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QAS 515.41 Human Factors in Quality Assurance

An Ergonomic Analysis of Glovebox Operators

Introduction:
In a nuclear facility, gloveboxes are a necessity in doing business. Gloveboxes are one of the most important elements in protection in a radiological environment associated with tritium or plutonium processing. All radiological work, requiring operator contact must be done in a glovebox, therefore long periods of glovebox involvement, by the operator, are not uncommon. Physological and psychological affects are common among operators that are required to maintain static postures while working.

The Neutron Tube Target Loading (NTTL) project, at Los Alamos National Laboratory, utilizes two identical gloveboxes for target processing. Although, glovebox manufacturers provide an assortment of standard and custom gloveboxes, adjustments to accommodate various operator sizes, for ergonomic comfort, have yet to become reality. These gloveboxes designs are not one-size fits all. Most glovebox are designed to ideally fit operators 6-foot to 6-foot 6-inches tall, yet the average white American male operator is 5-foot 10-inches tall. Discomfort is unavoidable for these operators.

The room is a class 1000 clean room. The ceiling is suspended with 24-inch x 48-inch sound-absorbing tiles with flush countersunk fluorescent lighting. The floor is raised with 24-inch x 24-inch metal perforated tile. The temperature, humidity and air movement is strictly monitored and controlled for room efficiency, equipment and operator comfort. See Figure 1.

The following is an ergonomic look at the gloveboxes that NTTL operators use on a daily basis and determine practical and economic solutions to the discomfort as a result of sustained static postures.

Subjects:
There are three qualified operators that work in these gloveboxes and of course are of different physical sizes. Range of experience for the operators are from one year (operators #2 and #3) to seven years (operator #1). Interviewing the operators unveiled only minor discomfort when working in the glovebox. Length of time working in the glovebox ranges from 1 minute to an hour. Discomfort is first felt at approximately 30 minutes, with the taller operator, and approximately 20 minutes with the shorter operators. For the next 10 minutes, discomfort intensifies as glovebox work continues then stabilizes. During the 10-minute time interval from initial discomfort through stabilization, operators either stopped or continued to work based on their threshold of pain.

Process:
The two-day single operator process starts with the operator putting on cotton gloves prior to placing his hands into the glovebox gloves. Understanding once you have placed your hands into the glovebox gloves, they are not easily removed. Dexterity is important when performing glovebox work, therefore, the operator's hands need to fit snug to the gloves. Loose gloves are very cumbersome especially to small operators.

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The operator then meticulously transfers 40 parts, each the size of a half dollar, from the transfer box into the loading fixture. The operators use a specially designed tweezers to handle the parts. Placing the parts on the loading fixture requires very steady hands and a sustained static posture for up to an hour and perhaps longer for trainees. The hydriding process then takes places, with no glovebox interaction by the operator, until the parts are ready for unloading. Loading basically is the same as the loading process, but in reverse. Meticulously removing each part from the loading fixture and placing them into the shipping container.

Methods:
The method chosen was utilizing the *cross-sectional* survey. This is a single-point-in-time measurement measures a given condition. I chose to measure five body dimensions on each operator as the discomfort was felt only in the trapezius and neck areas. All five measurements have direct or indirect affects on the discomfort of the operators as they are engaged in the gloves. Each operator was measured using the "standing naturally upright" position as this lends itself to a more natural position while working in a glovebox. See Table 1 and Figure 1 below.

Body Dimension	Operator #1	Operator #2	Operator #3
Stature (floor to top of skull)	75" (1905 mm)	68" (1727 mm)	70" (1778 mm)
Arm Length (shoulder-to-finger tip)	32" (813 mm)	28" (711 mm)	29.5" (749 mm)
Forearm Length (elbow-to-fingertip)	20" (508 mm)	17" (432 mm)	17.5" (445 mm)
Shoulder Height (floor-to-shoulder)	64" (1626 mm)	56" (1422 mm)	59" (1499 mm)
Elbow Height (floor-to-elbow)	48" (1219 mm)	43" (1092 mm)	44" (1118 mm)

Table 1

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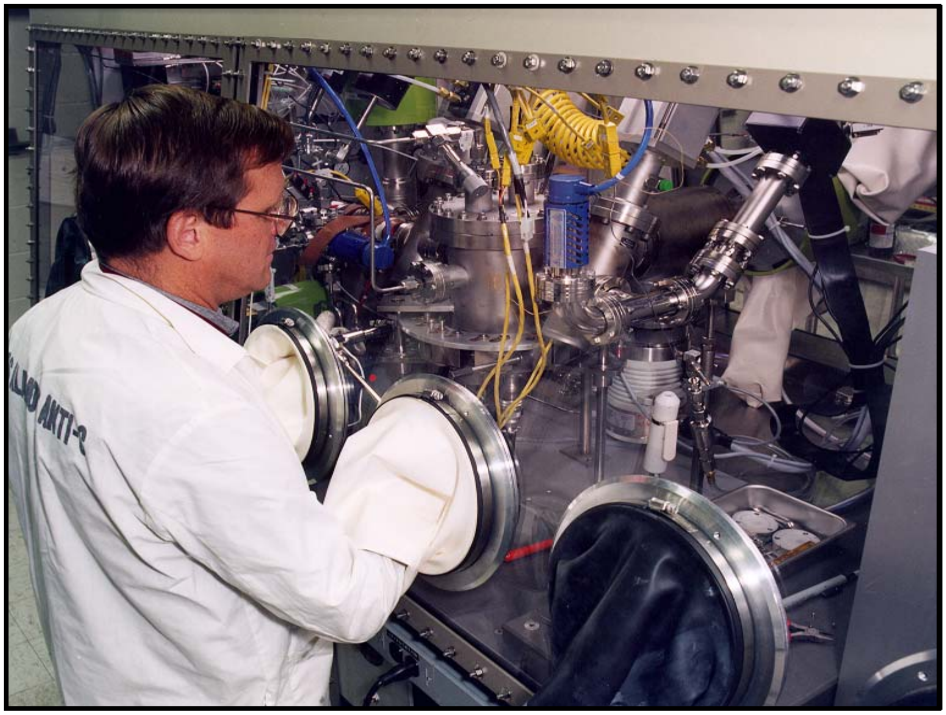

Figure 1

Measures:
The gloveboxes used are 144 inches in length, 90 inches in height high and 44 inches in width. The working surface, of the glovebox, is 39 inches from the floor. All glove port heights, measured from the floor to the middle of the glove ports, are 49 inches in height and placed in various positions along the horizontal plane. See Table 2 and Figure 2 below.

Glovebox Dimension	Measurement
Length	144” (3658 mm)
Width	44” (1118 mm)
Height	90” (2286 mm)
Working Surface Height (measured from floor)	39” (991 mm)
Glove Port Height (measured from floor)	49” (1245 mm)

Table 2

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Figure 2

Analyses of body and glovebox dimensions reveal two key elements that contribute to the operator discomfort.

1. Significant differences in elbow and glove port height in operator #2 (6-inches) and #3 (5-inches) while operator #1 (1-inch) is only a slight difference.
2. Operator #1's arm length is 2.5-inches to 4-inches longer than operator #2 and #3's arm length.

Observing the working zones for operators #2 and #3, their elbow height is significantly less than the glove port. In turn they compensate by lifting their shoulders up in order to place their arms in the gloves to work. This is the cause of their discomfort. With regards to arm length and reaching, operators with shorter arms have less range in the glovebox and must extend their reaches more frequently than operators with longer arms. Shorter arm operators must stand closer to the glovebox to help mitigate reach stresses.

To reduce discomfort, elbow and glove port height must be as close as possible in the same vertical plane. With bent-arm, the preferred working zone is the forearm parallel to the floor to slightly above parallel, but with straight-arm and reaching, the preferred working zone is the arm slightly below parallel, as opposed to, parallel to slightly above puts additional stress on the trapezius and neck areas.

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Countermeasures:
The most practical and economic way to mitigate such discomfort will in a static posture is have a height adjustment for the operator. An adjustable platform could be retrofitted to both sides of the gloveboxes with shock absorbing flooring on the stand platform. There would also be a need for controls inside the glovebox to adjust the platform while the operators are in their working postures to feel the most comfortable position.

In addition, once the glovebox is in place, there is equipment and systems that are typically integrated within the gloveboxes for particular processes, and activities can be performed. For example, a machining operation would require a lathe be installed in the glovebox. Another example would be a high vacuum system installed in the glovebox. Being mindful of the equipment and system configuration within the glovebox need special attending as making these configurations adjustable would provide increased flexibility to the glovebox and comfort to the operator. For example reaching for something across the other side of the glovebox can be stressful, but with an adjustable internal configuration, reach distances of the operator can be decreased.

The NTTL training program typically takes up to a year to demonstrate proficiency in the hydriding process. More experienced operators can reduce there stress. As operators become more proficient in their task, they can optimize their performance therefore reducing their time in the glovebox. This training program can accelerate this proficiency prior to qualification.

Scheduled breaks to disengage the operator from the glovebox are other practices that can be incorporated into the work schedule to alleviate operator discomfort. Taking breaks more frequently, when possible, will allow the muscle to rest and reducing the stress. This will enable the operator to work longer into their shift. Most of the time the operator chooses not to take a break as disengaging from the glovebox is an annoying activity and prolongs the process. They will typically work through the discomfort. The management and myself continue to encourage the operators to break more frequently regardless of schedule. This break could be as simple as resting your hands in the glovebox for five to tem minutes without disengaging. This would relief the tension on the neck and trapezius.

Impact:
Reduce or eliminate operator discomfort while engaged in the glovebox. This would result reduce time loss injuries and more productivity.

There would need to be a hazard analysis to determine impact to the safety envelope of the facility. If the is significant impact this could cause a change to the authorization basis of the facility. The authorization basis to this facility is the Safety Analysis Report (SAR). As a result of this analysis, many man-hours would be needed to conduct this analysis.

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Hiring decisions, based on optimum stature requirements of candidates, will be eliminated. With the adjustable platform modification, any glovebox can accommodate any size glovebox worker. This would give the hiring manager more latitude when making his final hiring decision.

Minimal retrofitting costs of the adjustable platforms are minimal compared to the gain from reducing operator muscular stress/strain. However, retrofitting glovebox internal configuration would have a significant impact on cost and down time, as this would require major redesign.

As a result of a redesign or retrofitting of the glovebox internal configuration, a significant decrease in glovebox capacity and throughput due to downtime. This would be more feasible to modify each glovebox on a staggered schedule to reduce the impact to production.

Some minimal cost associated with retraining the operators to operate the adjustable platform.

Conclusion:

The option of glovebox adjustments, to enhance glovebox operator comfort while is not currently available. When nonadjustable or standard gloveboxes are used, different sized operators adjust their working postures to compensate for discomfort. Operators have undue stress/strain placed on the trapezius and neck areas while working outside the preferred working zones. However, with the use of ergonomic models, methods, measures, and countermeasures, many of today's debilitating activities can be mitigated. Although, the proposed changes to the gloveboxes have not been proposed to management, it will mainly depend on the operator's tolerance level to discomfort. To the operator's credit, when it comes to safety at the laboratory, management is receptive to the needs of the their employees and typically pose little or no resistance to obtaining the proper equipment to make their job safer.