivalent Man (rem) could be reached. As a side note, when switching from leaded to unleaded gloves, external radiation readings should be taken, so that changes in radiological conditions are characterized. This must be done to ensure that the effect of the change on extremity doses is known as well as any changes in work area dose rates.

In summary, the use of unleaded instead of leaded gloves is likely to result in overall greater safety from mechanical hazards. This is particularly true and important for operations where better dexterity provide improved safety around equipment and or machinery that causes injury or penetration of the gloves (for example around rotating parts, sharps, or operations that require fine motor control). It is also useful, for situations in which the use of protective gloves over glove box gloves is called for in operations that involve sharps; the loss of dexterity that results when the protective gloves are used is lessened because gloves without lead are more flexible.

Conclusions

When dose to the extremities is not an issue, 30 mil. hypalon gloves should be used in place of 30 mil. leaded hypalon gloves in glovebox activities involving gross motor skills. Measures of this type improve the safety configuration of the glovebox system by lowering the overall risk in the current hazard control system and contribute to an organization's scientific and technological excellence by increasing its operational safety.

Acknowledgement

The authors would like to acknowledge the Department of Energy and LANL's Stockpile Manufacturing & Support and Nuclear & High Hazard Operations directorates, for support of this work.

References

1. Paraphrased from Plutonium Handbook, A Guide to the Technology, O.J. Wick, editor, American Nuclear Society, Vol. II, 1980, p. 833.

2. M.E. Cournoyer, J.M. Castro, M.B. Lee, C.M. Lawton, Y.H. Park, R.J. Lee and S. Schreiber, "*Elements of a Glovebox Glove Integrity Program*," Chemical Health & Safety, (2008), doi:10.1016/jachs.2008.03.001 and references therein.
3. <http://www.cutresist.com/cutresist/en388.asp>
4. ADSMS-07:036, Subject: *Pb/Non-Pb Glovebox (GB) Glove Selection*
5. http://www.ansell.be/industrial/index.cfm?pages=eu_standards_en420_marking&lang=EN

DRAFT