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EVALUATION OF AUTOMATED VS. MANUAL BAGGER EXPOSURES RELATED TO ERGONOMICS, DUST, AND NOISE AT A SAND MINE PROCESSNG PLANT

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by

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Abstract

Since 2000, the Mine Safety and Health Administration (MSHA) has reported 737 injuries involving bagging. Most of these injuries were related to "over-exertion" with an MSHA injury classification of "strains, sprains, and ruptured discs." "Over-exertion" accounted for 331,130 injuries totaling 14.2 billion dollars in workers compensation costs in 2012 according to the National Safety Council (NSC). According to NSC, the average total incurred cost of an "over-exertion" injury is $42,883/claim, and the average total incurred cost of a "strain/sprain" injury is $31,521/claim.

Manual bagging in a sand mine processing plant is a highly physical job. There are six physical workplace risk factors associated with the development of work-related musculoskeletal disorders (WMSDs); posture, compression, force, repetition, vibration, and duration. These must occur in some combination to cause WMSDs. Manual bagging risk factors include posture, compression, force, repetition, and duration. Despite all of these risk factors, implementing an automated bagging system is an expensive capital project that is generally difficult to justify for most companies.

The objectives of this research are to determine if implementing an automated bagging system will not only decrease exposures to physical work place risk factors (ergonomic hazards), but also decrease exposures to noise, respirable dust and respirable crystalline silica, as justification for the cost of such a system. Additionally, the research is investigating if there is a reduction in injuries and workers compensation costs to a plant that implements an automated system.

Ergonomic evaluations were performed on nine employees with the job description of "bagger" at four industrial mineral mine processing plant locations in the United States. Ergonomic analyses were performed using the NIOSH "Ergonomics Audits for Mining Bagging, Haul Truck, and Maintenance and Repair Operations" Auditing Tool and the Rapid Upper Limb Assessment (RULA) for the job sub-task of tying bulk-bags.

A nonparametric Wilcoxon sum-rank test was performed on the dust and noise data using SAS software considering exposures before and after the implementation of a fully automated bagging system.

The statistical analysis showed a statistically significant reduction in the noise exposures, however there was not a statistically significant reduction in the respirable dust or respirable crystalline silica exposures. The ergonomic hazards associated with manual bagging are numerous and have far reaching potential in regards to the risk of injury. Almost all of the risk factors associated with workplace musculoskeletal disorders are associated with manual bagging. The implementation of a completely automated bagging system would all but eliminate the ergonomic exposures. The yearly adjusted injury rate dropped from 2.76 per year to 0.72 per year after the implementation of an automated system in Plant A. Also, the estimated reduction in workers compensation claims is approximately $34,000 with a return on investment potential of less than 6 years on the conservative side.

Based on the ergonomic evaluation of manual bagging as well as the positive reduction in noise exposure it is safe to say that automated bagging systems are worth the upfront costs if they only prevent even one injury a year.

Keywords: Ergonomics, mining, manual materials handling, Rapid Upper Limb Analysis, NIOSH Ergonomics Audit, respirable dust, respirable crystalline silica, noise

Dedication

I would like to thank my parents for pushing me to get a useful education, my family for all of their love and encouragement, Megan for telling me to follow my heart and helping critique this thesis, my professors for all of their support throughout my time at Montana Tech, and a silly boy for being the reason I stayed in the first place. I am so very grateful.

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Introduction

Since the beginning of time… in mining, the job of digging coal and other useful minerals out of the ground has been considered one of the world's most dangerous occupations. From 1890 to 1910, mine explosions and accidents took the lives of thousands of miners. In the twentieth century public concern rose due to the death tolls, injuries, and destruction due to mine accidents. This prompted the passage of much-needed legislation, and intensified the search for safer methods and enhanced training and technology (MSHA, 2015).

Safety and health in U.S. mines made important advances in the 20th and 21st century, especially over the last 35 years. The Federal Mine Safety and Health Act was passed in 1977. The first year the Mine Safety and Health Administration (MSHA) operated under the new act was 1978 and 242 miners died in mining accidents. MSHA continues to work to reduce injuries, illnesses and death through heavy enforcement as well as active outreach, education and training, and technical support to the mining industry.

To evaluate ergonomic advances in an industrial mineral mine processing plant, a study was conducted to compare ergonomic hazards, as well as noise and dust exposures of baggers in a processing facility before and after automation was implemented. The objective of this research is to determine if implementing an automated bagging system will not only decrease exposures to ergonomic hazards, but also decrease exposures to noise and crystalline silica, as a justification for the cost of such a system.

1.1. Statement of the Problem

Manual bagging in a sand mine processing plant is a highly physical job. There are six physical workplace risk factors associated with the development of work-related musculoskeletal disorders (WMSDs); posture, compression, force, repetition, vibration, and duration. These must occur in some combination to cause WMSDs. Posture, compression, force, repetition, noise and duration are the physical workplace risk factors involved with manual bagging of silica. At the facilities in which this research was conducted, manual bagging occurs for as much as 8 hrs a day, forty hours a week, fifty-two weeks a year (duration), with baggers bagging as much as forty tons in deviated positions, (repetition/posture). The bags weigh fifty or one hundred pounds (compression/force).

Since 2000, the Mine Safety and Health Administration (MSHA) has reported 737 injuries involving bagging. Most of these injuries were related to "over-exertion" with an MSHA injury classification of "strains, sprains, and ruptured discs." "Over-exertion" accounted for 331,130 injuries totalling 14.2 billion dollars in workers compensation costs in 2012 according to the National Safety Council (NSC) (National Safety Council, 2015). According to NSC, the average total incurred cost of an "over-exertion" injury is $42,883/claim, and the average total incurred cost of a "strain/sprain" injury is $31,521/claim (National Safety Council, 2015).

Implementing an automated bagging systems is an expensive capital project for most companies. A complex fully-automated bagging system ranges from $500,000-$800,000 (M. Andrade, personal communication, November 5, 2015). Although they may seem like a valuable option it is sometimes difficult to justify the cost of such a system.

The objective of this research is to determine if implementing an automated bagging system will not only decrease exposures to physical work place risk factors (ergonomic hazards), but also decrease exposures to noise, and respirable dust and respirable crystalline silica, as a justification for the cost of such a system. As well, the research is investigating if there is a reduction in injuries and workers compensation costs to a plant that implements an automated system. Ergonomic evaluations were done on employees with the job description of "bagger" at four plant locations in the United States. Dust and noise samples were retrieved on a plant in the United States that has transitioned from manual bagging to a fully automated bagging system.

1.2. Research Hypotheses

The three research hypotheses refer to the implementation of an automated bagging system and the associated dust and noise exposures. The null hypotheses (H_O) for the first two indicate that there will not be a statistically significant reduction ($p<.05$) in the respirable dust and respirable crystalline silica exposure to baggers, while the alternative hypotheses (H_{A1} and H_{A2}) suggest that there will be a statistically significant reduction. The H_{O3} hypothesis predicts that bagger noise exposures will not decrease significantly ($p<.05$), and the H_{A3} suggests that noise exposures will decrease significantly.

- H_{O1} Implementation of a fully automated bagging system will not reduce bagger respirable dust exposures ($p<.05$).
- H_{A1} Implementation of a fully automated bagging system will reduce bagger respirable dust exposures ($p<.05$).
- H_{O2} Implementation of a fully automated bagging system will not reduce bagger respirable crystalline silica exposures ($p<.05$).
- H_{A2} Implementation of a fully automated bagging system will reduce bagger respirable crystalline silica exposures ($p<.05$).
- H_{O3} Implementation of a fully automated bagging system will not reduce bagger noise exposures ($p<.05$).
- H_{A3} Implementation of a fully automated bagging system will reduce bagger noise exposures ($p<.05$).

2. Background

2.1. Ergonomics

The discipline of ergonomics or human factors was formally founded as a profession in the late 1940s but gained acceptance during World War II. The Tayloristic principle of choosing a few special individuals to match pre-existing tasks became difficult at this time due to the fact that the United States was in “total war” which meant for the first time the workforce included both men and women, with varying body types. These variations forced equipment designers to take into account the physical characteristics of equipment to optimize the advantages of human capabilities and avoid the negative effects of human limitations for the first time. Gradually ergonomics broadened its influence, and in the 1960s non-military ergonomic research and application increased (Galley, 2002) in the areas of work place design, usability and vehicle interiors. Since that time many evaluation tools have been created to quantify and evaluate the risk of injury.

The recognition of the growing problem in work-related injuries of the lower back eventually lead to the creation of the National Institute for Occupational Safety and Health (NIOSH) Lifting Equation in 1981 with a revised version being released in 1993. This equation is used to determine a recommended weight limit and lifting index which is an index of relative physical stress associate with manual materials handling tasks (Hamrick, 2006) (Waters, Putz-Anderson, Garg, & Fine, 1993)**.** The Department of Defense created the Military Standard (MIL-STD) 1472, DESIGN CRITERIA STANDARD: HUMAN ENGINEERING in the 1970s. “The purpose of this standard is to present human engineering design criteria, principles, and practices to optimize system performance with full consideration of inherent human capabilities and limitations as part of the total system design trade space to more effectively integrate the human as part of the system, subsystems, equipment, and facilities to achieve mission success (MIL-STD-1472G, 2012)**.”** The MIL STD contains a weight handling section that provides guidelines for lifting limits, frequency, load size, twisting, and obstacles. Lifting limits include the maximum weight values for one and two lifters, non-uniform weight distribution, and lifting height limits.

The Rapid Upper Limb Assessment (RULA) tool is a survey method developed by McAtamney and Corlett (1993) to use in workplace ergonomic investigations where work-related upper limb disorders have been reported. McAtamney and Corlett (1993) validated RULAs reliability by having 120 professionals; trained on its use; score video-taped examples of tasks. They found a high consistency of scoring among the professionals.

2.1.1. Work-related Musculoskeletal Disorders

Work-related Musculoskeletal Disorders (WMSD) are defined by the Center for Disease Control and Prevention (CDC) as “injuries or disorders of the muscles, nerves, tendons, joints, cartilage, and spinal discs in which the work environment and performance of work contribute significantly to the condition; and/or the condition is made worse or persists longer due to work conditions (CDC, 2015).” The Occupational Safety and Health Administration (OSHA) estimates that work-related musculoskeletal disorders in the United States account for over 600,000 injuries and illnesses, that’s 34 percent of all lost workdays reported to the Bureau of Labor Statistics (BLS) (OSHA, 2014).Overexertion, repetition, and physical stress continue to be huge contributing factors in serious illnesses and injuries, and are the cause of one-third of all work-related injuries. Musculoskeletal disorders now account for one out of every three dollars spent on workers' compensation. It is estimated that employers spend upwards of $20 billion a year on the direct costs associated with musculoskeletal disorder-related workers' compensation, and up to five times that much on the indirect costs, which include the costs associated with hiring and training replacement workers (OSHA, 2015).

2.2. Crystalline Silica

Silica or silicon dioxide (SiO_2), is a group of IV metal oxides, which naturally occurs in both crystalline, and noncrystalline (amorphous) forms. Crystalline silica is found in the earth's crust, occurring in several forms including α-quartz, β-quartz, α-tridymite, β-tridymite, α-cristobalite, β-cristobalite, keatite, coesite, stichovite, and moganite. The most common form of crystalline silica is α-quartz which is found in sand, rock, concrete, mortar, stone, and brick. These materials are seen in numerous industries especially industrial mineral mining (Cancer, 2012).

2.2.1. Occupational Exposure

Due to crystalline silica's widespread natural occurrence in the earth's crust and its use in a variety of materials, workers may be exposed to crystalline silica in a wide array of industries and occupations (Cancer, 2012). Occupational exposure occurs commonly in workplace operations involving the cutting, sawing, drilling, and/or crushing of concrete, brick, rock, or stone products as well as operations producing or using sand products like industrial mineral mines, glass manufacturing companies, or foundries. These exposures can result in inhalation of respirable crystalline silica particles that are in the air.

Historically mining has been related to some of the highest exposures to crystalline silica (OSHA, 2015). The National Institute for Occupational Safety and Health (NIOSH) has long recognized this, *The Dust Control Handbook (2012)*, discusses the exposures that occur during the mining and processing of minerals, including how the "mined ore undergoes a number of crushing, grinding, cleaning, drying, and product sizing operations as it is processed into a marketable commodity (A. B. Cecala, 2012).” The handbook also states, that although these operations are highly mechanized, the processes can generate hefty amounts of dust. If control technologies are insufficient, hazardous levels of respirable crystalline silica could be liberated into the work environment, potentially exposing workers (A. B. Cecala, 2012).

2.2.2. Permissible Exposure Limits

The MSHA permissible exposure limit (PEL) follows the 1973 American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for respirable crystalline silica containing quartz. The permissible exposure limit is an additive formula permissible exposure limit. The formula was developed when the sampling technique for silica was changed from a particle count method to a gravimetric determination with quantitative analysis of the crystalline silica content (mg/m^3). Respirable dust has a TLV of 5.0 mg/m^3 and respirable crystalline silica has a TLV of 0.1 mg/m^3. The concentrations of each are put into formula 1 below. The intent of ACGIH was to control the quartz content to 0.1 mg/m^3 which is accomplished by the percent quartz in the denominator of formula 2. They also intended to control the respirable dust content to 5.0 mg/m^3 which is accomplished by the plus 2 in the denominator of formula 2.

$$\text{Formula 1: } \left(\frac{C_{silica}}{0.1}\right) + \left(\frac{C_{dust}}{5.0}\right) = 1$$

$$\text{Formula 2: } \frac{10\ mg/m^3}{\%\ SiO_2 + 2}$$

2.2.3. Health Effects

Occupational exposure to respirable crystalline silica dust can have numerous adverse health effects, including silicosis, tuberculosis, chronic bronchitis, emphysema, and chronic renal disease (NIOSH, 2002).

2.2.3.1. Silicosis

Silicosis is the disease most associated with crystalline silica exposure. Silicosis is an incurable and potentially fatal lung disease caused by the inhalation of respirable crystalline silica. Quartz as previously stated, is the most common single mineral in the earth's crust, and many mining operations involve direct contact with overburden and ore containing quartz. This results in workers throughout much of the mining industry being potentially exposed to respirable crystalline silica through their routine activities (Cecala, et al., 2012).

2.3. Noise

Sound is formally defined as the fluctuations in pressure above and below the ambient pressure of a medium that has elasticity and viscosity (Berger, 2003)**.** The terms sound and noise are often used interchangeably but “noise” is defined as undesirable sound. MSHA publicized Health Standards for Occupational Noise Exposure for the metal, nonmetal, and coal mining industry (30 CFR Part 62) in an effort to reduce the number of miners who experience hearing impairment (MSHA, 2012).

2.3.1. Occupational Exposure

According to NIOSH one out of every four mine workers has a severe hearing problem, and four out of five mine workers have a hearing impairment when they reach their mid-60s, the average age of retirement. Hazardous noise is the principal issue with 76% of mine workers being exposed to hazardous noise. That is the highest prevalence of all major industries (CDC, 2015)**.**

2.3.2. Permissible Exposure Limit

Part 62 of 30 CFR establishes the full shift Permissible Exposure Level (PEL) at a Time Weighted Average (TWA) over an 8-hr TWA of 90 dBA (100% Dose) and establishes an Action Level (AL) at an 8-hr TWA of 85 dBA (50% Dose). The operator is required to enroll affected miners in a Hearing Conservation Program if the AL is met or exceeded. If the PEL is exceeded, the mine operator is required to use all feasible engineering and/or administrative controls to reduce miner's exposure to the PEL (MSHA, 2012).

2.3.3. Health Effects

Noise is one of the most prevalent hazards to a miner's health, matched only by respirable crystalline silica and repetitive trauma (Matetic, Randolph, & Kovalchik, 2010). Noise is arguably the most inescapable hazardous agent in the workplace (Berger, 2003). The primary effects of workplace noise exposure include noise-induced temporary threshold shifts, noise-induced permanent threshold shifts, acoustic trauma, and tinnitus (Magrab, PhD, 1975). It is also suspected that noise exposures cause non-auditory physiological effects on the body. These include cardiovascular functions such as hypertension, changes in blood pressure and/or heart rate. Changes in breathing, sleep problems, as well as physical and mental health are also suspected (Berger, 2003).

3. Similar Studies

After an extensive literature review there was very little found on manual bagging ergonomic studies that included silica dust exposures along with noise exposures. A lot of research has been done on the individual components of this research including dust suppression systems and the ergonomic hazards associated with manual bagging but nothing was found correlating the exposures.

Gallagher, et al. (2011) conducted a field based study looking at the biomechanical and physiological demands in sand and limestone bagging operations. The study found that a vacuum hoist decreased worker spinal loads by 39% at a sand bagging plant. However vacuum hoists were seen as slow and cumbersome by operations with multiple baggers. At a limestone plant with no hoist assists biomechanical estimates indicated moderate to high spinal loads during manual palletizing operations. Although compressive loading on the spine was not high it was found that the frequency of lifting could lead to fatigue failure of spine tissues.

Cecala and Covelli (1990) compared two studies which evaluated workers' dust exposures in automated pallet loading processes while also acknowledging the ergonomic hazards. Both studies addressed the dust control and worker fatigue factors in different ways. The first study dealt with the Bureau of Mines designed pallet loading dust control system. Reduction of physiological and biomechanical strain placed on the worker by having the load at the most ergonomic height. Workers were protected by removing the dust generated during the process by using a push-pull ventilation system. This decreased dust exposure by 76%. The second study addressed the strain and the dust exposure of the worker by removing the worker from the process and having the function performed robotically. On a dust control basis, the results of the evaluation were impressive from both personnel as well as area samples, with most of the samples being well below the established MSHA standards.

4. Materials and Methods

The materials and methods used in the collection of the ergonomic, respirable dust, respirable crystalline silica, and noise exposures are discussed in the following sections. All data used in this research was existing data, therefore a data use agreement was signed and approval gained through the IRB at the University of Montana. It is important to note that the respirable dust, respirable crystalline silica, and noise data were all collected from Plant A, which has an automated bagging system. However, the ergonomic exposure data was collected at four different plants that are currently manual bagging their products (Plant B, Plant C, Plant D, and Plant E).

4.1. Ergonomics

Ergonomic analyses were performed using the NIOSH "Ergonomics Audits for Mining Bagging, Haul Truck, and Maintenance and Repair Operations" Auditing Tool and the Rapid Upper Limb Assessment (RULA) for the job sub-task of tying bulk-bags.

The ergonomic audits assess the hazards associated with the filling of small bags; defined as 100 pounds or less; and bulk-bags, closing them, and preparing them for shipment. The audits cover the individual filling stations as well as the environment in which the processes are housed.

4.1.1. Location

These assessments were done at four different bagging facilities (Plant B, C, D, and E,) of industrial minerals mine processing plants in the United States. Each facility had a slightly different set up in their bagging, sealing, stacking, and palletizing tasks. Plant B and C had fully manual bagging and stacking operations. Plant D was fully auto-mated except for the bagger placing the bags on the spouts in the small bag process. The bulk-bag process at Plant D was manual. Plant E had a fully automated small bagging system, but the bulk-bags were manually done.

4.1.2. Sampling Location

The assessments were performed in the bagging work location at Plant B, C, D, and E. They included analysis of the filling, palletizing, and (shrink) wrapping of small bags, as well as the filling and tying of bulk-bags.

4.1.3. Sampling Media and Equipment

A description of the two different auditing tools is in the following sections. The analysis was performed using the NIOSH tool to aide in an internal NIOSH review of the usefulness of the tool and to determine if it was comprehensive. Dempsey, et al (2012) uses the strengths and weaknesses associated with the collection of data and information pertaining to MSHA data, fatality reports, worksite observations and interviews, task analysis, field studies, lab studies, and the code of federal regulations for content validity of the NIOSH tool. The RULA Worksheet was used for the specific task of tying bulk bags because it was determined that the specific task required closer analysis.

4.1.3.1. The NIOSH Ergonomics Audits for Mining Bagging Auditing Tool

The bagging audit tool is composed of seven modules which are grouped under Facility Level that apply to facilities with any type of bagging operation. Module 1 asks specific questions about the characteristics of bagging operations to guide the user through the modules because not every module will apply to every bagging operation. The remainder of the Facility Level modules refer to general ergonomics and safety issues relative to the ambient environment, personal protective equipment (PPE), mobile equipment, and related factors that are present. The small and bulk-bag assessment levels consist of modules that cover each aspect of bagging operations from bag storage and retrieval through closing and palletizing. Figure 1 shows an example of the questions included within the NIOSH bagging audit tool.

10.1 **Part 1:** Which most closely describes the palletizing station?

a. Bags are stacked on a single pallet on the ground

b. Bags are stacked on a raised surface such as a stack of pallets

c. Bags are stacked on a pallet that is on surface with adjustable height such as a lift table

Part 2: What is the height of the lowest and highest bag on a full pallet (measured from the surface the worker is standing on to the middle of the bag; e.g., Figure A11)?

Fill in the blanks: Lowest height: ______ in Highest height: _____ in

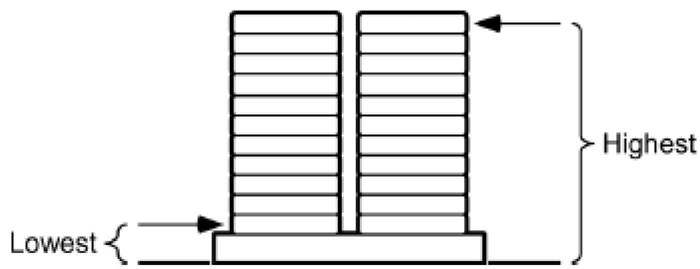

Figure A11. Lowest and highest bag measurement guidelines: Measure from the surface the worker is standing on to the center of the bag after it is placed on the pallet. Ensure that measurements of the bags are taken at the height they are loaded (e.g., if a lift table is used, the lowest and highest height may be the same).

Figure 1: Example of a question the Audit tool asks

4.1.3.2. The RULA Worksheet

The RULA worksheet as seen in Figure 2 is composed of two main sections. Section A is a wrist and arm analysis which takes into account the position of the upper arm, lower arm, wrist posture, and wrist twist. Section B is a neck, trunk, and leg analysis which takes into account the position of all three, as well as any twisting or bending. For both sections muscle use is analyzed based on whether or not the posture is mainly static, and how repetitive the task is. How repetitive the task is based on the number of movements performed per minute.

To determine the RULA score, the postures of different body parts are categorized into the predetermined categories and charts are then used to combine the postures and obtain a general score. Finally the force/load is analyzed for both sections based on the weight of the object being lifted/moved, and whether or not you have an intermittent, static, repeated or shock movement from the load. The general posture scores are then combined with the force/load scores to get your final score. The final score is a number from 1 to 7+. Recommendations are provided based on the final score, where one is an acceptable posture and anything over seven recommends an investigation and implementation of a change.

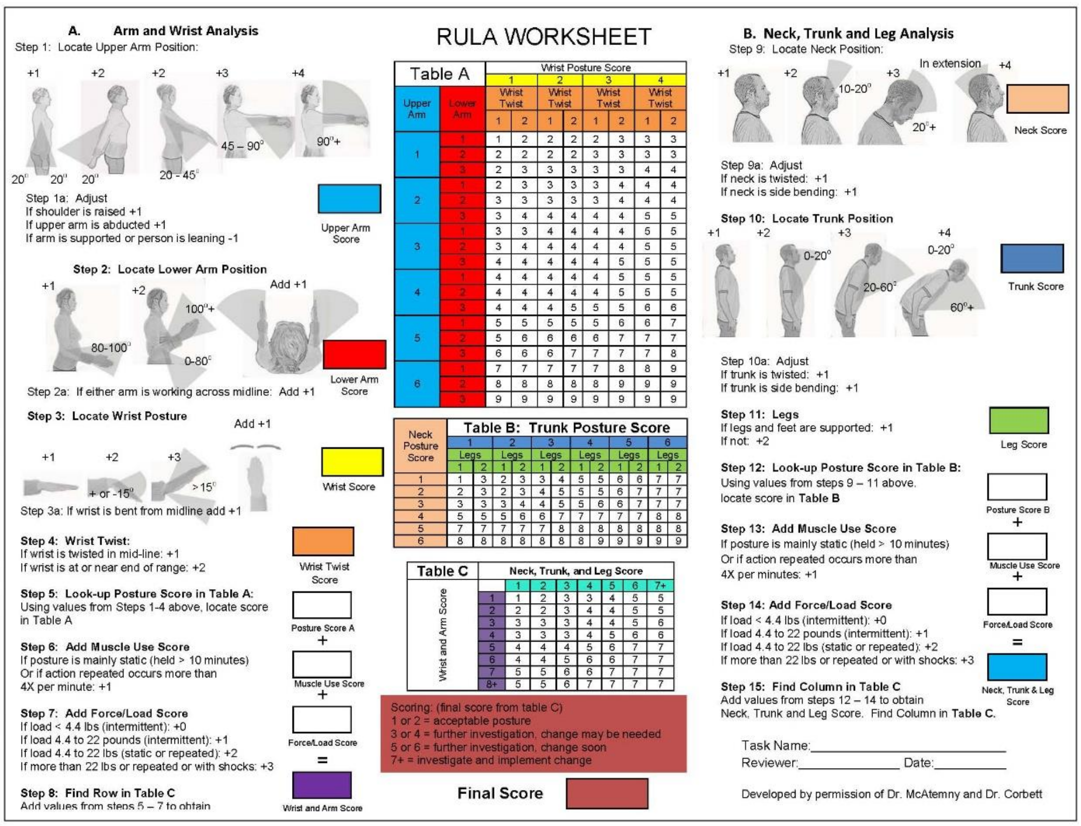

Figure 2: RULA Worksheet

4.1.4. Sampling Strategies

The goal of these audits was to create a holistic view of the manual bagging process from the storage and access of empty bags to the final (shrink) wrapping of pallets for shipment, as well as flag the potential and existing hazards associated with the process. It was also important to get analysis of multiple employees to see if the bagging stations were designed to accommodate the entire bagging workforce.

4.1.5. Sampling Analysis

The NIOSH audit tool provides immediate recommendations on the manual bagging task. The RULA Worksheet provides a risk rating from 1 to 7+ and recommends how quickly, if at all, action is required to change the ergonomic hazards associated with the task.

4.1.6. Injury Rates, Workers Compensation, and Return on Investment

Year adjusted injury rates were calculated using injury data from Plant A. Workers compensation cost reduction and return on investment were estimated hypothetically using the Washington State Ergonomics Calculator as well as the Hamer Inc. return on investment calculator.

4.2. Respirable Dust and Respirable Crystalline Silica

All of the respirable and respirable crystalline silica dust samples were existing data for Plant A. It was retrieved from an internal database. The following sections explain how the data was collected at the plant level by qualified personnel.

4.2.1. Location

The dust samples were collected in the work location titled “bagging” at an industrial mineral mine processing plants in the United States (Plant A). The bagging operation includes the filling, sealing, palletizing, and shrink wrapping of small bags defined as 100 pounds or less for this research, as well as bulk-bags.

4.2.2. Sampling Location

Personal samples were all collected from the work location title "bagging" but in various steps of the bagging process, with job titles including bag operator, forklift operator, and special production operator.

4.2.3. Sampling Media and Equipment

All respirable dust and respirable crystalline silica samples were collected using a size selective Dorr-Oliver cyclone. Air was pulled through the polyvinyl chloride (PVC) membrane 37mm filter by an Escort Elf Pump calibrated at 1.7 liters per minute using an M-5 model mini-BUCK primary flow calibrator.

4.2.4. Sampling Strategies

Personal sampling is conducted to determine if dust exposures of employees are within either government approved exposure limits or internal objective limits. Federal MSHA inspectors collect personal samples and the subsequent analysis of these samples are used to determine whether or not a facility will be cited for violating permissible exposure limits. Although personal samples may be collected at the discretion of the plant management, an annual sampling plan will be established in coordination with the Safety & Health Department. The number of samples and their locations will vary by facility, but the objective is to characterize individual employee exposures (Dust Sampling Program, 2012).

4.2.5. Sampling Analysis

All dust samples were analyzed by the American Industrial Hygiene Association (AIHA) accredited DCM Science Laboratory in Wheatridge, Colorado, using the NIOSH 7500 analytical method for respirable crystalline silica and the NIOSH 500 analytical method for respirable dust. The results were then recorded in the internal database from which they were retrieved.

4.2.6. Statistical Analysis

Statistical analysis was done using SAS software. A nonparametric alternative Wilcoxon rank-sum test was done as an alternative to the two-sided sample t-test.

4.3. Noise

All noise samples were existing data for Plant A. Data was retrieved from an internal database. The following sections explain how the data was collected at the plant level by qualified personnel.

4.3.1. Location

The noise samples were also taken in the work location titled “bagging” for Plant A, in various steps of the process. The job titles included bagger, bag operator, forklift operator, and special production operator.

4.3.2. Sampling Location

Full shift personal samples were collected from the work location title “bagging” but in various steps of the bagging process, with job titles including bagger, bag operator, forklift operator, and special production operator.

4.3.3. Sampling Media and Equipment

All samples were collected using a 3M Edge or NoisePro Dosimeter calibrated to 114 dBA at 1000 Hz, using an acoustic calibrator**.** All samples are A-weighted.

4.3.4. Sampling Strategies

Dosimetry sampling is conducted annually at each operation on all job classifications and should be representative of the work normally done by each employee sampled. All dosimetry data (collected by an employee or by a regulator) was entered into the internal database to ensure that accurate records of employee exposure are maintained (Hearing Conservation Program, 2010).

4.3.5. Sampling Analysis

The noise exposure data was compared to the MSHA Permissible Exposure Limit (PEL) of 90 dBA, as well as the Safety and Health developed Action Level (AL) of 80 dBA.

4.3.6. Statistical Analysis

Statistical analysis was done using SAS software. A nonparametric alternative Wilcoxon Rank-Sum Test was done as an alternative to the two-sided sample t-test.

5. Results

The results of this research are discussed in the following sections. The ergonomic results are discussed followed by the respirable dust and respirable crystalline silica, with the noise results at the end.

5.1. Ergonomic

The bagging audit tool is divided into three main sub categories. Facility level ergonomics, small bag assessment, and bulk-bag assessment. Baggers one through six perform both small and bulk-bag tasks. Baggers seven and nine are strictly bulk-baggers while bagger eight only does small bagging. For bagger seven, eight, and nine you will see a (-) where questions do not apply. Baggers four, five, and six were not filling bulk-bags on the day of observation so modules eleven and twelve are marked not available (N/A).

5.1.1. Facility Level

The facility level ergonomic section consists of the following modules:

- Module 1- Bagging Operation Characteristics
- Module 2- Personal Protective Equipment
- Module 3- Sit/Stand
- Module 4- Work Environment
- Module 5- Lighting
- Module 6- Mobile Equipment
- Module 13- Stretch and Shrink Wrapping

Baggers 1, 2, and 3 all work at Plant B. Baggers 4, 5, and 6 work at Plant C. Baggers 7 and 8 work at Plant D. Bagger 9 works at Plant E. Module 1 asks questions to determine which modules need to be filled out. Module 2 discusses the use of personal protective equipment, at all plants the proper personal protective equipment was used, including gloves and respirators where necessary. Module 3 asks questions pertaining to sitting and standing of the manual bagger. Bagger 8 is the only manual bagger that sits. The position of bagger 8's chair is with excessive arm, back, and leg deviation. All other baggers stand and have anti-fatigue mats which are limited in size and location. The work environment questions asked in Module 4 showed that there is an issue with the humidity and heat for baggers 4, 5, and 6 who are all at the same plant. Upon further investigation it was discovered that baggers 4, 5, and 6 are provided with a large fan to increase airflow as well as evaporative cooling in the bagging area. The only lighting issue was seen at bagger 8's work station. The light fixtures were extremely dusty. Module 6 on mobile equipment showed hazards associated with high pedestrian traffic areas and blind corners. Module 13 discovered hazards for baggers 4, 5, and 6. They do not have a completely automated stretch wrapping system which results in having to bend over to attach stretch wrap. Tables in Appendix A show the results of the questions for modules one, two, three, four, five, six, and thirteen.

5.1.2. Small Bags

The small bag sub category consists of the following modules:

- Module 7- Filling
- Module 8- Weighing
- Module 9- Sealing
- Module 10- Palletizing

Module 7 was not relevant because all filling is automated. Weighing hazards were discovered for baggers 4, 5, and 6. The scale used by these baggers is located at ground level which results in baggers having to bend over while carrying the fifty pound bags. The sealing process of small bags was automated at all plants. The palletizing module recognized hazards associated with pinch grips, awkward postures while stacking bags on pallets, as well as the height of the pallet. Bagger 3 does not utilize the pallet jack appropriately, keeping the stack well above the recommended height. Tables in Appendix A show the results of modules seven, eight, nine, and tens questions.

5.1.3. Bulk-bags

The bulk-bag sub category consists of:

- Module 11- Hanging, opening, and filling
- Module 12- Closing, and sealing

Module 11 discovered hazards associated with the hanging of bulk-bags. The height of the hooks for hanging bulk-bags is above the recommended height for baggers 1, 2, 3, and 7. The question in module 12 determined hazards associated with closing bulk-bags for bagger 1. Bagger 1 does not remove the bulk-bag prior to tying and stands on a non-ideal working surface while tying bulk-bags. Tables in Appendix A show the results of module eleven and twelves questions.

5.1.4. Injury Rates

Protecting workers and injury reduction is of primary concern at the company where this research was conducted. They have invested a lot of time and money on the emphasis and training of proper lifting techniques to minimize injuries.

Shoulder and back injuries over the past 5 years at the company are associated with significant costs. Think of the back as a lever and the spine is the fulcrum of that lever. When weight is evenly distributed and the fulcrum (spine) is at the center it takes fifty pounds of pressure to lift the fifty pound bags involved in manual bagging. When the weight is shifted outward, moving the fulcrum to the end of the lever; for example reaching across a pallet to lay down a bag; the pressure on the back is multiplied by tenfold. This is because the back operates at approximately a 10:1 ratio. That fifty pound bag is now five-hundred pounds of pressure on the spine. Adding in twisting while carrying that load only increases the chance of injury, and there is the potential for twisting in manual bagging with every bag placement.

Injury data specific to the bagging location for Plant A, where an automated system has been implemented, was evaluated to determine if automation could reduce injury rates. There was a total of 40 injuries with the work location bagging at Plant A from 1995 to 2015. Of those, 34 injuries occurred prior to the automated bagging system being implemented and 6 occurred after. The yearly adjusted injury rates show a reduction from 2.76 injuries per year to .72 injuries per year in the bagging location. That is a drastic reduction in injuries per year.

5.1.5. Workers Compensation

The Washington State Ergonomics Cost Benefit Calculator computes the average cost of injuries from the 2004 Sharp report on WMSDs. It uses average costs instead of actual costs assuming recent injuries may not have incurred the eventual total cost of the claim. Indirect costs are calculated using the Occupational Safety and Health Administrations e-tool. The effectiveness of solutions ratings are based off of the assumptions of Oxenburgh (Oxenburgh, Marlow, & Oxenburgh, 2004), as well as the review of 250 case studies of ergonomic interventions. The productivity benefits are based on the fact that employees are never 100% productive, they may only be 85% productive or even less as their working conditions decreases. The calculator anticipates that ergonomic solutions can make up a portion of that lost 15% in productivity by improving employee working conditions and improving the efficiency. The calculator chooses to be conservative with productivity measurements and ranks high increases in productivity at 10%, medium increases at 5%, and low increases at 2.5%. The value of productivity is then calculated by multiplying the worker's salary by the percentage increase in productivity (Goggins, 2012).

Based on the calculator the typical cost of common (manual bagging) injuries are shown in Table I. Implementing a fully automated bagging system nearly eliminates the employee's exposure to the ergonomic physical workplace hazards involved with manual bagging, reducing workers compensation claims by an estimated 70%.

Table I: Summary of injury costs

Type of Injury	Typical Cost	3 yr average annual WMSD claim cost	Estimated Annual Indirect Cost
back strain	$ 8,723.00	$ 2908.00	$ 3489.00
shoulder strain	$11,565.00	$ 3855.00	$ 4241.00
neck strain	$11,520.00	$ 3840.00	$ 4224.00
hand/wrist strain	$ 8,562.00	$ 2854.00	$ 3425.00
rotator cuff injury	$24,626.00	$ 8209.00	$ 9030.00

5.1.6. Return on Investment

The Washington State Ergonomics Cost Benefit Calculator also estimates a return on investment based on workers' compensation claim reduction, indirect cost reduction, and increases in productivity. For example, 6 employees are in the bagging department, each earning $18.00 per hour. Department employees experienced one back strain, one neck strain, and one rotator cuff injury over the last three years, costs of which are shown in Table II. The annual benefit accrued from implementing an automated bagging system is $34,429.00. Considering the total cost of implementation which from the scenario is $854,540.00, it would take 24.82 years to recover the purchase cost, based off of workers' compensation claim reduction, reduction in indirect costs, and a conservative estimation of productivity increases.

Table II: Costs for hypothetical situation

Year	Type of Injury	Typical Cost	Average annual WMSD claim cost	Estimated Annual Indirect Cost
First	back strain	$ 8,723.00	$ 2908.00	$ 3489.00
Second	neck strain	$11,520.00	$ 3840.00	$ 4224.00
Third	rotator cuff injury	$24,626.00	$ 8209.00	$ 9030.00

Using the return on investment (ROI) calculator provided by the automated bagging company producing the system implemented at the plant results in a quicker ROI. This calculator takes into account the reduction of employee hours annually, and the annual savings when changing bag type (necessary when implementing the automated system). The ROI with this calculator is 2.9 years based on the annual savings total of $292,560.00 seen in Table III.

Table III: Return on investment calculator summary

Labor	Employee Reduction	Hrs/ Yr	Hourly Rate w/Benefits	Annual Savings
	4	1980	$18.00	$142,560.00
Bag Material	**Cost Savings per Bag**		**Bags/ Yr.**	**Annual Savings**
PE film vs. Pre-made Paper	$0.08		1,500,000	$120,000.00
PE film vs. Pre-made Polywoven	$0.06		500,000	$30,000.00
	$0.00			$0.00
Total Annual Savings				**$292,560.00**
Return on Investment				
Investment	$854,140			
Total Annual Savings	$292,560			
ROI - % - Year 1	34.25%			
ROI - Years	2.9			

The calculator provided by the bagging system producer does assume the elimination of costs due to four employees. If those employees are moved to another point in the production process, the annual cost savings would be $150,000.00, resulting in an ROI of 5.7 years.

5.2. Respirable Dust and Respirable Crystalline Silica

There were 170 total samples taken from 1979 to 2015 at Plant A. Of those samples, 140 were taken before an automated bagging system was implemented and 30 samples were taken after. For the rest of this paper sample data taken before the automated bagging system was implemented is referred to as “before” data, and sample data taken after is referred to as “after” data.

5.2.1. Respirable Dust

Table IV is a summary of the respirable dust exposure data. It includes the geometric mean and standard deviation of the data.

Table IV: Summary of the respirable dust results

respirable dust	geometric mean	standard deviation
before	0.064	0.063
after	0.071	0.038

Table V shows all of the respirable dust exposure concentrations before the automated bagging system was implemented.

Table V: Respirable dust exposure data before automated bagging system

respirable dust concentration (mg/m3)	respirable dust concentration (mg/m3)	respirable dust concentration (mg/m3)	respirable dust concentration (mg/m3)	respirable dust concentration (mg/m3)
0.17	0.135	0.123	0.001	0.063
0.297	0.123	0.055	0.097	0.001
0.137	0.123	0.001	0.001	0.131
0.17	0.121	0.055	0.098	0.074
0.17	0.123	0.06	0.049	0.086
0.115	0.123	0.065	0.06	0.035
0.123	0.105	0.034	0.016	0.024
0.113	0.106	0.102	0.037	0.186
0.148	0.125	0.082	0.108	0.136
0.176	0.129	0.051	0.123	0.074
0.076	0.131	0.001	0.11	0.098
0.146	0.123	0.063	0.085	0.012
0.06	0.123	0.38	0.061	0.024
0.016	0.367	0.001	0.122	0.136
0.125	0.123	0.001	0.025	0.073
0.123	0.123	0.071	0.023	0.073
0.173	0.122	0.001	0.072	0.074
0.123	0.122	0.144	0.001	0.1
0.125	0.122	0.069	0.09	0.12
0.123	0.122	0.11	0.039	0.061
0.123	0.122	0.012	0.061	0.084
0.25	0.122	0.208	0.047	0.088
0.123	0.2	0.025	0.024	0.084
0.124	0.1	0.184	0.101	0.07
0.123	0.122	0.049	0.112	0.108
0.13	0.1	0.001	0.019	0.037
0.123	0.1	0.025	0.058	0.073
0.123	0.123	0.159	0.059	0.077

Table VI shows all of the respirable dust exposure concentrations after the automated bagging system was implemented.

Table VI: Respirable dust exposure data after automated bagging system

respirable dust concentration (mg/m3)	respirable dust concentration (mg/m3)	respirable dust concentration (mg/m3)
0.12	0.114	0.097
0.085	0.084	0.172
0.131	0.095	0.1
0.06	0.086	0.075
0.142	0.084	0.003
0.001	0.11	0.062
0.097	0.122	0.058
0.097	0.097	0.07
0.124	0.098	0.037
0.142	0.098	0.057

5.2.2. Respirable Crystalline Silica

Table VII is a summary of the respirable crystalline silica exposures. It includes the geometric mean and the standard deviation of the data.

Table VII: Summary of respirable crystalline silica results

respirable crystalline silica	geometric mean	standard deviation
before	0.012	0.018
after	0.011	0.011

Table Table VIII shows all of the respirable crystalline silica exposure concentrations before the automated bagging system was implemented.

Table VIII: Respirable crystalline silica exposure data before automated bagging system

respirable crystalline silica concentration (mg/m^3)	respirable crystalline silica concentration (mg/m^3)	respirable crystalline silica concentration (mg/m^3)	respirable crystalline silica concentration (mg/m^3)	respirable crystalline silica concentration (mg/m^3)
0.01	0.04	0.028	0.003	0.003
0.04	0.01	0.03	0.01	0.003
0.01	0.01	0.003	0.003	0.014
0.04	0.01	0.026	0.036	0.015
0.01	0.04	0.026	0.003	0.003
0.01	0.01	0.02	0.022	0.003
0.01	0.01	0.003	0.003	0.003
0.02	0.01	0.03	0.003	0.051
0.02	0.03	0.026	0.007	0.033
0.01	0.01	0.003	0.024	0.003
0.01	0.03	0.003	0.063	0.026
0.14	0.01	0.003	0.013	0.003
0.01	0.01	0.033	0.004	0.003
0.01	0.05	0.003	0.031	0.021
0.01	0.01	0.003	0.003	0.029
0.01	0.01	0.022	0.003	0.003
0.01	0.03	0.003	0.042	0.03
0.05	0.01	0.042	0.003	0.003
0.03	0.04	0.012	0.028	0.003
0.05	0.01	0.033	0.003	0.01
0.03	0.01	0.003	0.026	0.006
0.03	0.03	0.025	0.003	0.016
0.04	0.06	0.003	0.003	0.017
0.03	0.02	0.034	0.023	0.003
0.01	0.025	0.003	0.022	0.003
0.01	0.02	0.003	0.003	0.003
0.01	0.02	0.003	0.02	0.013
0.03	0.03	0.053	0.01	0.016

Table IX shows all of the respirable crystalline silica exposure concentrations after the automated bagging system was implemented.

Table IX: Respirable crystalline silica exposure data after automated bagging system

respirable crystalline silica concentration (mg/m^3)	respirable crystalline silica concentration (mg/m^3)	respirable crystalline silica concentration (mg/m^3)
0.003	0.046	0.02
0.018	0.019	0.028
0.024	0.022	0.01
0.003	0.006	0.011
0.013	0.012	0.003
0.003	0.017	0.01
0.016	0.011	0.007
0.033	0.014	0.003
0.034	0.008	0.003
0.036	0.009	0.003

5.3. Noise

Seventy total noise samples collected at Plant A from 1996 to 2015. Of those, 49 were taken prior to the addition of the automated bagging system and 21 were taken after. Table X shows a summary of the noise exposure data and includes the geometric means and standard deviations for before and after an automated system was installed. To calculate the geometric mean of the before data, the “0” had to be removed from the data set.

Table X: Summary of noise exposure results

Noise Exposures in dBA	Before	After
Standard Deviation	13.4	4.6
Geometric Mean	54.0	69

Table XI shows the noise exposures in A-weighted decibels (dBA) before the automated bagging system was put in.

Table XI: Noise exposures data before automated bagging system

Noise Exposure in dBA	Noise Exposure in dBA	Noise Exposure in dBA	Noise Exposure in dBA
84	87.6	76.1	86
79	79.5	64.1	71.2
79	84.9	65.3	65.1
82	78.6	84.9	68.6
60.6	72.1	65.6	73.5
74.7	82.3	71.1	63.9
74.2	73.6	79.3	66.8
86.9	71.4	66.5	50.3
77	86.4	71.2	76.5
85.2	57.6	72.5	64.9
74.4	71.4	67	75.2
0	73.7	70.8	69.2
85.8			

Table XII shows the noise exposures in dBA after the automated bagging system was put in.

Table XII: Noise exposures data after automated bagging system

Noise Exposure in dBA	Noise Exposure in dBA
67.8	69.6
71.4	65.7
62.8	68.7
69.1	69.4
81	65.3
63.1	66.3
62.8	66.7
69.4	70.4
73.6	78.8
69.4	71.4
66.7	

6. Discussion

A discussion of the ergonomic, respirable dust, respirable crystalline silica, and noise results are in the following sections.

6.1. Ergonomic

The audit identified specific hazards as well as gaps in training. The subsequent sections discuss the hazards discovered by the audit tool as well as recommendations to decrease of eliminate them.

6.1.1. Facility Level

Bag operators one, two, three, four, five, six, seven, and nine are standing for the duration of manual bagging. Anti-fatigue mats are located directly in front of bagging station for operator one, three, four, and five as seen in Figure 3. Larger anti-fatigue mats are recommended to cover more area because operators are moving off mats frequently in the palletizing process. Changing posture can help unload the joints and reduce stresses associated with prolonged static standing. If extended bagging occurs, insure that workers can change posture by providing a sit/stand station, lean stand, or foot rests. If discomfort still occurs, consider anti-fatigue insoles for operators. Figure 3 shows the current anti-fatigue mat for bagger one. (Question 3.1, 3.2, Appendix B)

Figure 3: Anti-fatigue mat for bagger one

Bagger eight is sitting during the bagging process, and has to lean forward and fully extend arms to load the four-spout bag filler. Seated workstations limit posture and minimize movement contributing to injury risk. They can also require awkward arm and back postures. To allow workers to change postures frequently and reduce the stresses associated with prolonged sitting, a sit/stand station is ideal. To reduce the awkward postures seen in Figure 4, spouts should be positioned so that worker can easily reach them without bending forward and fully extending arm. Conveyor belt should be removed from under the baggers body. It is important to note that occasional reaches beyond this range are permissible, but should be minimized. (Question 3.1b, Appendix B)

Figure 4: Bagger 8 loading four spout

6.1.1.1. Mobile Equipment

The addition of domed mirrors on the corners in plants where applicable will help ensure proper visibility because mobile equipment (i.e. forklifts) is used in indoor areas where foot traffic is common. Also, painting mobile equipment lines on the floor in the warehouses will help keep pedestrian traffic out of common travel lanes for mobile equipment. (Question 6.1, Appendix B)

6.1.2. Manual Bagging

Ways to decrease or eliminate hazards associated with filling and palletizing are discussed in the following sections.

6.1.2.1. Filling

Bag operator eight is not able to rest their feet comfortably with near 90˚ angles at the hips and knees. The seat should have height adjustability so that worker can modify the seat to assume the correct posture while sitting. (Question 3.4, Appendix B)

Bagging operators one, two, three, four, five, six, and eight performed several different hand motions and postures that can cause inflammation and pain in the hands and fingers. Some of these motions (i.e. pinch grips) can lead to repetitive trauma disorders such as carpal tunnel syndrome or tendonitis. Ideally, it would be best to automate the filling station eliminating the need for manual handling of bags. If automation is not feasible, train bagging operators to keep their hands and wrist in the neutral position when they move filled bags from station to pallet. Using a tool that requires a power grip is beneficial. (Question 7.4, 7.5, 7.6, Appendix B)

6.1.2.2. Palletizing

Bag operator three performed lifts above the recommended maximum height of 50 inches as seen in Figure 5. Pallet jacks are already in place, all lifting should be done between knuckle and shoulder height keeping the bags close to the body (ideal power position). Full automation is the ideal recommendation. If automation is not feasible reinforce training of bagging operators on proper lifting techniques including bending at the knees, keeping wrists and hands in the neutral position, and keeping weight near the body. Using a tool that requires the power grip is beneficial. (Question 10.1, Appendix B)

Figure 5: Bagger 3 not utilizing pallet jack

Empty pallets should be positioned using forklifts to eliminate manual handling. If it is not possible to use a forklift, ensure that pallets are stored close to the bagging station, around 30 inches off the ground, and consider using two workers to lift pallets. (Question 10.2, 11.1, Appendix B)

During manual bagging, bag operators one, two, three, four, five, and six transfer bags directly from the filling station to pallet. Figure 6 shows an example of a pinch grip. Some of these motions (i.e. twisting, pinch grip) can lead to repetitive trauma disorders such as bulging discs, carpal tunnel syndrome and/or tendonitis. Reinforce shoulder and back training of operators to ensure no twisting, arm extension, and bending at the knees. Also train baggers on proper carrying techniques minimizing wrist deviation from neutral postures while carrying a load or using a tool that requires the power grip. (Question 10.3, 10.11, 10.12, Appendix B)

Figure 6: Bagger one using a pinch grip

6.1.3. Bulk Bags

The hazards pertaining to hanging bulk-bags as well as closing bulk-bags are discussed below. Along with the discussing of the hazards are recommendations for eliminating them.

6.1.3.1. Hanging, Opening, and Filling

Stacks of empty bulk-bags at all facilities are currently stored so that the last bag is below the recommended 10 inches. They should be stored between 10 and 50 inches to minimize repetitive bending. (Question 11.2, Appendix B)

Under current conditions, bag operator one must stand on pallet and platform to reach the spout and hooks. The stand and pallet are not considered an ideal work surface according to MSHA, especially with a filled bag. Figure 7 shows bag operator one standing on the unstable working surface.

Figure 7: Bag operator one attaching bulk-bag

Bag operator seven currently stands on the ledge to attach front of bag to hooks. This is not an ideal working surface according to MSHA. Currently, there is a platform for baggers to stand on to reach the front hooks, but bag operator one stated that it is too time consuming to use. Having access to the platform from the front may increase chances that bag operators will use platform.

Hooks and filling spouts should be between 40 and 57 inches (between elbow and shoulder height when standing) from the surface on which the worker stands. Ideally, you would adjust your filling spouts and hooks to these recommended heights. If this is not feasible, consider adding a platform for workers to stand on that allows them to work in the suggested 40-57 inches. (Question 11.3, Appendix B)

6.1.3.2. Closing and Sealing

A Rapid Upper Limb Assessment (RULA) was done on video of the bulk-bag operators closing and sealing bulk-bags. Two bagger operators remove the bag from the filling station prior to tying (baggers eight and nine), and the other ties the bag while it is up on the filling station (bagger one). Results show that significant shoulder deviation is apparent in the last. When possible, remove the bulk-bags from the filling station prior to sealing. Figure 8 shows bagger one tying the filled bag which is elevated. This forces bagger one to stand on the edge of platform (not an ideal work surface) and extend arms beyond the recommended 57 inch height to tie off bags. (Question 12.1, Appendix B)

Figure 8: Bagger 1 standing on platform to reach spout

Bulk-bag operators were observed using multiple tying techniques. The ideal technique recommended by the NIOSH ergonomics tool is the flowering method which is shown in Figure 9. The flowering method requires a minimal amount of physical effort, which may help decrease risk of injury to the hands and arms. (Question 12.3, Appendix B)

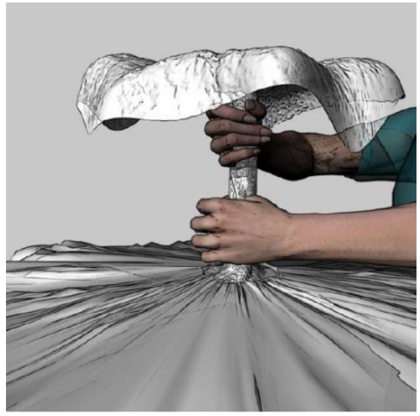

Figure 9: Flowering method for bag tying

6.2. Respirable Dust and Respirable Crystalline Silica

The respirable dust and respirable crystalline silica concentration results were not normally distributed, for this reason a nonparametric Wilcoxon sum-rank test was performed. The concentration results were log transformed for the statistical analysis.

6.2.1. Respirable Dust Statistical Analysis

The results of the respirable dust analysis had a p-value of .29, which is higher than the alpha value of .05. Figure 10 shows the boxplot for respirable dust exposures before and after the automated bagging system was installed. As you can see the means are almost identical. The results of this test accept the null hypothesis (H_{O1}). The null hypothesis states that the implementation of an automated bagging system does not reduce respirable dust exposure of the bagger.

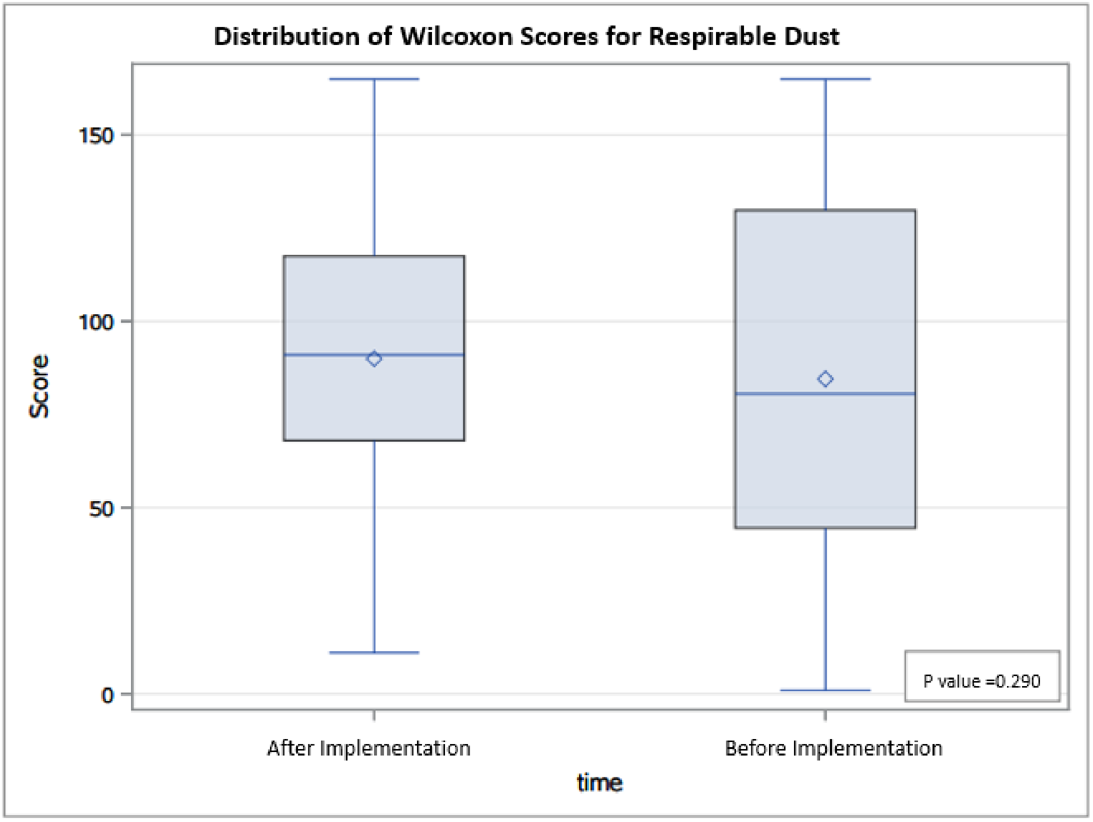

Figure 10: Boxplot of bagger respirable dust exposures

6.2.2. Respirable Crystalline Silica Statistical Analysis

The p-value for the total respirable crystalline silica analysis was .33 which is higher than the alpha value of .05. The results show no statistical difference in before and after data which accepts the null hypothesis (H_{O2}). Figure 11 illustrates the distribution of the Wilcoxon Scores in a boxplot. The implementation of an automated system does not significantly decrease bagger respirable dust exposures.

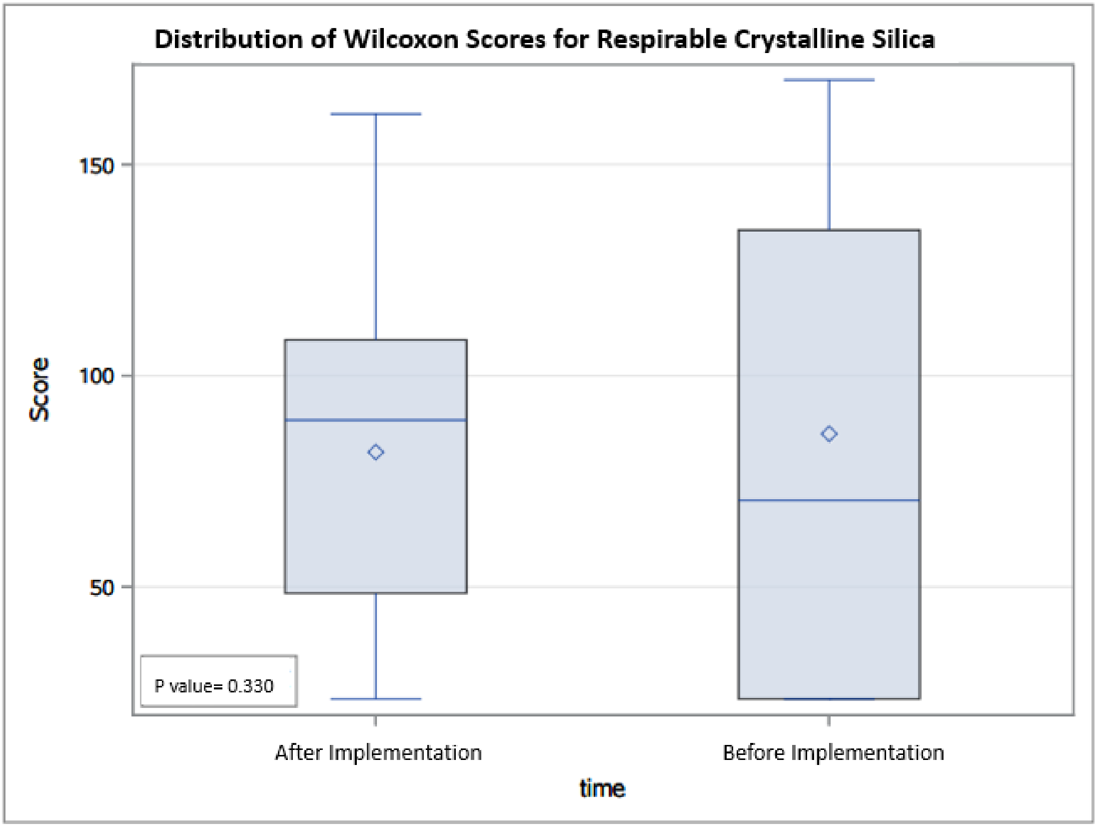

Figure 11: Boxplot of bagger respirable crystalline silica exposures

6.3. Noise Statistical Analysis

The noise data was statistically significant. The results had a p-value of .0065 which is lower than the alpha value of .05. The results of this analysis reject the null hypothesis (H_{O2}) in favor of the alternative hypothesis (H_{A2}), suggesting that noise exposure decreased for baggers after implementation of an automated bagging system. Figure 12 illustrates the difference in noise exposures using boxplots. Although the means seem close, it is important to remember that a difference of 3 dbA according to ACGIH doubles your allowable exposure time.

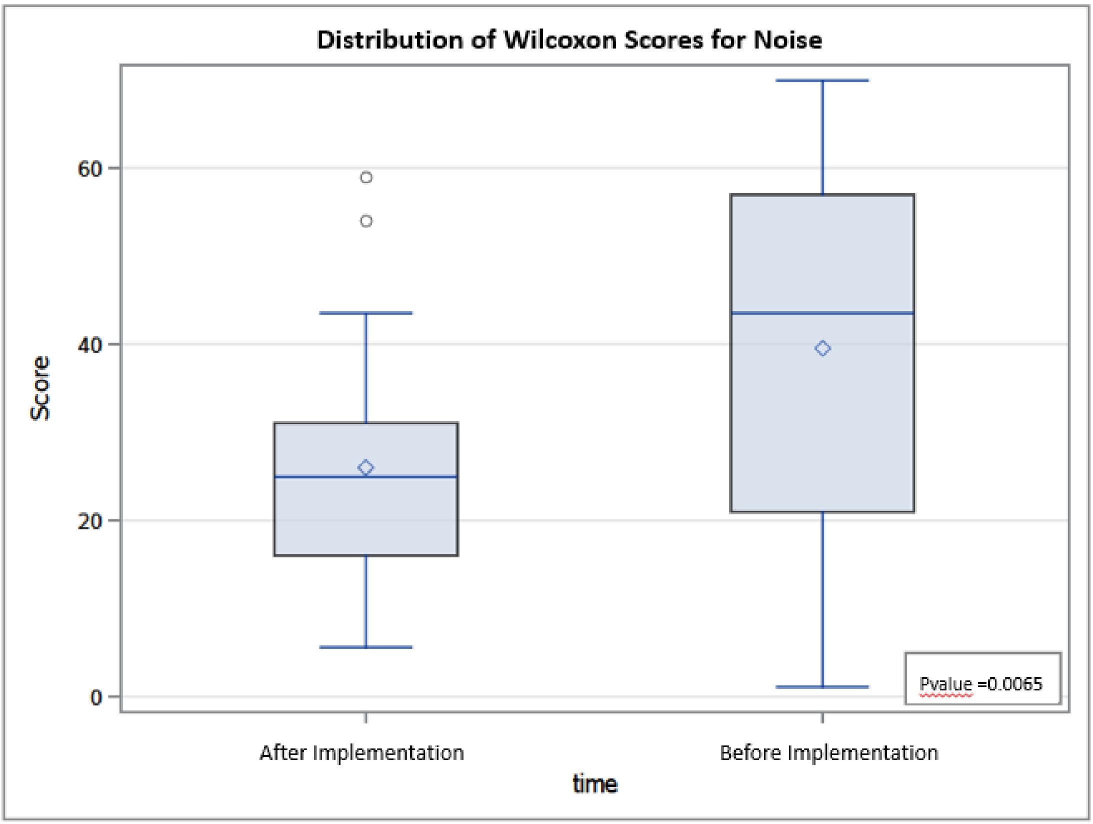

Figure 12: Boxplot of bagger noise exposures

7. Limitations and Future Work

The limitations and future work associated with this research are discussed in the subsequent sections.

7.1. Limitations

The limitations associated with the ergonomic research of this study are discussed, as well as those related to the respirable dust, respirable crystalline silica, and noise samples that were analyzed.

7.1.1. Ergonomic

It was not possible to gather ergonomic data on the before and after implementation of an automated bagging system. So it is assumed that pre-automation manual baggers were using similar techniques. This is based off of the assumption of uniform companywide training on how to properly lift and palletize small bags as well as hang and tie bulk-bags.

7.1.2. Respirable Dust and Respirable Crystalline Silica

The samples were sorted by bagging work location. Exposure profiles could be significantly different in job classifications of the general bagging area. There were not enough individual samples for each job classification to do this, so the exposure profile for bagging is generalized to location.

7.1.3. Noise

Noise data was sorted by the work location of bagging. This generalized the noise exposure to the entire location. There were not enough samples in each of the job classifications to analyze the specific exposures of each.

7.2. Future Work

Due to the lack of literature specific to this topic it is suggested that the research be repeated and validated with exposure data from additional industrial mineral processing plants. Analyzing specific job tasks would focus exposure profiles to specific tasks. It would also be pertinent to look at different levels of automation (i.e. robotic palletizer, automated bag filling, conveyor transport to pallets, pallet jacks) individually to see how effective they minimize ergonomic hazard exposures, as well as noise and dust exposures.

8. Conclusions

The analysis of manual bagging from a holistic ergonomic approach at an industrial mineral sand mine processing plant was conducted for this research. The research focused not only on ergonomic hazards, workers compensation costs, and the return on investment of an automated system, but also the hazards associated with dust and noise exposures.

It was found that the implementation of an automated bagging system did not have significant effects on the reduction of respirable dust and respirable crystalline silica exposures. However, the automated system did significantly reduce the exposure of bagger operators to noise.

The ergonomic hazards associated with manual bagging are numerous and have far reaching potential in regards to the risk of injury. Almost all of the risk factors associated with workplace musculoskeletal disorders are associated with manual bagging. They include force, repetition, duration, compression, and posture. The implementation of a completely automated bagging system would all but eliminate the ergonomic exposures. The yearly adjusted injury rate dropped from 2.76 per year to .72 per year after the implementation of an automated system in the plant associated with the study (plant A). The only exposures after putting in an automated system would be those associated with routine and non-routine maintenance tasks of the equipment and loading of empty bags. Also, the estimated reduction in workers compensation claims is approximately $34,000 with a return on investment potential of less than 6 years on the conservative side.

Based on the ergonomic evaluation of manual bagging as well as the positive reduction in noise exposure it is safe to say that automated bagging systems are worth the upfront costs if they only prevent even one injury a year.

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10. Appendix A: Answer Tables from NIOSH Audit Tool

Table XIII: Module 1 Results

Module 1	1	1.1	1.2	1.3	1.4	1.5	1.6	2	2.1	2.2	2.3	2.4	3	4
bagger 1	yes	b	b	b	b	a	y	y	y	y	b	a	2+	y
bagger 2	yes	b	b	b	b	a	y	y	y	y	b	a	2+	y
bagger 3	yes	b	b	b	b	a	y	y	y	y	b	a	2+	y
bagger 4	yes	b	b	a	b	b	y	y	y	y	b	N/A[1]	2+	y
bagger 5	yes	b	b	a	b	b	y	y	y	y	b	N/A	2+	y
bagger 6	yes	b	b	a	b	b	y	y	y	y	b	N/A	2+	y
bagger 7	yes	-	-	-	-	-	-	-	-	-	-	-	-	-
bagger 8	yes	b	a	a	a	a	no	yes	yes	yes	b	C	2+	no
bagger 9	yes	-	-	-	-	-	-	-	-	-	-	-	-	-

(-) is defined as not applicable, N/A is defined as not available

Table XIV: Module 2 Results

module 2	1	2
bagger 1	no	yes
bagger 2	no	yes
bagger 3	no	yes
bagger 4	yes	yes
bagger 5	yes	yes
bagger 6	yes	yes
bagger 7	no	yes
bagger 8	yes	yes
bagger 9	yes	yes

(-) is defined as not applicable

Table XV: Module 3 Results

module 3	1	1.1	2	3	4	5
bagger 1	101	a	c	-	-	-
bagger 2	201	a	c	-	-	-
bagger 3	302	a	c	-	-	-
bagger 4	bagging	a	b	-	-	-
bagger 5	bagging	a	b	-	-	-
bagger 6	bagging	a	b	-	-	-
bagger 7	-	-	-	-	-	-
bagger 8	small bags	b	-	b	no	b
bagger 9	-	-	-	-	-	-

(-) is defined as not applicable

Table XVII: Module 4 Results

module 4		1	2	3	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8
bagger 1		no	yes	yes	101	101	1	1	1	0	1	0	1
bagger 2		no	yes	yes	201	201	1	1	1	0	1	0	1
bagger 3		no	yes	yes	302	302	1	1	1	0	1	0	1
bagger 4		no	no	yes	bagging	bagging	1	2	1	1	1	0	1 to 2
bagger 5		no	no	yes	bagging	bagging	1	2	1	1	1	0	1 to 2
bagger 6		no	no	yes	bagging	bagging	1	2	1	1	1	0	1 to 2
bagger 7		-	-	-	-	-	-	-	-	-	-	-	-
bagger 8		no	no	not needed	small bags	small bags	0	0	0	-2	1	0	0
bagger 9		-	-	-	-	-	-	-	-	-	-	-	-

(-) is defined as not applicable

Table XVII: Module 5 Results

module 5	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
bagger 1	101	yes	yes	yes	no	no	no	no	no	c	no	no	d	no	no
bagger 2	201	yes	yes	yes	no	no	no	no	no	c	no	no	d	no	no
bagger 3	302	yes	yes	yes	no	no	no	no	no	c	no	no	d	no	no
bagger 4	bagging	yes	yes	yes	no	yes	yes	no	no	c	no	yes	d	no	no
bagger 5	bagging	yes	yes	yes	no	yes	yes	no	no	c	no	yes	d	no	no
bagger 6	bagging	yes	yes	yes	no	yes	yes	no	no	c	no	yes	d	no	no
bagger 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
bagger 8	small bags	yes	no	yes	no	no	no	yes	no	a	no	no	d	no	no
bagger 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

(-) is defined as not applicable

Table XVIII: Module 6 Results

module 6	1	2	3	4	5	6	7
bagger 1	yes	yes	c	yes	no	yes	no
bagger 2	yes	yes	c	yes	no	yes	no
bagger 3	yes	yes	c	yes	no	yes	no
bagger 4	yes	yes	b	yes	yes	yes	no
bagger 5	yes	yes	b	yes	yes	yes	no
bagger 6	yes	yes	b	yes	yes	yes	no
bagger 7	-	-	-	-	-	-	-
bagger 8	yes						
bagger 9	-	-	-	-	-	-	-

(-) is defined as not applicable

Table XIX: Module 13 Results

module 13	0	1	2	3	4	5	6
bagger 1	104	a	fully automated	just stretch	just stretch	just stretch	just stretch
bagger 2	202	a	fully automated	just stretch	just stretch	just stretch	just stretch
bagger 3	301	a	fully automated	just stretch	just stretch	just stretch	just stretch
bagger 4	bagging	a	f	just stretch	just stretch	just stretch	just stretch
bagger 5	bagging	a	f	just stretch	just stretch	just stretch	just stretch
bagger 6	bagging	a	f	just stretch	just stretch	just stretch	just stretch
bagger 7	sc 137	a	fully automated	just stretch	just stretch	just stretch	just stretch
bagger 8	-	-	-	-	-	-	-
bagger 9	bulk	a	fully automated	just stretch	just stretch	just stretch	just stretch

(-) is defined as not applicable

Table XX: Module 7 Results

module 7	0	1	1b	2	3	4	5	6
bagger 1	101	b	e	no	a	a	c	a
bagger 2	201	b	e	no	a	a	c	a
bagger 3	302	b	e	no	a	a	c	a
bagger 4	bagging	b	e	no	a	a	c	c
bagger 5	bagging	b	e	no	a	a	c	c
bagger 6	bagging	b	e	no	a	a	c	c
bagger 7	-	-	-	-	-	-	-	-
bagger 8	small bags	b	d	yes	a	c	a	b
bagger 9	-	-	-	-	-	-	-	-

(-) is defined as not applicable

Table XXI: Module 8 Results

module 8	0	1	2
bagger 1	101	33.5”	b
bagger 2	201	33.5”	b
bagger 3	302	33.5”	b
bagger 4	bagging	8”	c
bagger 5	bagging	8”	c
bagger 6	bagging	8”	c
bagger 7	-	-	-
bagger 8	small bags	automated	b
bagger 9	-	-	-

(-) is defined as not applicable

Table XXII: Module 9 Results

module 9	0	1	2	3	4	5
bagger 1	101	automatic	automatic	automatic	automatic	automatic
bagger 2	201	automatic	automatic	automatic	automatic	automatic
bagger 3	302	automatic	automatic	automatic	automatic	automatic
bagger 4	bagging	automatic	automatic	automatic	automatic	automatic
bagger 5	bagging	automatic	automatic	automatic	automatic	automatic
bagger 6	bagging	automatic	automatic	automatic	automatic	automatic
bagger 7	-	-	-	-	-	-
bagger 8	small bags	automated	automated	automated	automated	automated
bagger 9	-	-	-	-	-	-

(-) is defined as not applicable

Table XXIII: Results for Module 10

module 10	10	1a	1b	1c	2	3	4	5	6	7	8	9	10	11	12
bagger 1	101	c	6"	32"	a	31.5"	c	no	no	no	no	no	yes	no	no
bagger 2	201	d	5.5"	60"	b	60"	c	no	no	no	no	no	yes	no	no
bagger 3	302	c	25.5”	43"	a	43"	c	no	no	no	no	no	yes	no	no
bagger 4	bagging	c	32"	47"	b	52"	b	no	no	no	no	no	yes	b	b
bagger 5	bagging	c	32"	47"	b	52"	b	no	no	no	no	no	yes	b	b
bagger 6	bagging	c	32"	47"	b	52"	b	no	no	no	no	no	yes	b	b
bagger 7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
bagger 8	small bags	auto[1]	auto	auto	auto	auto	auto	auto	auto	auto	auto	auto	auto	auto	auto
bagger 9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

(-) is defined as not applicable, 1-auto is defined as automated

Table XXIV: Results for Module 11

module 11		0	1	2	2b	3	3b	4	4b	5	6	7	8
bagger 1		104	a	5"	28"	68" or 73"	79" or 84"	d	yes	no	a	a	d
bagger 2		-	-	-	-	-	-	-	-	-	-	-	-
bagger 3		-	-	-	-	-	-	-	-	-	-	-	-
bagger 4		N/A[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/
bagger 5		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/
bagger 6		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/
bagger 7		sc 137	c	0	58"	87"/49" (61)	89"/51" (63)	d	yes	no	a	a	d
bagger 8		-	-	-	-	-	-	-	-	-	-	-	-
bagger 9		bulk						d	yes	no	a	a	d

1- N/A is defined as not available, (-) is defined as not applicable

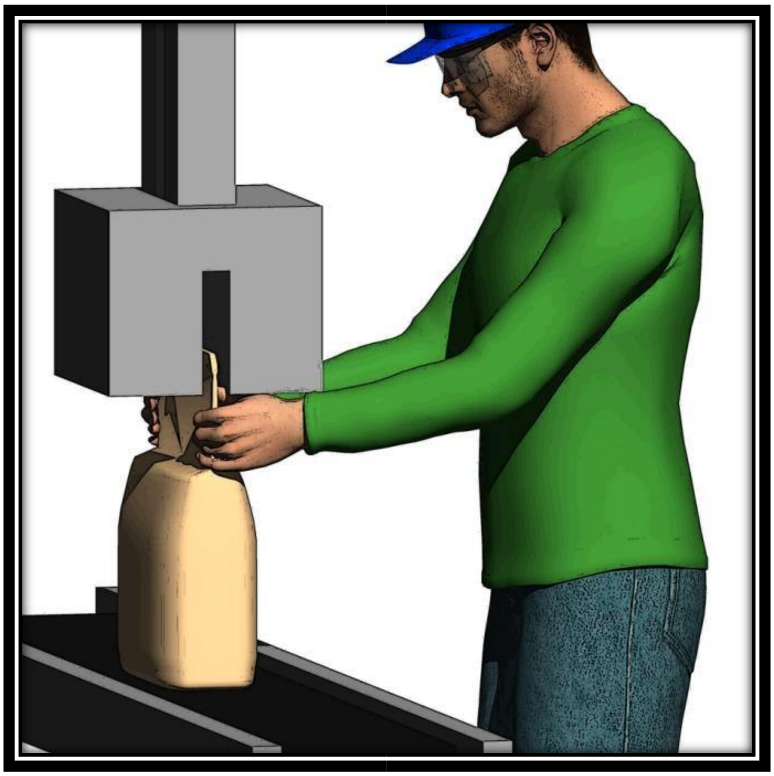
Table XXV: Results for Module 12

module 12	0	1	2	3	4
bagger 1	104	73”	no	c	f
bagger 2	202	73”	no	c	f
bagger 3	301	73”	no	c	f
bagger 4	N/A[1]	N/A	N/A	N/A	N/A
bagger 5	N/A	N/A	N/A	N/A	N/A
bagger 6	N/A	N/A	N/A	N/A	N/A
bagger 7	sc 137	46”	no	b	f
bagger 8	-	-	-	-	-
bagger 9	bulk		no	b	f

1-N/A is defined as not available, (-) is defined as not applicable

11. Appendix B: NIOSH Manual Bagging Ergonomics Audits Tool

Bagging Audit Tool



This audit assesses the ergonomics of the processes for filling small bags (100 lb or less) and bulk bags (i.e., intermediate bulk container), closing them, and preparing them for shipment. The audits cover the individual filling stations as well as the environment in which the processes are housed.

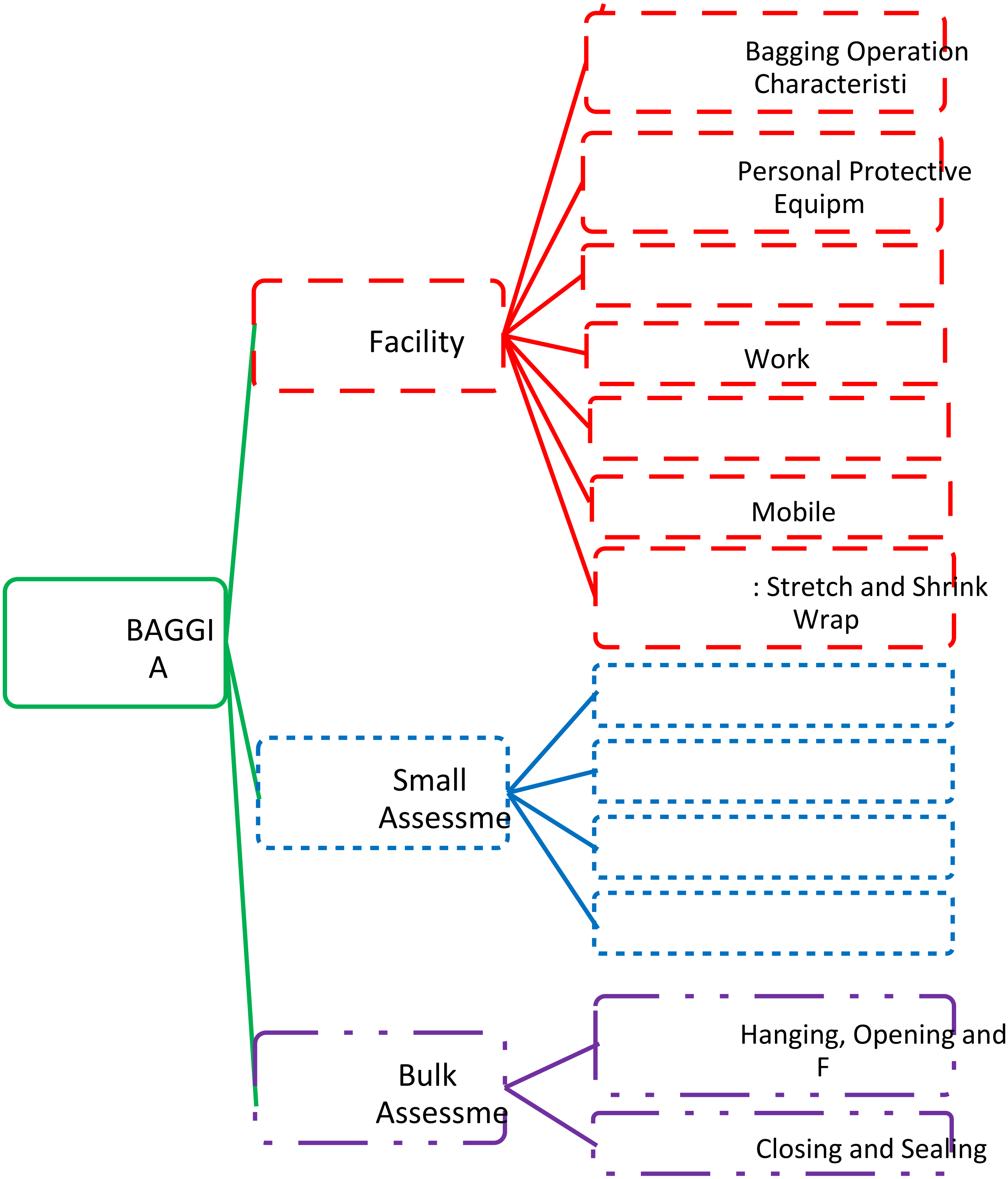


Figure 1. Structure of bagging audit modules.

Bagging Audit Instructions

The bagging audit package contains four documents that are necessary to conduct a bagging audit. A description and intended use of each document is provided below.

Bagging Audit Information Page. This page allows the bagging audit user to record pertinent information to be filed with the audit results and recommendations. It should be used when conducting an audit of multiple locations or at multiple times.

Bagging Audit Answer Sheet. This document can be used to record responses to bagging audit questions, thereby allowing the user to reuse the Bagging Audit Questions Document multiple times without the need for additional copies of the questions.

Bagging Audit Questions Document. This document contains the full set of bagging audit questions and is arranged in a modular format.

Bagging Audit Recommendations Document. This document contains all the recommendations for the bagging audit questions. It includes a checkbox beside each recommendation, allowing the user to check the recommendation that corresponds to each of the answers recorded on the answer sheet.

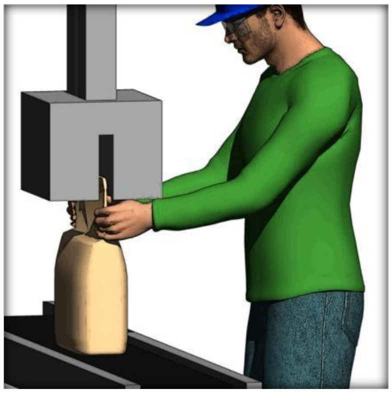
Bagging Audit Table of Contents

Bagging Audit Information Page
……………………………………………..……………………………………Page 1

Bagging Audit Questions Document
………………………………………..………………………………….Page 2

Bagging Audit Answer Sheet …………………………………………………………………………………….
Page 36

Bagging Audit Recommendations Document ……………………………………………………………….
Page 39



Bagging Audit Information Page

Name of Auditor: ___________________________________

Location of Audit: ___________________________________

Date of Audit: ______________________________________

Comments:

____

____

____

____

____

____

____

Bagging Audit Information Page: Page

Bagging Audit Answer Sheet

Facility Level Modules

Module 1 – Bagging Operation

Characteristics

1.1 ___________________________

1.1.1__________________________

1.1.2__________________________

1.1.3__________________________

1.1.4 _________________________

1.1.5 _________________________

1.1.6 _________________________

1.2___________________________

1.2.1_______________________

1.2.2__________________________

1.2.3__________________________

1.2.4 _________________________

1.3 ___________________________

1.4___________________________

Module 2 – Personal Protective

Equipment

2.1_____________________

2.2______________________

Module 3 – Work Posture

3.0______________________

3.1______________________

3.2______________________

3.3_____________________

3.4______________________

3.5______________________

Module 4 – Work

Environment

4.1______________________

4.2______________________

4.3______________________

4.4______________________

4.4.1 Name of

Area:____________

4.4.2 Air Temp:__________

4.4.3 Humidity: _______________

4.4.4 Thermal Radiation:______

4.4.5 Air Movement: ___________

4.4.6 Workload:______________

4.4.7 Clothing: ________________

4.4.8 Opinion:________________

Module 5 – Lighting

5.0___________________________

5.1___________________________

5.2___________________________

5.3___________________________

5.4___________________________

5.5___________________________

5.6___________________________

5.7___________________________

5.8___________________________

5.9___________________________

5.10__________________________

5.11__________________________

5.12__________________________

5.13__________________________

5.14____________________

Module 6 – Mobile Equipment

6.1______________________

6.2______________________

6.3______________________

6.4______________________

6.5______________________

6.6______________________

6.7______________________

Small Bag Modules

Module 7 – Filling

7.0______________________

7.1______________________

7.2______________________

7.3______________________

7.4___________________________

7.5___________________________

7.6___________________________

Module 8 – Weighing

8.0___________________________

8.1___________________________

8.2___________________________

Module 9 – Sealing

9.0__________________________

9.1 Part 1________Part2_________

9.2___________________________

9.3___________________________

9.4___________________________

9.5___________________________

Module 10 – Palletizing

10.0 _________________________

10.1 Part 1:___________________

10.1 Part 2: Lowest height ______

10.1 Part 2: Highest height _____

10.2 __________________________

10.3Height:_____________

10.4_____________________

10.5_____________________

10.6_____________________

10.7_____________________

10.8_____________________

10.9_____________________

10.10____________________

10.11____________________

10.12____________________

Bulk Bag Modules

Module 11 – Hanging, Opening, and Filling

11.0_____________________

11.1_____________________

11.2 Lowest height:_____

11.2 Highest height:______

11.3 Part 1: Height: ______

11.3 Part 2: Height: ______

11.4 Part 1:___________________

11.4 Part 2:___________________

11.5 ________________________

11.6 ________________________

11.7 ________________________

11.8 ________________________

Module 12 – Closing and Sealing

12.0 _________________________

12.1 Height:___________________

12.2 _________________________

12.3 _________________________

12.4 _________________________

Small and Bulk Bags

Module

Module 13 – Stretch and Shrink

Wrapping

13.0_________________________

13.1___________________

13.2___________________

13.3___________________

13.4___________________

13.5___________________

13.6___________________

FACILITY LEVEL MODULES

This series of modules asks about the nature of the bagging operations, facilities, equipment, and PPE postures used during bagging.

Module 1: Bagging Operation Characteristics

This module asks about characteristics and processes of your bagging operations and determines which sections of this audit should be conducted.

1.1 Are small bags (typically 100 lb or less) used?   Yes / No

If yes, proceed to question 1.1.1

If no, proceed to question 1.2

1.1.1 What is the filling process for small bags?

Automated process (empty and full bags are not manually handled)

Process requiring some manual handling such as adding empty bags or removing full bags from a filling spout

If A, do not complete Module 7

If B, complete Module 7

1.1.2 What is the process for checking the weight of small bags after filling?

Automated process (no manual handling during weighing)

Process requiring some manual handling such as lifting a filled bag and moving to a scale

If A, do not complete Module 8

If B, complete Module 8

1.1.3 What is the sealing process for small bags?

Automated process (no manual handling during sealing)

Process requiring some manual handling such as manually feeding the bag through the sealing machine or rolling/folding the top of the bag

If A, do not complete Module 9

If B, complete Module 9

1.1.4 What is the palletizing process for small bags?

Automated process (no manual handling during palletizing)

Process requiring some manual handling such as manually moving filled bags to pallet or using a vacuum hoist to lift and move the bags to the pallets

If A, do not complete Module 10

If B, complete Module 10

1.1.5 What is the stretch/shrink wrapping process for small bags?

Automated process (no manual handling of shrink/stretch wrap)

Process requiring some manual handling such as manually applying wrap

Small bags are not stretch/shrink wrapped

If A or C, do not complete Module 13 (unless your answer to 1.2.4 is B) If B, complete Module 13

1.1.6 Do bag failures (broken bags) occur? Yes / No

If yes, proceed to next question

If no, proceed to Module 2

1.1.7 During which processes do bag failures occur?

Choose all that apply:

a) Bag filling

b) Transporting on conveyor

c) Weighing

d) Sealing

e) Palletizing

f) Storing

1.2 Are bulk bags (e.g., super sacks) used? Yes / NoIf yes, proceed to question 1.2.1

If no, proceed to Module 2

1.2.1 Are liners ever used inside the bulk bags? Yes / No

If yes, proceed to question 1.2.2

If no, proceed to question 1.2.3

1.2.2 Is the liner attached (e.g., semi or fully glued or sewn to the bag)?

Yes / Sometimes / No

1.2.3 What is the top design of the bulk bag (Figure A1)?

Choose all that apply:

a. Spout

a. Cone

b. Duffle or open

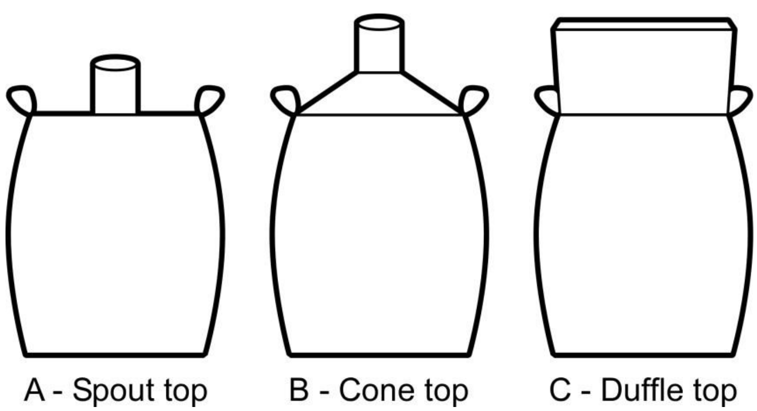


Figure A1. Types of bag tops.

1.2.4 Is the bulk bag stretch/shrink wrapping process:

Automated process (no manual handling of shrink/stretch wrap)

Process requiring some manual handling such as manually applying wrap

Bulk bags are not stretch/shrink wrapped

If A or C and you answered A or C to 1.1.5, do not complete Module 13

If B, complete Module 13

1.3 At any given time, how many workers are typically involved in bagging tasks? One / two or more

If one, proceed to Module 2

If two or more, proceed to next question

1.4 Do workers rotate between tasks (e.g., driving fork lift, palletizing, bagging)? Yes / No

Module 2: Personal Protective Equipment

This module asks about personal protective equipment worn while bagging.

2.1 Are respirators (dust masks) required for bagging activities? Yes / No

2.2 Are gloves ever worn during bagging activities? Yes / No

Module 3: Work Posture

This module asks about postures observed while workers are bagging. This module should be completed for each bagging work station.

3.0 Please record the name of the bagging station you are evaluating:________________________

3.1 What posture is used for the task?

a) Standing

b) Sitting

Mix of standing and sitting with the ability to move freely and frequently

If A, answer 3.2 and proceed to Module 4

If B, proceed to question 3.3

If C, proceed to question 3.2

3.2 What type of floor surface is the worker on?

Hard surface (e.g. concrete)

Cushioned surface (e.g. anti-fatigue mat)

Mix of hard and cushioned surfaces

3.3 Is the seat fixed or sliding/swivel?

Fixed

Sliding/Swivel

Is the worker able to rest their feet comfortably with a near 90˚ angle at the hip and knee (e.g., Figure A2) and not like Figure A3?   Yes   /   No

Figure A2. Worker is sitting with hip and knee at same level, hip and knee at approximately 90 degrees, and feet supported.

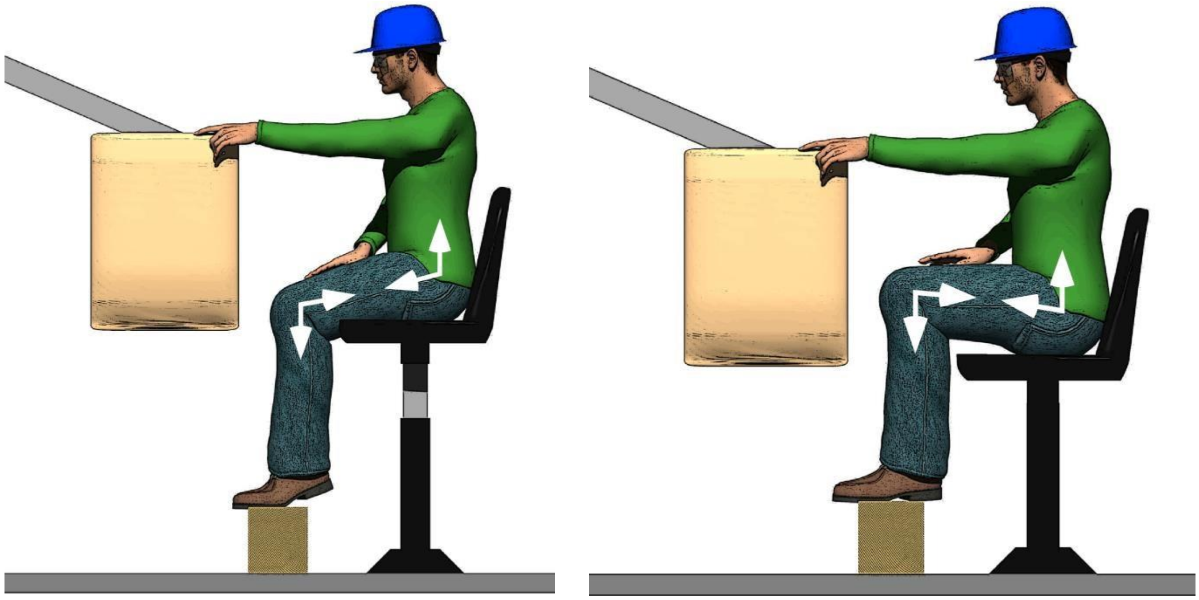


Figure A3. Worker is sitting too far from the foot support, resulting in the knee being below the hip and a greater than 90-degree angle at the hip and knee (left); worker is sitting too close to the foot support, resulting in the knee being above the hip and a less than 90-degree angle at the hip and knee (right).

By asking the worker, what is the condition of the seat?

Good (no rips in seat cover, padding intact, provides proper support, and sliding/swivel function still working properly)

Fair/poor (seat cover ripped, padding lost or no longer comfortable, pieces broken off, sliding/swivel function is not working properly)

Module 4: Work Environment

This module asks about environmental conditions, particularly factors affecting thermal comfort.

4.1 During the summer months, is work performed outdoors? Yes / No

4.2 During the winter months, is work performed outdoors? Yes / No

If yes, proceed to next question

If no, proceed to question 4.4

Are workers provided portable heating sources, if needed? Yes / No / Not needed

Using Table A1, ask employees who routinely work in the area being audited to score their current thermal environment. Complete this for each working area.

Input a name for the work area you are currently evaluating: ___________________

Air Temperature Score: _____________

Humidity Score: __________

Thermal Radiation Score: _______________

Air Movements Score:______________

Physical Workload Score: _______________

Clothing Score:______________

Opinion of Workers Score:_______________

Table A1. Thermal working conditions scores[1].

Score	Condition
	Air Temperature
-3	Generally freezing
-2	Generally between 32˚F and 50˚F
-1	Generally between 50˚F and 64˚F
0	Generally between 64˚F and 75˚F
1	Generally between 75˚F and 90˚F
2	Generally between 90˚F and 104˚F
3	Generally greater than 104˚F
	Humidity
-1	Dry throat/eyes after 2–3 hours
0	Normal
1	Moist skin

[1] 9 ISO [2004]. ISO 15265 Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions. Geneva, Switzerland: International Organization for Standardization, pp. 4–5.

2	Skin completely wet
	Thermal Radiation
-1	Cold on the face after 2–3 minutes
0	No radiation discernible
1	Warm on face after 2–3 minutes
2	Unbearable on the face after more than 2 minutes
3	Immediate burning sensation
	Air Movements
-2	Cold strong air movements
-1	Cold light air movements
0	No air movements
1	Warm light air movements
2	Warm strong air movements

	Physical Work Load
0	Office work: easy, low muscular constraints, occasional movements at normal speed
1	Moderate work with arms or legs: use of heavy machines, steadily walking
2	Intense work with arms and trunk: handling heavy objects, shoveling, woodcutting, walking rapidly, or while carrying a heavy load
3	Very intense work at high speed: stairs, ladders
	Clothing
0	Light, flexible, not interfering with the work
1	Long, heavier, interfering slightly with the work
2	Clumsy, heavy, special for radiation, humidity or cold temperatures
3	Special overalls with gloves, hoods, shoes
	Opinions of the Workers
-3	Shivering, strong discomfort for the whole body
-2	Strong local discomfort; overall sensation of coolness

-1	Slight local cool discomfort
0	No discomfort
1	Slight sweating and discomfort; thirst
2	Heavy sweating, strong thirst, work pace modified
3	Excessive sweating, very tiring work, special clothing

Module 5: Lighting

This module asks about lighting characteristics of the work area. This module should be completed for each work area.

5.0 Input a name for the work area you are currently evaluating:

____

5.1 Are all of the light sources working? Yes / No

5.2 Are LED lights used for overhead lighting everywhere? Yes / No

If yes, proceed to question 5.4

If no, proceed to next question

Are fluorescent bulbs used? Yes / No

Does flicker exist? Yes / No

Are all light fixtures clean (e.g., free from dirt/paint)? Yes / No

Are light sources provided with shades or glare shields? Yes / No

Is additional lighting provided in areas with high spillage and near bagging equipment? Yes / No

Is additional lighting provided in passageways and entrances/exits? Yes / No

By asking workers, how should current lighting be changed?

Increase amount of light (brighter)

Decrease amount of light (less bright)

Current levels of light do not need to be changed

By asking workers, do current sources of light create shadows or glare that interfere with task performance or safety? Yes / No

By asking workers, do workers look from bright to dark places routinely? Yes / No

Which types, if any, of portable lighting are used? Choose all that apply:

Flashlight or other hand-held light

Head lamp

Standing/floor lamp

No portable lighting used

If A, proceed to next question

If B or C, proceed to question 5.14

If D, proceed to Module 6

By asking workers, do hand-held lighting sources need to be held when walking up/down stairs, walking on inclined walkways, climbing or descending ladders or while holding other objects? Yes / No

By asking workers, do workers experience any difficulties handling portable light sources due to the size or weight of the lighting equipment? Yes / No

Module 6: Mobile Equipment

This module asks about mobile equipment (such as fork lifts) that may be present in bagging areas.

6.1 Is mobile equipment (e.g., bobcat, forklift, backhoe) used indoors in areas with foot traffic?   Yes / No

6.2 Are propane cylinders stored and rechargeable mobile equipment charged in well-ventilated areas?   Yes / No

6.3 Are pre-shift inspection reports always reviewed by someone other than the driver before the mobile equipment is put into operation each shift?

Yes

No

Only if there is a problem

Does the operator have the option to not drive a piece of mobile equipment due to a safety concern which did not cause the vehicle to be out of service?   Yes / No

Does anyone other than a mechanic have the authority to put a truck back into service? Yes / No

Are drivers required to set the parking brake whenever parking the truck?   Yes / No

Do operators always physically immobilize (e.g., use wheel chocks) mobile equipment when parking?   Yes / No

SMALL BAG MODULES

This series of modules asks about the characteristics of small bag filling stations.

Module 7: Filling

This module should be completed for each small bag filling station.

7.0 Input a name for the small bag filling station you are currently evaluating:

____

7.1 Part 1: Where are empty bags located relative to the worker when worker is facing filling spout? a. Behind

To the side

In front

Part 2: What is the height of the stack of empty bags at the filling station (measured from the surface the worker is on to the middle of the stack)?

If worker is *seated,* choose one of the following:

below elbow level

between elbow and chest level

above chest level

If worker is *standing*, choose one of the following:

below 30 in

between 30 and 50 in

above 50 in

Are there obstructions that influence posture for any worker (e.g., guardrail that causes worker to bend to reach filling spout: (Figure A4)? Yes / No

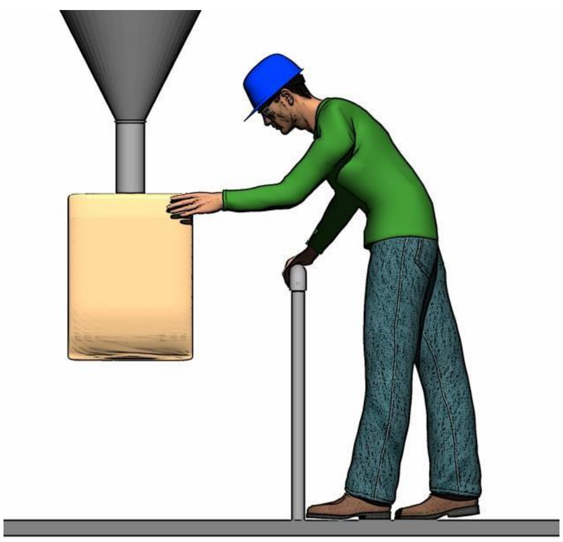


Figure A4. The guardrail is an obstruction. The worker must lean forward to place the bag on the spout. If the standing surface were closer to the spouts, the worker may not need to bend over as far and the guardrail could be modified to prevent the worker from falling onto the conveyor.

How are bags supported during filling?

By the filling machine

Manually held by the worker

7.4 How is the filling machine activated?

Hand button or switch

Footswitch or pedal

Automatically

7.5 How often are pinch or wide finger grips observed during bag filling (e.g., Figure A5)?

a. Rarely

Sometimes

Frequently

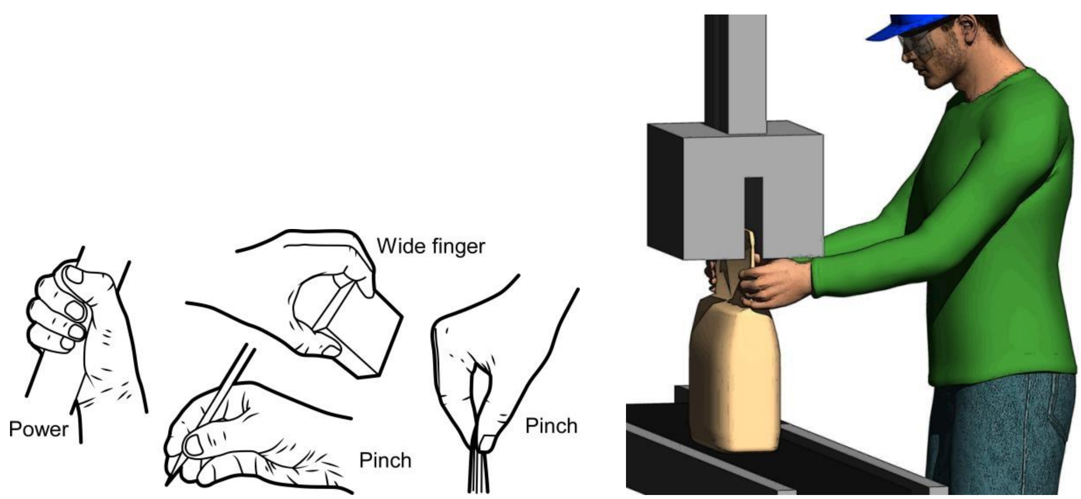


Figure A5. Types of hand grips (left) and example of pinch grip (right).

7.6 How often is wrist bending or deviating observed during bag filling (e.g., Figure A6)?

a. Rarely

Sometimes

Frequently

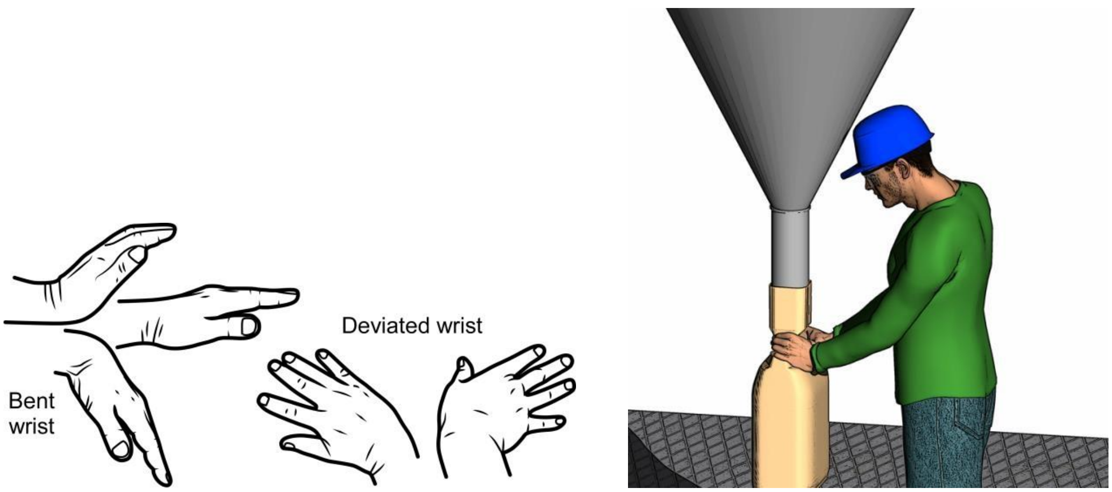


Figure A6. Types of wrist postures (left). Wrist bending and deviating (right).

Module 8: Weighing

This module should be completed for each small bag weighing station.

8.0 Input a name for the small bag weighing station you are currently evaluating:

____

8.1 What is the highest height of the hands when placing bag on or taking bag off scale (measured from the surface the worker is standing on to the highest height of the middle knuckle, Figure A8)? Fill in the blank: Height: _______

8.2 If the weight is not within tolerance, what action is performed?

Product added to or taken out of bag

Bag and product discarded or recycled

No change to filled bag

Module 9: Sealing

This module asks about characteristics of the sealing process such as methods and worker posture. This module should be completed for each small bag sealing station.

9.0 Input a name for the small bag sealing station you are currently evaluating:

____

9.1 How is the bag sealed?

Manual process such as rolling or folding the top of the bag

Semi-automatic process such as manually feeding the bag through the sealing machine or using a sealing machine that requires manual control

9.2 Part 1: Is sealing performed standing or sitting?

Standing

Sitting

Part 2: What is the highest height of the hands when sealing is performed (measured to the highest position of the middle knuckle, Figure A8). *If the worker is standing*, measure from the surface the worker is standing on (e.g., Figure A7); *if the worker is sitting*, measure from the seat of the chair. Fill in the blank: Height: ___ in

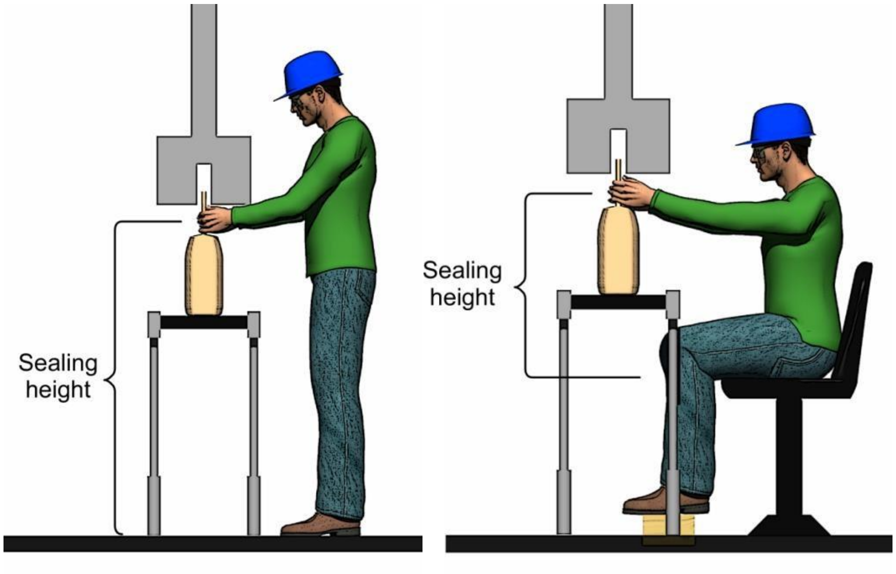


Figure A7. When the worker is standing, the height of the hands is measured from the surface the worker is standing on to the highest position of the middle knuckle when performing the sealing

task. If the worker is sitting, the height is measured from the seat of the chair the worker is sitting on to the highest position of the middle knuckle.

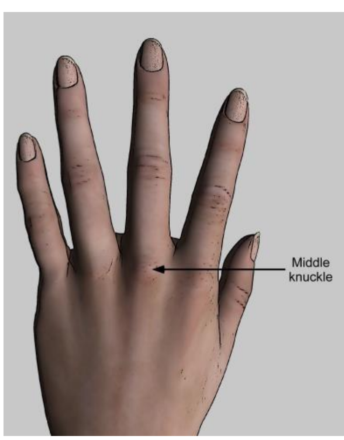


Figure A8. The middle knuckle is the knuckle between the middle finger and the back of the hand.

Does the worker support the weight of the bag during the sealing process? Yes / No

How often is a pinch or wide finger grip observed during bag sealing (e.g., Figure A9)? a. Rarely

Sometimes

Frequently

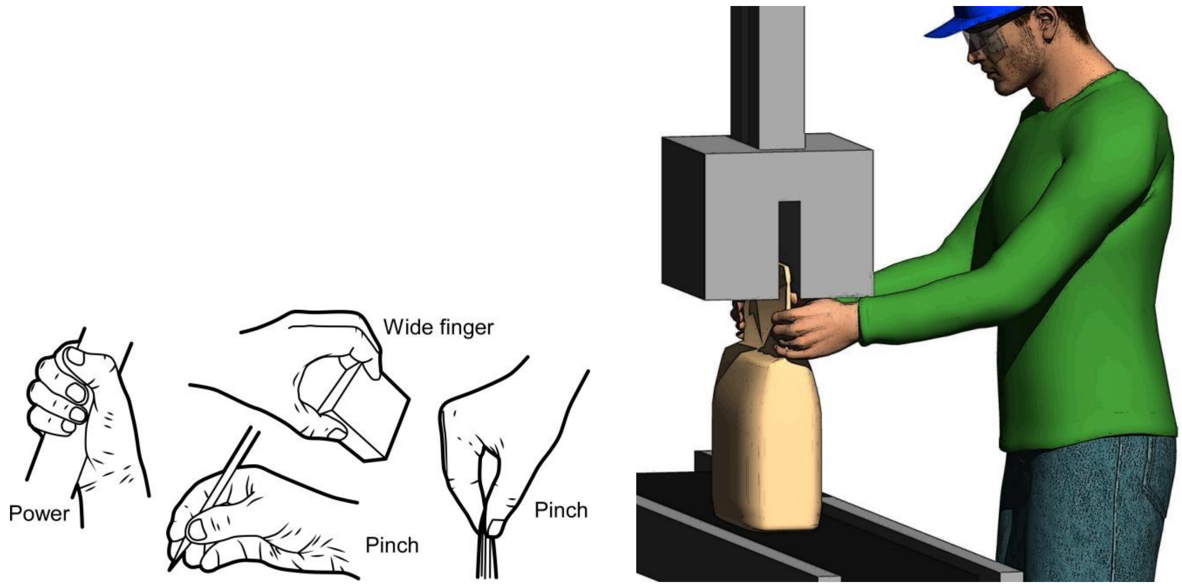


Figure A9. Types of hand grips (left) and example of pinch grip during sealing (right).

9.5 How often is wrist bending or deviating observed during bag sealing (e.g., Figure A10)? a. Rarely

b. Sometimes or Frequently

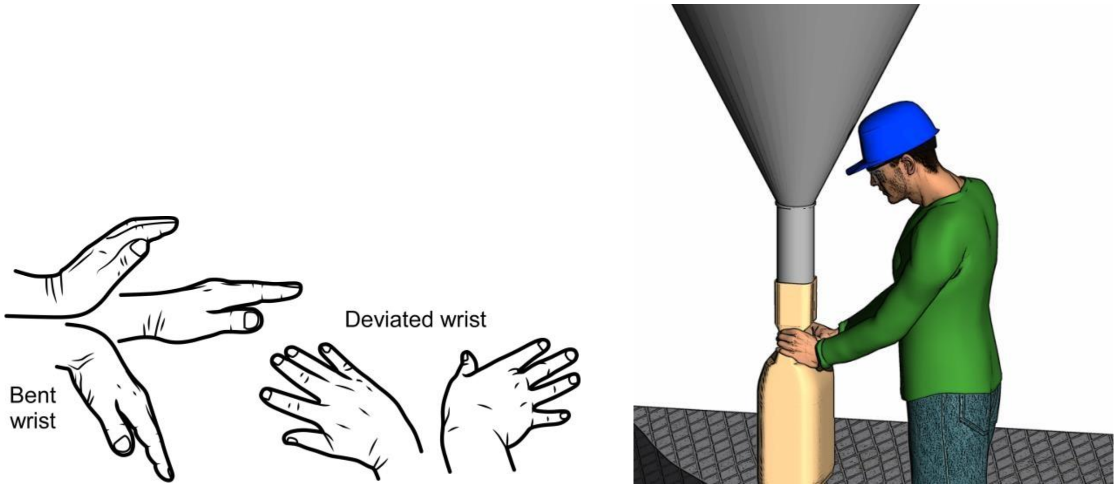


Figure A10. Types of wrist postures (left). Wrist bending and deviating during sealing (right).

Module 10: Palletizing

This module asks questions about the characteristics of palletizing such as pallet dimensions and worker posture. This module should be completed for each small bag palletizing station.

10.0 Input a name for the small bag palletizing station you are currently evaluating: _______________

10.1 Part 1: Which most closely describes the palletizing station?

Bags are stacked on a single pallet on the ground

Bags are stacked on a raised surface such as a stack of pallets

Bags are stacked on a pallet that is on surface with adjustable height such as a lift table

Part 2: What is the height of the lowest and highest bag on a full pallet (measured from the surface the worker is standing on to the middle of the bag; e.g., Figure A11)? Fill in the blanks:

Lowest height: ______ in Highest height: _____ in

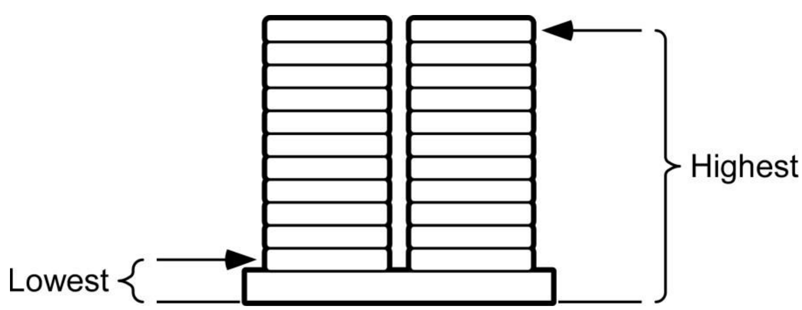


Figure A11. Lowest and highest bag measurement guidelines: Measure from the surface the worker is standing on to the center of the bag after it is placed on the pallet. Ensure that

measurements of the bags are taken at the height they are loaded (e.g., if a lift table is used, the lowest and highest height may be the same).

10.2 How are empty pallets positioned for loading?

Mechanically (e.g., forklift)

Manually

What is the highest height of the hands when lifting bags from the conveyor (measured from the surface the worker is standing on to the middle knuckle of the highest hand when lifting the bag; e.g., Figure A12)? Fill in the blank: Height: _______ in

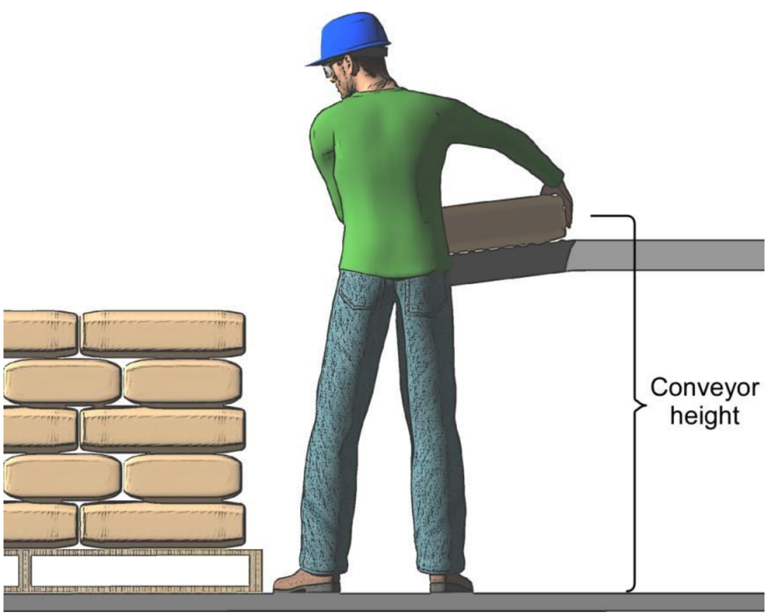


Figure A12. Bag height is measured from the surface the worker is standing on to the middle knuckle of the highest hand.

Relative to the worker's forward facing direction when retrieving bags from the conveyor, where is the pallet located? If multiple workers perform palletizing, evaluate the position for each worker.

Choose all that apply:

In front of worker (Figure A13 and Figure A14)

To the side of worker (Figure A15 and Figure A16)

Behind worker (Figure A17)

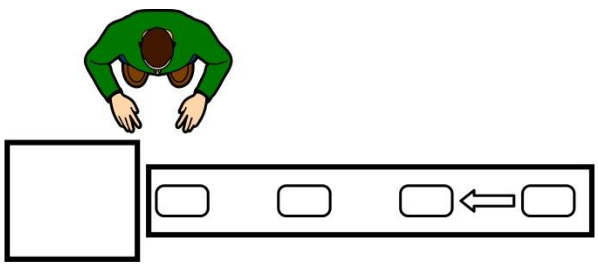


Figure A13. Pallet is in front of worker.

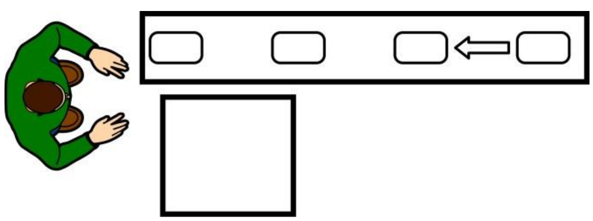


Figure A14. Pallet is in front of worker.

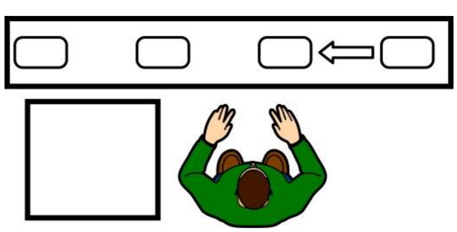


Figure A15. Pallet is to the side of worker.

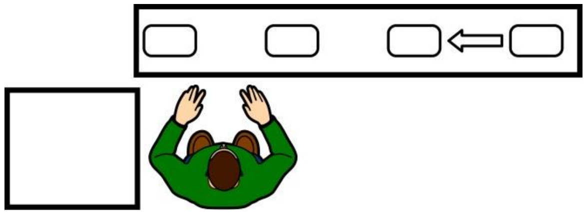


Figure A16. Pallet is to the side of worker.

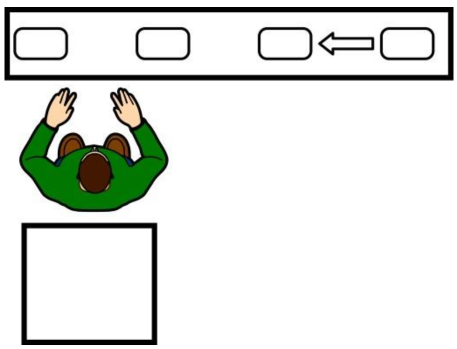


Figure A17. Pallet is behind worker.

Is a turnable lift table used (e.g., Figure A18)?   Yes   /   No

Figure A18. Turnable lift table. This style of table rotates and lowers as bags are placed on it.

Is a vacuum hoist or other lift-assist tool always used for lifting the bags?   Yes   /   No

Do workers ever slide bags while on the conveyor before they are lifted?   Yes   /   No

Are there barriers or objects that prevent the worker from keeping the bags close to the body when lifting or placing the bags (e.g., Figure A19)?   Yes   /   No

Figure A19. The pallet can be a barrier, requiring reaching away from the body to place the bag (left). The bag should be kept close to the body during all parts of the lifting/lowering process (right).

Is a corner frame or backboard used when palletizing (e.g., Figure A20)? Yes / No

If yes: proceed to next question

If no, proceed to question 10.11

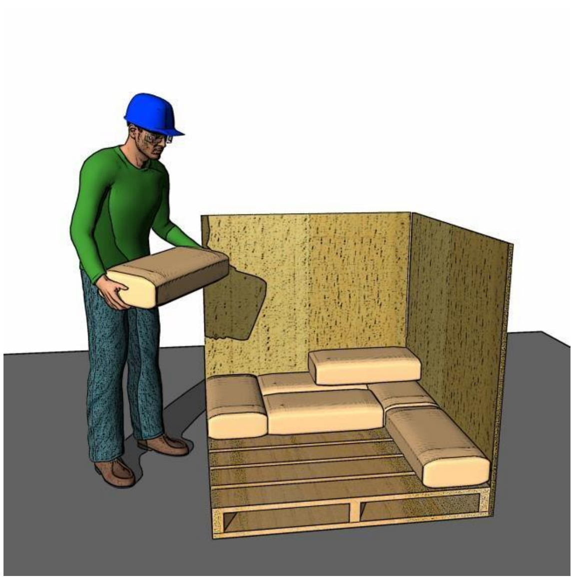


Figure A20. Corner frame used for palletizing.

Do workers ever bend their back or reach with their arms while palletizing? Yes / No

How often is wrist bending or deviating observed during palletizing (e.g., Figure A21)? a. Rarely

b. Sometimes or Frequently

Figure A21. Types of awkward wrist postures (left), wrist bent (middle), wrist bent and deviated (right).

10.12 How often are pinch or wide finger grips observed during palletizing (e.g., Figure A22)? : a. Rarely

b. Sometimes or Frequently

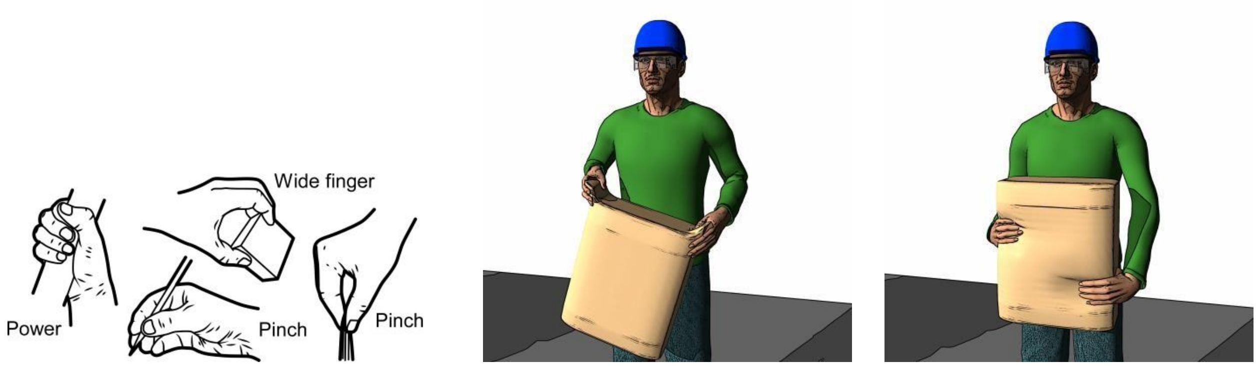


Figure A22. Types of awkward hand grips (left), pinch grip (middle), wide finger grip (right).

BULK BAG MODULES

This series of modules asks about the characteristics of bulk bag filling stations.

Module 11: Hanging, Opening, and Filling

The module asks about attaching empty bulk bags to the filling station and the filling procedures. This module should be completed for each bulk bag filling station.

11.0 Input a name for the bulk bag filling station you are currently evaluating:

____

11.1 How are empty pallets moved into position for loading?

Mechanically (e.g., forklift)

Manually

Pallet not used under bulk bag

What are the lowest and highest heights of empty bags (measured from the surface the worker is standing on)? Fill in the blanks: Lowest height: _____ in Highest height:______ in

Part 1: What is the height of the hooks/forks on which the bags are hung for filling (measured from the surface the worker is standing on; e.g., Figure A23)? Fill in the blank: Height: _____ in

Part 2: What is the highest height of the hands when attaching the bag to the filling spout (measured from the surface the worker stands on to the highest position of the middle knuckle; Figure A8)? Fill in the blank: Height:_____ in

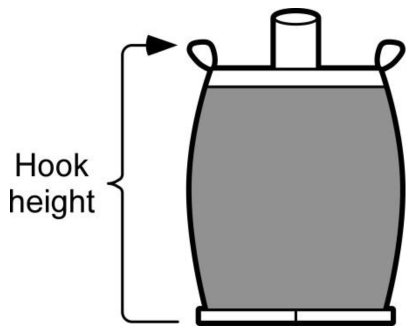


Figure A23. Height of hooks is measured from the surface the worker stands on to the top of the hooks.

Part 1: How is the bag secured to the filling spout (e.g., Figure A24)?

Hook

Clamp

Tension cord

Air bladder

Not secured

Other

Part 2: Does the bag ever separate from the filling spout during filling? Yes / No / NA

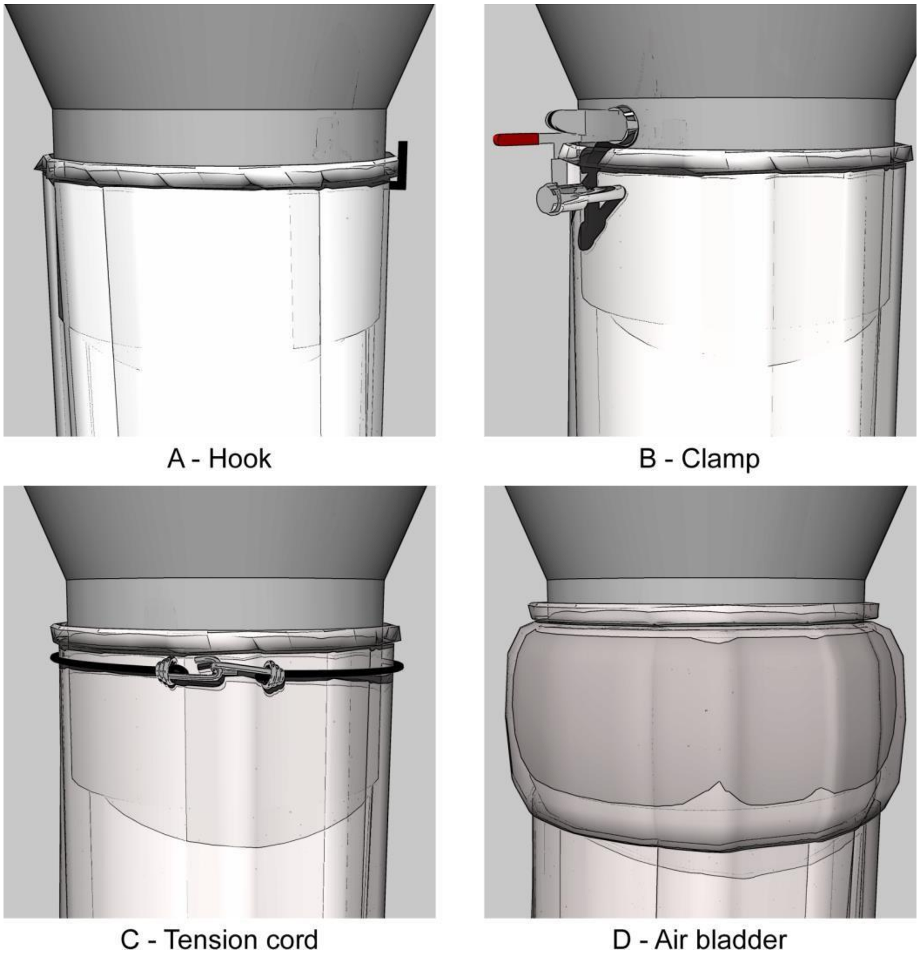


Figure A24. Methods of securing bag to filling spout.

11.5 Is the bag filled with air automatically by the filling machine prior to filling? Yes / No

If yes, proceed to question 11.7

If no, proceed to next question

11.6 How is the bag opened prior to filling?

Manually (e.g., bottom corners of bag spread apart)

With a tool (e.g., broom used to spread out bottom corners from inside bag, leaf blower used to fill bag with air)

Bag not opened prior to filling

11.7 How is filling of the bag controlled?

Automatic release/stoppage (e.g., push button or foot pedal)

Manual release/stoppage (e.g., hand lever)

11.8 Why are bags adjusted during the filling process?

Choose all that apply:

Bags are adjusted to prevent folds in the bag

Bags are adjusted because product isn't evenly filling bag

Bags are adjusted due to placement on the pallet

Bags are not adjusted during filling process

Module 12: Closing and Sealing

This module asks about how the bulk bags are closed and sealed after filling. This module should be completed for each bulk bag closing/sealing station.

12.0 Input a name for the bulk bag closing/sealing station you are currently evaluating: ___________

12.1 What is the highest position of the hands as the bags are closed/sealed (measured from the surface the worker is standing on to the highest position of the middle knuckle during closing/sealing)? Fill in the blank: Height: ______ in

If 42 in ≤ height ≤ 57 in and answered yes to 1.2.1: proceed to next question 12.2

If height < 42 in or height > 57 in and answered yes to 1.2.1: proceed to next question

If 42 in ≤ height ≤ 57 in and answered no to 1.2.1: proceed to question 12.3

If height < 42 in or height > 57 in and answered no to 1.2.1: proceed to question 12.3

Does the worker close the liner separately from closing the outer bag? Yes / No

Which of the following closure techniques is used for the bag and/or liner (Figure A25)?

Choose all that apply:

Snaking (the bag/liner is gathered, twisted, and sealed)

Flowering (the bag/liner is gathered in the center and sealed)

Other

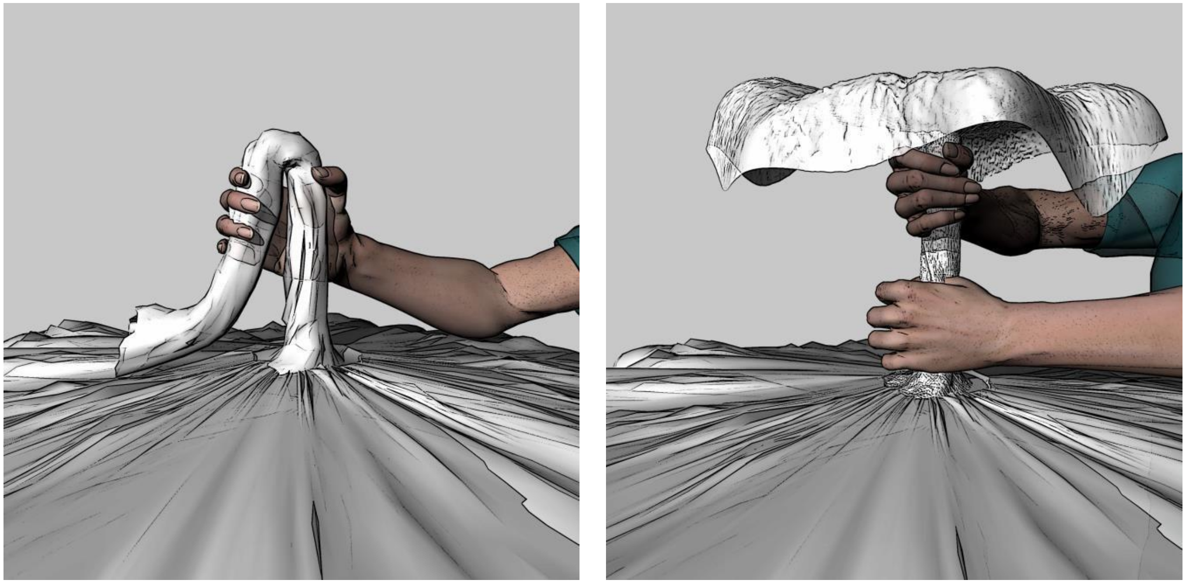


Figure A25. Snaking the liner of a bag (left) and flowering the liner (right).

12.4 How is the bag and/or liner sealed (e.g., Figure A26)?

Choose all that apply:

Manual cable or wire ties

Cable tie gun

Pneumatic cable tie gun

Wire tie twist tool

Cord or B-lock

Drawstring or string

Other

Not sealed

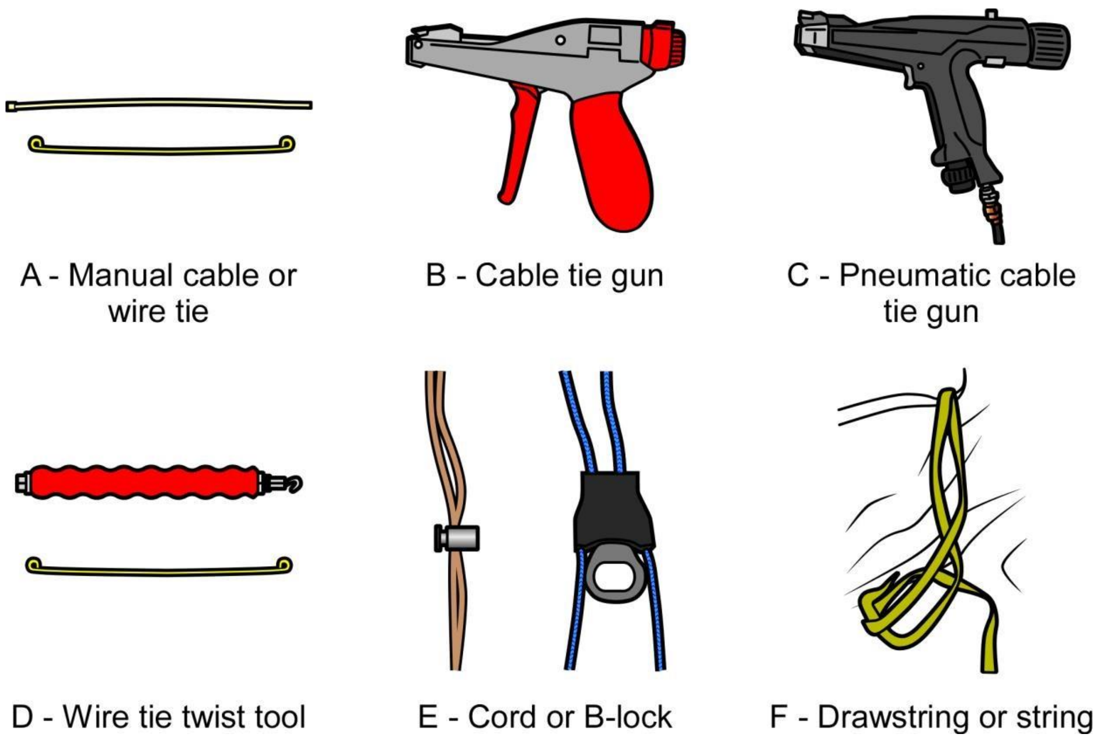


Figure A26. Methods of sealing bulk bags.

SMALL AND BULK BAGS

The following module is applicable to small and bulk bagging wrapping stations.

Module 13: Stretch and Shrink Wrapping

This module asks questions about procedures and tools for stretch- or shrink-wrapping pallets. This module should be completed for each wrapping station.

13.0 Input a name for the wrapping station you are currently evaluating:

____

13.1 Do you stretch wrap or shrink wrap pallets?

Choose all that apply: a. Stretch wrap

b. Shrink wrap

If A, proceed to next question

If B, proceed to question 13.3

13.2 Which most closely resembles the tool used for stretch wrapping (Figure A27)?

Stretch wrap held by hand

Stretch wrap held by end caps (hand savers)

Extended core

Mechanical brake (j-tool)

Pole wrapper

Portable stretch wrapper

If you did not answer B to 13.1, end bagging audit

If you did answer B to 13.1: proceed to question 13.3

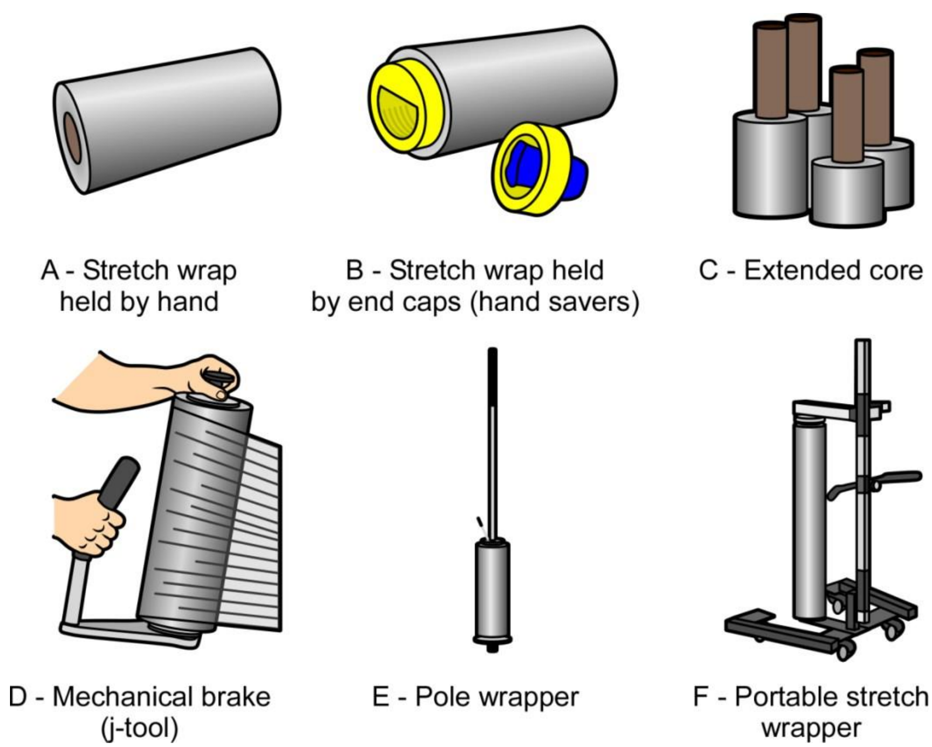


Figure A27. Tools used for stretch wrapping.

Are awkward arm or back postures used when applying shrink wrap (e.g., arms reaching up or to the side, back bending or twisting; e.g., Figure A28)? Yes / No

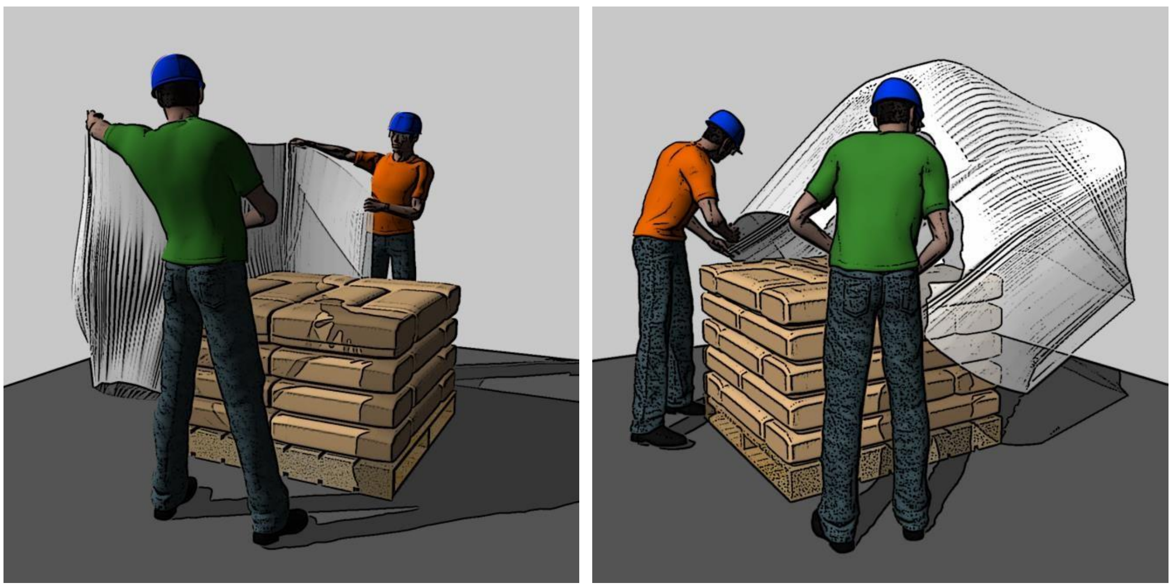


Figure A28. Awkward postures during shrink wrapping: workers' arms are reaching at or above shoulder (left), worker in back is bending and twisting back to the side (right).

What is the source of the heat used?

Gas/propane

Electricity

If A, proceed to next question

If B, end bagging audit

13.5 Does the worker ever move the gas tank?

Yes, worker carries gas tank

Yes, worker uses rolling cart to move gas tank

No

13.6 Does the gas tank need to be moved while shrink wrapping a single pallet?

Yes, worker carries gas tank

Yes, worker uses rolling cart to move gas tank

No, gas tank has a long enough gas line to stay in one place

Bagging Audit Recommendations

Module 1: Bagging Operation Characteristics

- (Bag Q 1.1.6 yes) You indicated that bag failures occur. Bag failures increase waste and increase manual handling of bags, which can increase the risk of injuries. If the source of bag breakage cannot be identified, consider discussing bag breakage with your manufacturer to determine if any changes need to be made to the bag to reduce breakage.
- (Bag Q 1.1.7 a) You indicated that bag failures occur during filling. Bag failures may be caused by the product being dispensed too quickly, or by the filling valve coming into contact with the bag and breaking/tearing it. Adjust the dispensing speed and/or valve placement if this is the cause of your bag failures. If you are using perforated bags, consider instead using airflow extensible craft paper. This type of paper is porous and does not need perforations, which can reduce the strength of bags and increase the risk of bag breakage.
- (Bag Q 1.1.7 b) You indicated that bag failures occur during transportation along the conveyor. Identify and eliminate sharp edges or other areas that may be breaking or tearing bags.
- (Bag Q 1.1.7 c) You indicated that bag failures occur during weighing. Ideally, weighing should be incorporated into the filling station or conveyor (e.g., inline scale) to eliminate the need to manually handle the bags to weigh them. If this is not

possible, ensure that bags are carefully transported onto the nearby scale (ideally the scale should be within a few steps) and that the scale has a smooth clean surface.

- (Bag Q 1.1.7 d) You indicated that bag failures occur during sealing. Bag failures may be occurring due to improper functioning of the sealing machine, which can be corrected with proper inspection and maintenance. If the sealing machine is working properly, ensure that workers are carefully prepping bags for the sealing machine, and that the conveyor belt has a smooth clean surface.

- (Bag Q 1.1.7 e) You indicated that bag failures occur during palletizing. Bag failures can be caused by nails or splinters on the pallet, which can be reduced by using a protective sheet (e.g., cardboard sheet) over the pallet before bags are loaded. Further, throwing or dropping bags onto pallets increases the potential for bag breakage. Palletizing at an optimal height (around 30 in from the floor) will reduce the need for throwing or dropping bags onto the pallet.

- (Bag Q 1.1.7 f) You indicated that bag failures occur during storage. Ensure that bags are stored separately from other work areas in a clean environment, that they are covered, and that they are not in the way of foot traffic or mobile equipment. In addition, ensure that stored bags are protected from water, as this can damage the structural integrity of the bags and lead to bag breakage, particularly for paper bags.

 (Bag Q 1.2 no) You indicated that bulk bags are not used in your facility. Ask your customers if they are amenable to receiving the product in bulk bags instead of small bags. Using bulk bags instead of small bags reduces manual handling of bags and can greatly reduce injury risk to bagging personnel.

 (Bag Q 1.2.1 yes) You indicated that liners are used inside bulk bags. Consider if liners are necessary or if a bag without a liner or a different bag material can be used to eliminate the need for a liner. Contact the bag manufacturer for more information on bag types and liner choices to determine if it would be appropriate to package your material without a liner. If a liner is necessary, consider using a thinner liner and a spout or cone top bag (Figure A29); these bags have less material than a duffle/open top bag and may have reduced physical demands when closing the liner.

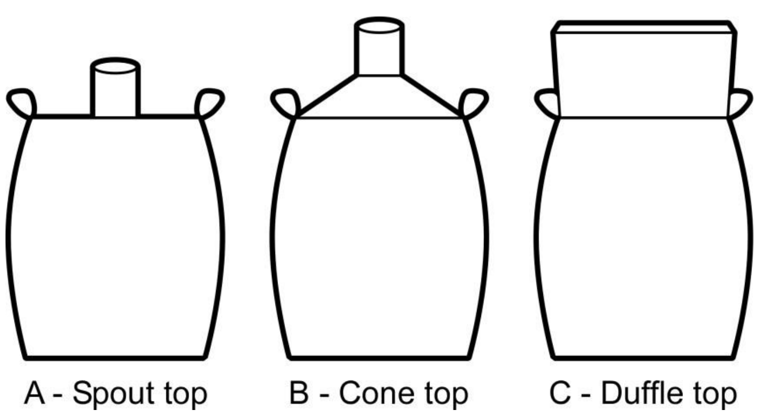


Figure A29. Types of bag tops.

 (Bag Q 1.2.2 no or sometimes) You indicated that the liner is not always attached to the bulk bag. Some attachment of the liner is preferable; an unattached liner can require awkward back and shoulder postures to spread the liner out in addition to spreading out the bag.

 (Bag Q 1.2.3 b) You indicated that you use a cone top bulk bag. Consider if the extra space at the top of a cone top is needed for even bag filling (Figure A30). If a cone top bag is not needed, consider using a spout top bag. Using a cone top bag increases the height of the top of the bag where it attaches to the filling spout. This increases the reach required by the arms, which can increase the risk of arm/shoulder injury.

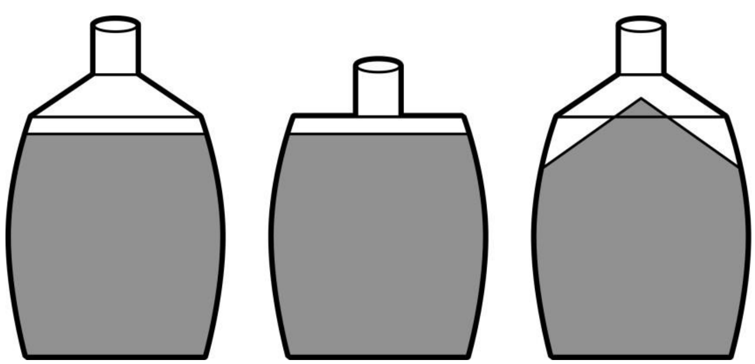


Figure A30. If the top of the product is flat during filling, the extra material at the top of the cone top bag is not filled and is unnecessary (left); product properly fills spout-top bag (center). A cone-top bag is only needed if the product piles in the center during filling (also referred to as having a high angle of repose, right).

- (Bag Q 1.2.3 c) You indicated that you use a duffle or open-top bulk bag. Consider using a spout or cone-top bag; these types of bags can be helpful in reducing dust exposure and may be easier to close. When choosing between a spout and cone-top bag, consider how the product piles when poured. A cone-top bag is only needed if the product piles in the center during filling (Figure A30). If the product stays flat on top during filling, a spout-top bag is appropriate.
- (Bag Q 1.4 no) You indicated that workers do not rotate between tasks (e.g., driving fork lift, palletizing, bagging). Rotating between tasks every few hours is recommended as it allows workers to reduce the duration of repetitive tasks. If it is not possible to rotate between tasks, consider having workers involved in palletizing rotate between sides of the pallet.

Module 2: Personal Protective Equipment

- (Bag Q 2.1 yes) You indicated that respirators are required for bagging activities. Whenever respirators are required, mines must establish a respirator program. For more information on controlling dust, see NIOSH's Dust Control Handbook (http://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/2012-112.pdf) and the National Industrial Sand Association's Occupational Health Program for Exposure to Crystalline Silica (http://www.sand.org/Silica-Occupational-Health-Program).

Whenever respiratory protective equipment is used, a program for selection, maintenance, training, fitting, supervision, cleaning, and use shall meet the following minimum requirements:

(a) Only respirators approved by NIOSH under 42 CFR § 84 which are applicable and suitable for the purpose intended shall be furnished and used in accordance with training and instruction. (b) The program shall be consistent with the requirements of ANSI Z88.2-1969, published by the

American National Standards Institute and entitled "American National Standards Practices for

Respiratory Protection ANSI Z88.2-1969." This publication may be obtained from the American National Standards Institute, http://www.ansi.org, or at https://law.resource.org/pub/us/cfr/ibr/002/ansi.z88.2.1992.pdf. It also may be examined in any Metal and Nonmetal Mine Safety and Health District Office of the Mine Safety and Health Administration. A brief outline of the ANSI standard is below.

Respirator protection programs should be administered by an individual having sufficient knowledge of the subject to properly supervise the program. Standard operating procedures must be written and cover respirator selection and respirator use. Respirator protection programs should include:

Employee training – must cover employees and supervisors

Nature of hazard and why protection is needed

Engineering controls

Respirator selection use, capabilities, and limitations

Fit Testing. Performed for each employee using a respirator. Should include a written record of:

Name of employee tested

Date of testing

Respirator manufacturer, model, style, and size

Fit test protocol and name of person administering test

Fit test results

Respirator cleaning and disinfecting

Cleaning and disinfecting respirators on a regular basis or after each use if shared.

Employees should get a new disposable respirator if theirs becomes unusable, unsanitary, or makes breathing difficult.

Respirator Storage. Convenient, clean, and sanitary storage.

Respirator Inspection. Respirators should be inspected before and after each use and during cleaning.

No written record of inspections are needed.

Any deficiencies found during inspections must be corrected.

Surveillance. Work area must be checked to ensure respirator use, monitor conditions, and employee exposure.

Program evaluation. The respiratory protection program must be evaluated regularly.

The MSHA inspector will evaluate the effectiveness of the respiratory protection in order to determine whether miners are protected from overexposure. Respiratory protection programs are evaluated in terms of proper selection, fit testing, training, cleaning, sanitizing, and maintenance of respirators.

Be aware that wearing a respirator may increase the risk of heat strain and fatigue. Any mask reduces work capacity to some degree, and it is important to reduce the pace of work and increase rest breaks accordingly.

Care and Use:

Respirators should be stored in a clean place where they will not be exposed to dust.

Respirators should be inspected for cracks, tears, punctures, etc. before each use. Additionally, seal checks should be performed on respirators before each use. Supervisors should be notified and respirators replaced if the respirator does not seal properly.

If your respirators use cartridges, make sure they are not expired and that they protect you for the correct environment you are entering.

Respirators are to be cleaned and maintained according to manufacturer’s instructions.

○ Bandanas, kerchiefs, headbands, or any objects that interfere with the seal must be removed before wearing a respirator, and workers must be clean shaven where the respirator's facial seal contacts the worker's face

See MSHA tips for using respiratory protection in mining:

http://www.msha.gov/illness_prevention/ideas/respirator.htm.

 (Bag Q 2.1 no) You indicated that respirators are not required for bagging activities. The 30 CFR § 56/57.5001(a) requires that a miner's exposure shall not exceed the permissible limit of any substance on the threshold limit value (TLV) list. When the TLV is exceeded, 30 CFR §

56/57.5005 mandates that operators install all feasible engineering controls to reduce a miner's exposure to the TLV. Respiratory protection is required when controls are not feasible, as well as when establishing controls, and during occasional entry into hazardous atmospheres to perform short-term maintenance or investigations.

If workers furnish their own respirators, they need to take precautions to be sure that the respirator itself does not present a hazard. See list below for guidelines for care and use of respirators.

Care and Use:

Respirators should be stored in a clean place where they will not be exposed to dust.

Respirators should be inspected for cracks, tears, punctures, etc. before each use. Additionally, seal checks should be performed on respirators before each use. Supervisors should be notified and respirators replaced if the respirator does not seal properly.

If your respirators use cartridges, make sure they are not expired and that they protect you for the correct environment you are entering.

Respirators are to be cleaned and maintained according to manufacturer’s instructions.

Bandanas, kerchiefs, headbands, or any objects that interfere with the seal must be removed before wearing a respirator, and workers must be clean shaven where the respirator’s facial seal contacts the worker’s face.

For organizations covered by OSHA, OSHA provides the following information:

Information for Workers Using Respirators When Not Required Under the Standard Taken from 29 CFR § 1910.134 Appendix D - (OSHA) Workers should:

Read and heed all instructions provided by the manufacturer on use, maintenance, cleaning and care, and warnings regarding the respirator’s limitations.

Choose respirators certified for use to protect against the contaminant of concern. The National Institute for Occupational Safety and Health (NIOSH) of the U.S. Department of Health and Human Services certifies respirators. A label or statement of certification should appear on the respirator or respirator packaging. It will tell you what the respirator is designed for and how much it will protect you.

Do not wear your respirator into atmospheres containing contaminants for which your respirator is not designed to protect against. For example, a respirator designed to filter dust particles will not protect you against gases, vapors, or very small solid particles of fumes or smoke.

Keep track of your respirator so that you do not mistakenly use someone else's respirator.

- (Bag Q 2.2 yes) You indicated that gloves are worn on the jobsite. Gloves can be beneficial in protecting workers, but may not be appropriate for all bagging tasks. If the task requires a high amount of dexterity (e.g., sewing), consider not wearing gloves for that task. If gloves can be worn while performing the task, ensure that the gloves fit workers’ hands snuggly. Gloves with a loose fit can reduce grip strength and dexterity, and can increase the possibility of gloves getting caught in equipment (e.g., sealing mechanism). It is also important to consider the type of task when choosing glove material. For bag handling tasks, ensure that the glove material provides sufficient grip and protection from the material being bagged. If heat sealing is used, consider heat-resistant gloves for sealing tasks. Ensure that gloves are well-maintained and replaced when any physical damage is visible.

- (Bag Q 2.2 no) You indicated that gloves are not worn on the jobsite. Consider providing gloves for workers. Wearing gloves can reduce the possibility of acute hand injuries (e.g., cuts/scrapes), and can protect workers' hands from exposure to chemicals and the drying effects of handling paper bags. However, gloves may not be appropriate for all bagging tasks. If the task requires a high amount of dexterity (e.g., sewing), consider not wearing gloves for that task. If gloves can be worn while performing the task, ensure that the gloves fit workers' hands snuggly. Gloves with a loose fit can reduce grip strength and dexterity, and can increase the possibility of gloves getting caught in equipment (e.g., sealing mechanism). It is also important to consider the type of task when choosing glove material. For bag handling tasks, ensure that the glove material provides sufficient friction and protection from the material being bagged. If heat sealing is used, consider heat-resistant gloves for sealing tasks. Ensure that gloves are well-maintained and replaced when any physical damage is visible.

Module 3: Work Posture

□ (Bag Q 3.1 a) You indicated that standing is the posture used for the task. Prolonged standing requires more energy and muscular effort and can lead to back and knee pain. Allowing workers to change postures frequently, by providing a sit/stand workstation, lean stand, or adding foot rests (Figure A31), can help unload these joints and reduce the stresses associated with prolonged standing.

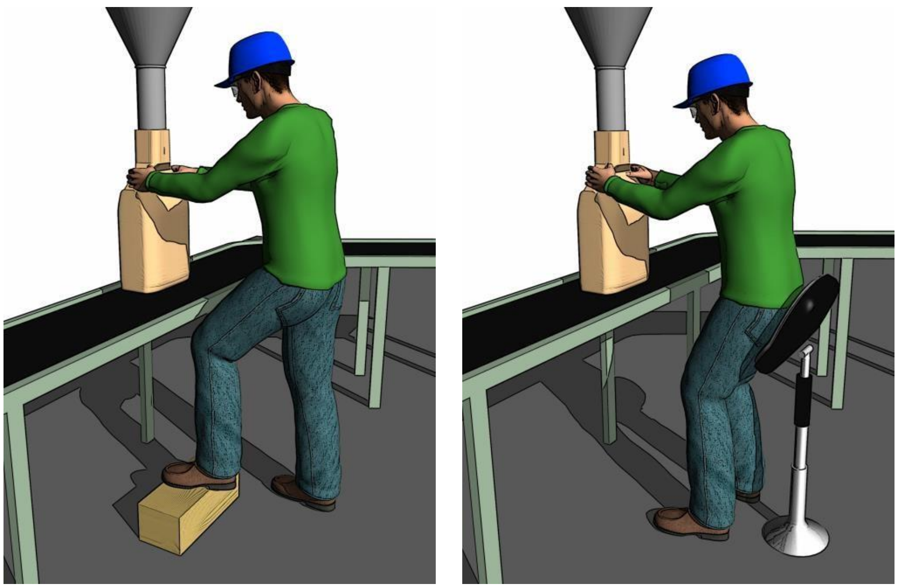


Figure A31. Possible solutions to prolonged standing postures: foot rest (left) and lean stand (right).

□ (Bag Q 3.1 b) You indicated that sitting is the posture used for the task. Ideally sit/stand workstations should be used to allow workers to change postures frequently and reduce the stresses associated with prolonged sitting. Seated workstations constrain posture and do not allow for much movement, which contributes to injury risk. Further, seated workstations can require awkward arm and back postures to handle objects. To reduce these awkward postures, objects should be positioned so that workers can handle them at their side or to their front.

Occasional reaches beyond this range are permissible, but should be minimized.

- (Bag Q 3.2 a) You indicated that the worker is on a hard floor surface. If the worker is standing on a hard surface, a slip-resistant, anti-fatigue mat can be helpful in reducing stress on the body and increasing blood flow to the leg muscles, which can reduce fatigue. Be sure that mats are secured to the floor and do not create a tripping hazard. Also anti-fatigue insoles may provide additional comfort for workers, and should be considered especially if the floor surface does not easily allow for securing a mat to the floor.
- (Bag Q 3.2 b) You indicated that the worker is on a cushioned floor surface. If a cushioned mat is used, be sure that it is secured to the floor and does not create a tripping hazard. Anti-fatigue

insoles may provide additional comfort for workers, and should be considered especially if the floor surface does not easily allow for securing the mat to the floor.

 (Bag Q 3.2 c) You indicated that the worker is on a mix of hard and cushioned floor surfaces. Consider adding slip-resistant, anti-fatigue mats to hard surfaces. Be sure that mats are secured to the floor and do not create a tripping hazard. Anti-fatigue insoles may provide additional comfort for workers, and should be considered especially if the floor surface does not easily allow for securing a mat to the floor.

 (Bag Q 3.3 a) You indicated that the worker sits on a fixed seat for the task. Ideally, the seat should be sliding or swivel to reduce bending and reaching required by the worker. If a fixed seat is used, all objects handled should be directly in front or slightly to the side of the worker (e.g., Figure A32), and all controls should be located such that the worker does not have to bend or stretch to use controls.

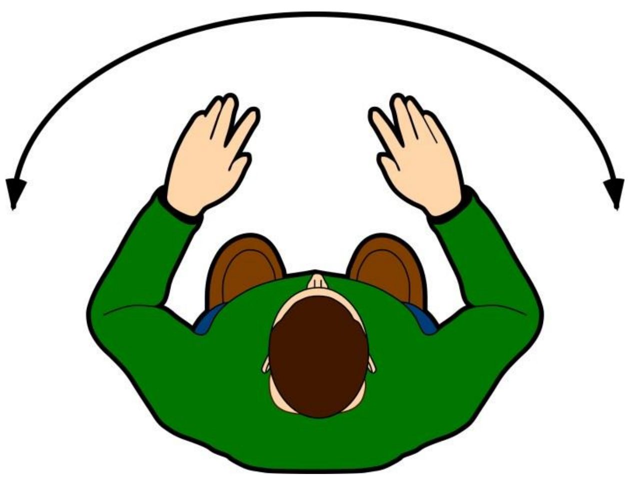


Figure A32. If a fixed seat is used, ensure that all objects handled frequently are within easy reach of the arms (within the area shown by the line).

- (Bag Q 3.3 b) You indicated that the worker sits on a sliding/swivel seat for the task. Ensure that the sliding/swiveling mechanism is maintained so that it doesn’t require unnecessarily high effort to operate (e.g., forcefully pushing off to slide or heavy twisting to swivel).

- (Bag Q 3.4 no) You indicated that the worker is not able to rest their feet comfortably with near 90˚ angles at the hips and knees. Ensure that workers’ chairs are at a height that allows for approximately 90˚ angles at the hips and backs of the knees (Figure A33) and that feet are supported comfortably; consider using an adjustable footrest if needed. Seats should have height adjustability so that each worker can modify the seat to assume the correct posture while sitting. If feet do not comfortably reach the floor, blood circulation and nerve sensations may be reduced resulting in numbness or pain (Figure A34 left). If necessary, provide a foot support

(bar, platform, or footstool). Further, if the workers’ seat is too close to the floor, excessive strain can be placed on the knees and hips (Figure A34 right).

Figure A33. Worker is sitting with the hips and knees at the same level. Both the hips and knees are at approximately 90˚ angles and the feet are supported.

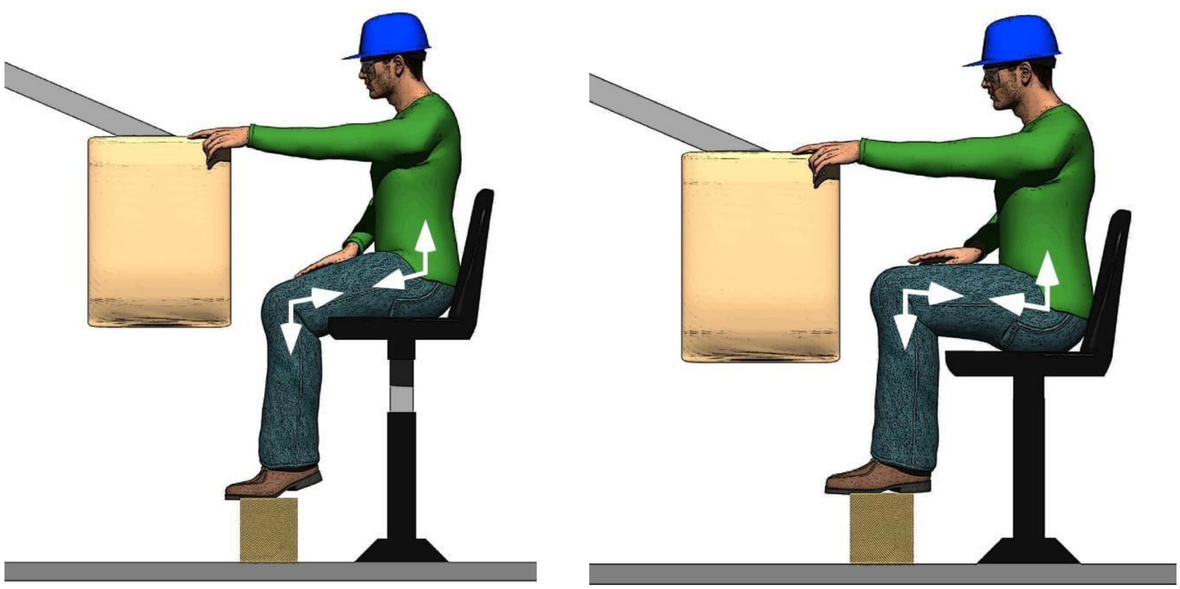


Figure A34. Worker is sitting too far from the foot support, resulting in the knee being below the hip and greater than 90˚ angles at the hips and knees (left); worker is sitting too close to the foot support, resulting in the knees being above the hips and less than 90˚ angles at the hips and knees (right).

 (Bag Q 3.5 b) You indicated that the seat condition is fair/poor. Consider replacing or repairing the seat or seat cover. A seat in poor condition may no longer provide proper body support and can lead to discomfort.

Module 4: Work Environment

 (Bag Q 4.1 yes) You indicated that work is performed outdoors during the summer months. During summer months, the risk of heat stress and heat exhaustion can be higher than the risk during the rest of the year. Heat stress and heat exhaustion can be hard to detect and are often detected too late. Prevention is essential to ensure workers remain healthy while working in high heat. MSHA provides seven key recommendations for preventing heat stress in workers.

Arrange for miners who are to be exposed to heat stress to have a medical examination by a physician prior to assignment. Be sure that the physician is informed of the heat exposure so as to make the proper evaluation.

Allow new workers in heat exposure a period of 5 to 6 workdays to become acclimatized by gradually increasing workload and exposure time during this period. Start by allowing new workers to work only 50% of regular work time in the heat. Check at the end of the 6workday period to see how they are doing.

Schedule rest periods during the work shift as necessary to avoid severe strain among acclimatized workers. Schedule the heaviest work, particularly manual labor, for the cooler parts of the shift if possible.

Ensure that workers wear lightweight, loose-fitting clothing for protection against the sun and to allow for air circulation, and a hard hat with sun protection (e.g., consider a hard hat with a longer brim to offer more sun protection).

Consider using air-conditioning inside the cabs of heavy equipment and ventilating and circulating fans, where appropriate. Provide shelters for protection against the sun during rest periods.

Supply adequate quantities of drinking water, cooled if possible, and salt tablets to workers for their use as desired. Providing salt can help ensure workers maintain appropriate balance of electrolytes.

Plan in advance to ensure that first-aid treatment for heat ailments is available, as well as transportation for medical treatment, if necessary. Workers should be allowed frequent rest breaks to remove them from the heat and rehydrate. Air-conditioned recovery areas are recommended. However, when this isn't feasible, a shaded area with airflow may be used. Hydration and rest are needed more frequently when working in high heat.

- (Bag Q 4.3 no) You indicated that workers are not provided portable heat sources. Provide heat sources for employees. Adding additional layers of clothing may help to retain body heat but is likely to reduce flexibility and range of motion; therefore, providing heat sources is the most appropriate solution.

- (Bag Q 4.4 Air temperature < -1) You indicated an air temperature below the acceptable range. Provide heating sources for employees. Adding additional layers of clothing may help to retain body heat but is likely to reduce flexibility and range of motion; therefore, providing heat sources is the most appropriate solution.

- (Bag Q 4.4 Air temperature > 1) You indicated an air temperature above the acceptable range.

Heat stress and heat exhaustion can be hard to detect and are often detected too late. Prevention is essential to ensure workers remain healthy while working in high heat. MSHA provides seven key recommendations for preventing heat stress in workers.

Arrange for miners who are to be exposed to heat stress to have a medical examination by a physician prior to assignment. Be sure that the physician is informed of the heat exposure so as to make the proper evaluation.

Allow new workers in heat exposure a period of 5 to 6 workdays to become acclimatized by gradually increasing workload and exposure time during this period.

Start by allowing new workers to work only 50% of regular work time in the heat. Check at the end of the 6-workday period to see how they are doing.

Schedule rest periods during the work shift as necessary to avoid severe strain among acclimatized workers. Schedule the heaviest work, particularly manual labor, for the cooler parts of the shift if possible.

Ensure that workers wear lightweight, loose-fitting clothing for protection against the sun and to allow for air circulation, and a hard hat with sun protection (e.g., consider a hard hat with a longer brim to offer more sun protection).

Consider using air-conditioning inside the cabs of heavy equipment and ventilating and circulating fans, where appropriate. Provide shelters for protection against the sun during rest periods.

Supply adequate quantities of drinking water, cooled if possible, and salt tablets to workers for their use as desired. Providing salt can help ensure workers maintain appropriate balance of electrolytes.

Plan in advance to ensure that first-aid treatment for heat ailments is available, as well as transportation for medical treatment, if necessary. Workers should be allowed frequent rest breaks to remove them from the heat and rehydrate. Airconditioned recovery areas are recommended. However, when this isn't feasible, a shaded area with airflow may be used. Hydration and rest are needed more frequently when working in high heat.

☐ (Bag Q 4.4 Humidity <- 1) You indicated humidity levels below the acceptable range. Low humidity allows the body to cool through sweating but may have drying effects on the skin and eyes which can cause discomfort. Air mists can be provided to add some moisture to the air, making it more comfortable for workers in hot, dry areas. Not only will the air mists increase the humidity in the air, but they will also provide a cooling effect by cooling the air in the working area.

(Bag Q 4.4 Humidity > 1) You indicated humidity above the acceptable range. In addition to high air temperatures, outdoor workers are exposed to radiant heat from the sun, and sometimes high humidity as well. High humidity reduces heat loss from the body by evaporation of perspiration (sweat), the main avenue of heat loss in hot environments. In general, increased air velocity or movement increases the cooling effects of sweating. When reducing the humidity isn't possible, increasing the air velocity through fans may improve cooling of the body when air temperatures are less than 93° F.

- (Bag Q 4.4 Thermal radiation > 1) You indicated thermal radiation above the acceptable range. Provide a means to deflect radiation heat, such as sunlight or artificial light sources, away from workers through reflective shades or screens. Whenever possible, move work to a shaded area. Work scheduling may also need to be adjusted to ensure workers are not working in areas with high sun exposures during peak times (e.g., midday). This work should be scheduled earlier in the morning or later in the evening.

- (Bag Q 4.4 Air movements < -1) You indicated cold air movement above the acceptable range. Provide a means to reduce these cold air current through deflection. Add tarps over working areas when needed and provide a means to heat the area. Wind chill can affect the health and safety of workers even at temperatures above freezing and should be mitigated through heat sources and wind protection. MSHA provided the following chart with recommendations regarding cold weather working conditions (Table A2. Wind Chill Factor ChartError! Reference source not found.).

Table A2. Wind Chill Factor Chart

WIND CHILL FACTOR CHART

Wind Speed (m.p.h.)	Actual Temperature Reading (°F)									
	50F	40F	30F	20F	10F	0F	-10F	-20F	-30F	-40F
Calm	50	40	30	20	10	0	-10	-20	-30	-40
5	48	37	27	16	6	-5	-15	-26	-36	-47
10	40	28	16	4	-9	-21	-33	-46	-58	-70
15	36	22	9	-5	-18	-36	-45	-58	-72	-85
20	32	18	4	-10	-25	-39	-53	-67	-82	-96
25	30	16	0	-15	-29	-44	-59	-74	-88	-104
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109
35	27	11	-4	-20	-35	-49	-67	-82	-98	-113
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116
	NO WORK RESTRICTIONS Little potential danger (for properly clothed person)				RESTRICTED WORK Increasing Potential Danger (Danger from freezing of exposed flesh)			RESTRICED WORK Great Potential Danger		

NOTE: Wind speed over 40 mph has little added effect.

- (Bag Q 4.4 Air movements > 1) You indicated hot air movement above the acceptable range. Provide a means to reduce these hot air currents through deflection. Add tarps over working areas when needed and provide a means to cool the area.

- (Bag Q 4.4 Physical work load > 2) You indicated physical work load above the acceptable range for employee's thermal comfort. In these working conditions fatigue may occur quickly. Environmental factors should be modified to be within a comfortable range to ensure worker health and safety at this level of physical exertion. Thermal Working Conditions scores should be between -1 and +1 for air temperature, humidity, thermal radiation, air movements, clothing, and opinions of workers.

- (Bag Q 4.4 Clothing > 1) You indicated a clothing score above the acceptable range. Many jobs require specialized clothing to protect workers from their hazards. However, specialized clothing can also become hazardous when it doesn't allow for natural cooling through the evaporation of sweat, is bulky and limits flexibility, or has an overall ill fit. Selection of suitable, moisture wicking, and properly sized clothing is essential to ensure proper functionality of specialized clothing and to reduce the risks of the clothing becoming its own hazard.

(Bag Q 4.4 Worker opinion < -1) You indicated that workers feel the environment is too cold. Care should be taken to ensure that workers are provided necessary heating sources, protection from wind chill, and suitable cold weather clothing. Thermal Working Conditions scores should be between -1 and +1 for air temperature, humidity, thermal radiation, and air movements.

 (Bag Q 4.4 Worker opinion > 1) You indicated that workers feel the environment is too hot. Care should be taken to ensure that workers are provided necessary cooling sources, hydration, reduction in sun exposure, and rest breaks. Also, clothing should be suitable for working in hot environments. Thermal Working Conditions scores should be between -1 and +1 for air temperature, humidity, thermal radiation, and air movements.

Module 5: Lighting

- (Bag Q 5.1 no) You indicated that not all light sources are working. Properly illuminating work and travel areas is important to ensure worker safety. Replace all nonworking light sources as soon as possible.
- (Bag Q 5.2 no) You indicated that LEDs are not used for overhead lighting everywhere. Using cool-white LEDs can reduce glare for older workers in low-light conditions. Additionally, due to their long-life and associated decrease in maintenance requirements, using LEDs can reduce the potential for maintenance-related accidents that result from replacing spent bulbs/lamps in lighting systems.
- (Bag Q 5.4 yes) You indicated that flicker exists. Exposure to flicker can contribute to worker discomfort, headaches, and impaired visual performance. To ensure that lighting does not impair worker safety or health, replace the flickering bulbs or repair the light fixture to eliminate the flicker.
- (Bag Q 5.5 no) You indicated that light fixtures are not clean. Bulbs should be cleaned regularly so that they output the full amount of light, and should be inspected regularly to ensure that they are staying clean.
- (Bag Q 5.6 no) You indicated light sources are not provided with shades or glare shields. Glare can impair vision and cause discomfort for workers, which can reduce

task performance and safety. All light sources should have shades or glare shields to protect workers.

- (Bag Q 5.7 no) You indicated that additional lighting is not provided in areas with high spillage or near equipment. To improve hazard identification and detection, increase the light levels near walking areas and equipment, especially where there is a high chance of debris and contaminants accumulating. A minimum of 20 lux is recommended. Light meters can be purchased to measure lux levels. When adding lighting, ensure that it does not create glare for workers (e.g., do not aim light directly in workers' line of sight, use a glare shield).
- (Bag Q 5.8 no) You indicated that additional lighting is not provided around entrances/exits. It is important to consider the transition of light levels, especially in entrances to enclosed spaces from outside. A slow transition in lighting levels should be provided, allowing eyes to adapt to the changing light levels and reducing negative impacts on vision (e.g., sunlight from outdoors is likely much brighter than indoor light levels; providing extra lighting in the entrances/exits can reduce transition effects from going from brighter into darker areas). When adding lighting, ensure that it does not create glare for workers (e.g., do not aim light directly in workers' line of sight, use a glare shield).

(Bag Q 5.9 a) You indicated that the provided light is insufficient and workers would choose to increase the amount of lighting. Evaluate the work environment and consult workers to determine specific areas that are in need of additional lighting. When adding lighting, ensure that it does not create glare for workers (e.g., do not aim light directly in workers' line of sight, use a glare shield). If portable lighting is added, ensure that it does not interfere with task performance or safety (e.g., if the worker needs both hands for the task, provide portable lighting that does not need to be held).

- (Bag Q 5.9 b) You indicated that the provided light is more than sufficient and that workers would choose to decrease the amount of lighting. Evaluate the work environment and consult workers to determine specific areas that need decreased lighting. When removing lighting, ensure that the remaining light sources evenly illuminate the work environment (e.g., ensure that shadows are not created). Ensure that the placement of the light sources is not the cause of the lighting problem. Lighting should not be mounted at eye level or in the workers direct line of sight.
- (Bag Q 5.10 yes) You indicated workers report that shadows or glare are present that interfere with task performance or safety. Evaluate the work environment and consult workers to determine specific areas that have shadows or glare. Where shadows are present, consider redirecting current light sources to more evenly illuminate the area, or consider adding additional light sources to cover areas that are shadowed. Where glare is present, consider redirecting the light sources to eliminate

the glare (e.g., ensure that light sources are not in the line of sight of workers) and ensure that all lights have shades or glare shields.

- (Bag Q 5.11 yes) You indicated that workers look from bright to dark places routinely. Transitioning from bright to dark lighting can impair vision, and therefore can reduce task performance and safety. Ensure that lighting within a work area is consistent, and that no glare or shadows are being created from current light sources. Consider adding or removing additional lighting, such as adding or removing task lighting (e.g., mounted lights near the task, head lamps) to make light levels more consistent.
- (Bag Q 5.13 yes) You indicated that hand-held lighting sources need to be held while walking or while holding other objects. Holding a light source while walking or holding other objects can decrease safety by increasing the risk of falling (e.g., worker might not be able to maintain three points of contact on stairs) or dropping objects. Wherever possible, provide sufficient ambient lighting so that portable lighting is not needed. If it is not possible to increase the ambient lighting, consider using head lamps instead of hand-held lighting. Ensure that additional light sources do not create shadows or glare (e.g., do not aim light directly in workers' line of sight, use a glare shield).

 (Bag Q 5.14 yes) You indicated that workers experience difficulties handling portable light sources due to the size or weight of lighting equipment. Wherever possible, provide sufficient ambient lighting that portable lighting is not needed. If it is not possible to increase ambient lighting and the worker primarily works in one area, consider providing floor lamps or the means to suspend light sources (e.g., hook or strap suspended from ceiling or attached to wall, magnetic attachments to attach lights to equipment). If the worker travels between areas frequently, consider providing lightweight headlamps. This will decrease the amount of manual handling needed to use light sources. Ensure that additional light sources do not create shadows or glare (e.g., Do not aim light directly in workers' line of sight, use a glare shield).

Module 6: Mobile Equipment

- (Bag Q 6.1 yes) You indicated that mobile equipment is used indoors in areas with foot traffic. Ensure proper visibility is given in these areas. Add domed mirrors around corners to ensure the workers can see mobile equipment traffic. Also, implement a process for providing other signals for mobile equipment in areas with corners and passageways (e.g., add a colored flashing light to mobile equipment in areas with high noise levels or where employees frequently wear hearing protection, honk horn when approaching corners and passageways in areas with low noise). If possible, paint mobile equipment travel lanes on the floor.
- (Bag Q 6.2 no) You indicated that propane cylinders are not stored and mobile equipment not recharged in well-ventilated areas. Ensure that adequate ventilation is provided, especially in areas where there are risks for air contamination with hazardous vapors and gases.
- (Bag Q 6.3 b or c) You indicated that pre-shift inspection reports are not reviewed by someone other than the operator before the mobile equipment is put into operation each shift. Pre-shift inspection reports with any issues of concern should always be reviewed by a shift foreman, a designated management official, or a mechanic prior to the mobile equipment being placed into operation each shift.
- (Bag Q 6.4 no) You indicated that the mobile equipment driver does not have the option to not drive the equipment due to a safety concern which did not cause it

to be out of service. All drivers should be given the option to not drive mobile equipment if they have concerns that it is unsafe.

- (Bag Q 6.5 yes) You indicated that someone other than a mechanic has the authority to put mobile equipment back into service. A mechanic should examine the mobile equipment to ensure all safety concerns raised by the driver on the pre-shift inspection report have been satisfactorily resolved and inform the shift foreman, maintenance supervisor, or designated management official who is responsible for returning the mobile equipment back into service. The authority to put mobile equipment back into service should only be held by the knowledgeable person responsible for making repairs to the mobile equipment.
- (Bag Q 6.6 no) You indicated that operators are not required to set the parking brake and physically immobilize mobile equipment when parking. Operators must set the vehicle to the park position and use parking brakes whenever parking per MSHA regulations (30 CFR §
56.14207).

- (Bag Q 6.7 no) You indicated operators do not always physically immobilize mobile equipment when parking. Operators should physically immobilize equipment, such as by using wheel chocks, every time a vehicle is parked. Even in situations of little to no grade, mobile equipment can unexpectedly move and cause injuries. When using wheel chocks on level ground, use at least one pair of chocks on one wheel (Figure A35). When using wheel chocks on a grade, ensure that at least one chock is used below the center of gravity of the vehicle on the downhill side of two separate wheels.

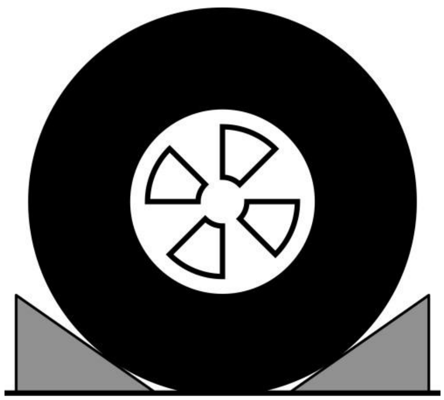


Figure A35. Correct placement of a pair of wheel chocks for level ground.

SMALL BAG MODULES

Module 7: Filling

- (Bag Q 7.1 part 1 is a and part 2 is d or f) You indicated that bags are stored behind workers and are at an unacceptable height. Bags should be stored in front of or to the side of the worker and should be around workers' elbow height (e.g.,
- Figure A36). Picking up a bag should not require twisting or bending of the back, and the arms should not have to fully extend or reach behind the body or above chest height (e.g., Figure A37). These postures can lead to increased risk of injury for the arms, shoulders, and back.

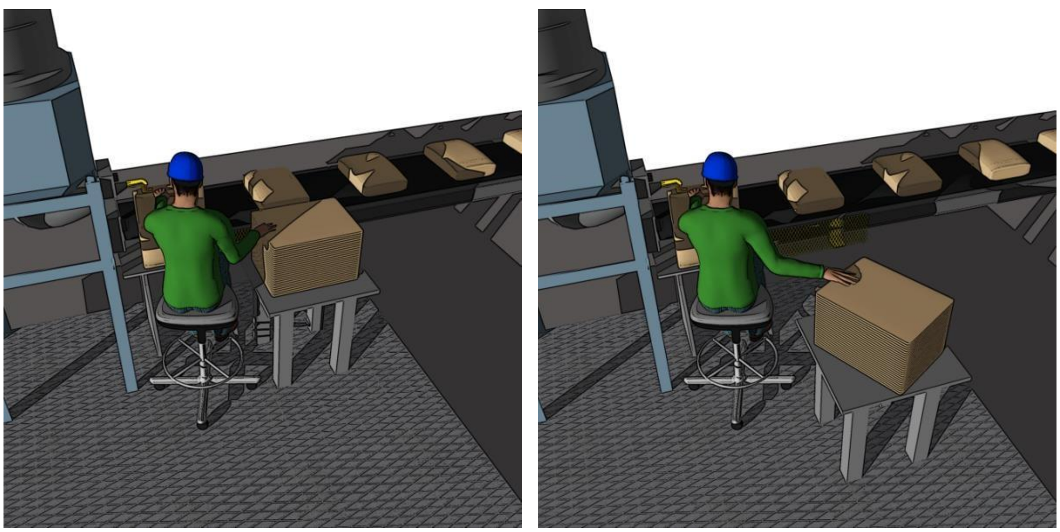


Figure A36. Bags are placed around elbow height and to the side of and close to the worker. Ideal bag placement is shown on the left, where the bag is close to the worker's side and slightly in front of the worker. This posture allows the worker to pick up bags without twisting/bending the back, or fully extending the arms. The placement shown on the right is not ideal; the worker is reaching slightly behind and must almost fully extend arm to reach the stack of bags.

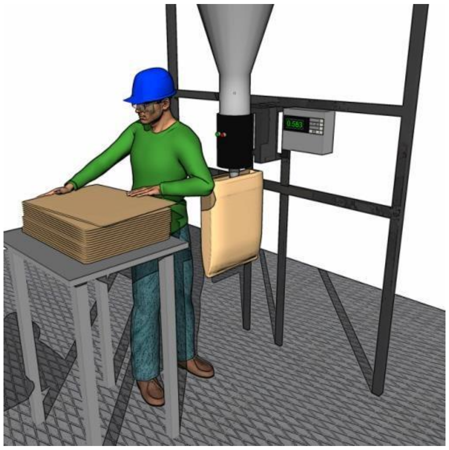


Figure A37. Bag placement behind the worker requires the worker to twist and reach behind to pick up empty bags.

☐ (Bag Q 7.2 yes) You indicated that there are obstructions that influence posture. Obstructions such as handrails, pallets, and supplies can force workers to adopt awkward postures, including reaching with the arms and bending with the back (Figure A38). Obstructions should be moved or modified in order to minimize awkward postures.

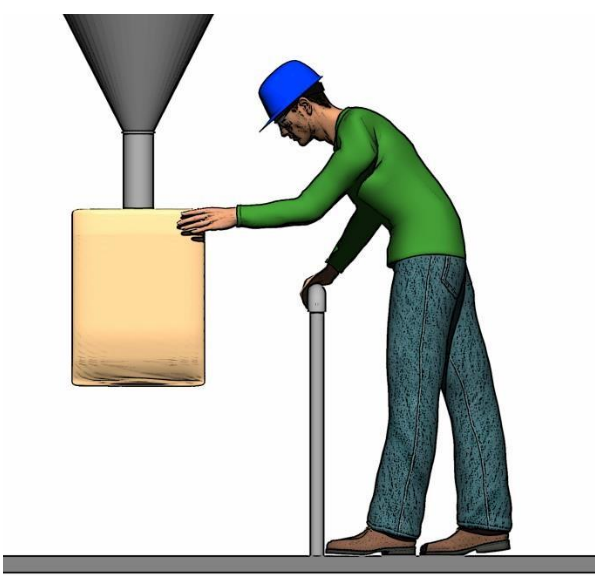


Figure A38. The guardrail is an obstruction. The worker must lean forward to place the bag on the spout. If the standing surface were closer to the spout, the worker may not need to bend over as far, and the guardrail could be modified to prevent the worker from falling onto the conveyor.

 (Bag Q 7.3 b) You indicated that bags are manually held by the worker during filling. Ideally, the worker should not need to support the bags during filling; consider installing a platform underneath the filling station or provide other means to support the weight of the bag during filling. This will reduce required muscular effort by the worker, and reduce the risk of injury.

 (Bag Q 7.4 a) You indicated that the filling machine is activated by a hand button or switch. Ideally, the filling station should be automated so that the filling automatically starts when a bag is placed on the spout (e.g., adding a small switch or sensor to the spout that is activated when the bag is placed on the spout). If this is not possible, consider using a footswitch. Workers who repeatedly press a button/switch to fill each bag may develop musculoskeletal disorders. Further, placement of the button may require awkward bending of the back and/or reaching of the arms that can increase risk of injury (Figure A39).

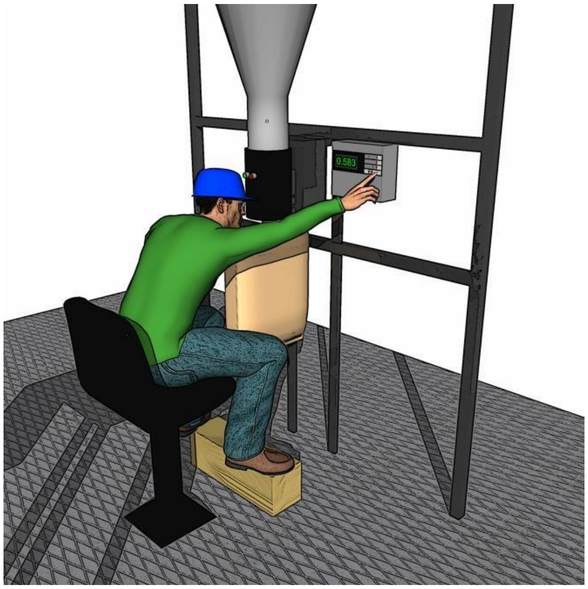


Figure A39. Location of controls requires worker to lean forward and reach with the arms, increasing injury risk for both the back and arms.

- (Bag Q 7.4 b) You indicated that the filling machine is activated by a footswitch or pedal. Ideally, the filling station should be automated so that the filling automatically starts when a bag is placed on the spout (e.g., adding a small switch or sensor to the spout that is activated when the bag is placed on the spout). Automatically starting the filling process will eliminate exposure to risk factors associated with manually pressing the footswitch/pedal.
- (Bag Q 7.5 b) You indicated that a pinch or wide finger grip occurs during filling. Prolonged use of these postures can cause inflammation and pain in the hands/fingers. Ideally the filling process should be automated to eliminate the need for manual handling of bags. If this is not possible, encourage workers to hold the bags with a neutral hand posture (straight wrist) or use a tool that requires a power grip.

☐ (Bag Q 7.6 b) You indicated that wrist bending or deviating occurs during filling. Prolonged wrist bending and deviation can cause inflammation and pain in the wrist, and may lead to repetitive trauma disorders such as carpal tunnel syndrome or tendonitis. Ideally, the filling process should be automated to eliminate the need for manual sealing of bags. If this is not possible, encourage workers to maintain a neutral (straight) wrist whenever possible.

Module 8: Weighing

☐ (Bag Q 8.1 height ≠ 30) You indicated that the hands are not at an ideal height when placing bags on or lifting bags off scale. Ideally, weighing should be incorporated into the filling station or conveyor (e.g., inline scale) to eliminate the need to manually handle the bags to weigh them. Reducing manual handling of bags will reduce the risk of injury for the back and arms. If this is not possible, ensure that the scale is located close to the work area (within a few steps) and that the middle knuckle is around 30 in from the ground when placing bags on scale and lifting bags off of scale; scale placement above or below this height can result in awkward arm and back postures to move the bag (e.g., Figure A40, left). A possible solution is to add a table to raise the height of the scale (Figure A40, right).

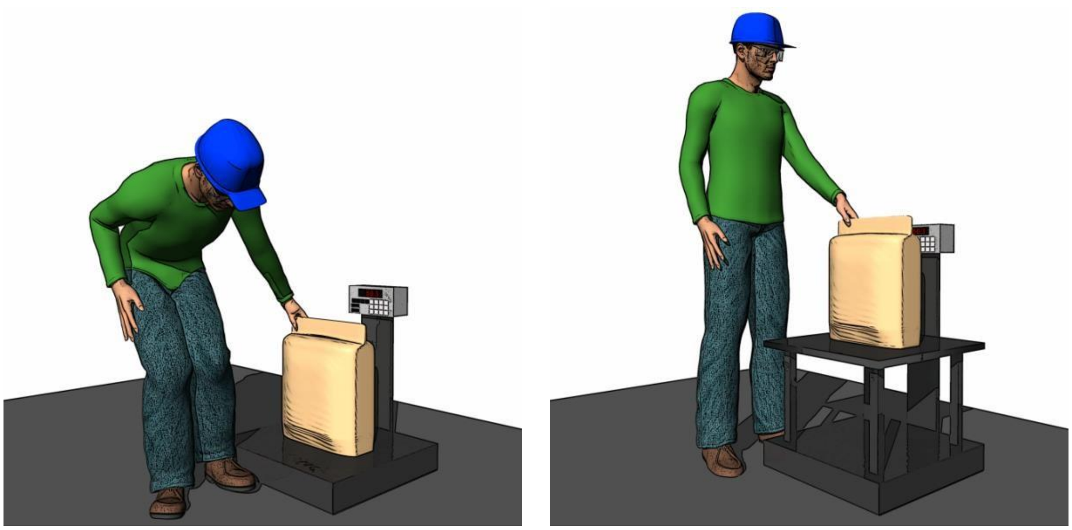


Figure A40. Scale placement on the ground requires worker to bend to pick up the bag from the scale (left). A table has been added on the scale to improve height and reduce bending required by workers (right).

- (Bag Q 8.2 a) You indicated that product is added or taken out of bag if the weight is not within tolerance. Small narrow shovels or trowels are useful for adding or removing product from bags through the spout openings. If bags have to be manually adjusted frequently, you may want to evaluate the filling station for recalibration.

- (Bag Q 8.2 b) You indicated that the bag and product are discarded or recycled if the weight is not within tolerance. Consider weighing the bag before sealing to enable adjusting the bag weight and avoid discarding bags. This can reduce waste of product and can reduce manual handling of rejected bags. If inline weighing is used, under or over weight should be diverted onto another conveyor line in order to reduce unnecessary handling of bags. If rejected bags need to be discarded, ensure that the dumpster (or other trash depository) is nearby and that the top of the dumpster is no higher than 70 in. Lifting bags above 70 in can increase the risk of worker injury.

- (Bag Q 8.2 c) You indicated that no change is made to filled bags if the weight is not within tolerance. Consider weighing the bags before sealing if this occurs frequently. This can prevent manual handling of unnecessarily heavy bags.

Module 9: Sealing

- (Bag Q 9.1 a) You indicated that bags are sealed using a manual process. Consider using selfsealing bags or sealing the bags through semi-automatic sewing or heat sealing. This will reduce repetitive motions during manual sealing.
- (Bag Q 9.1 b) You indicated that bags are sealed using a semi-automatic process. Consider automating the process to feed the bags through the sealing machine (e.g., a system that closes the bag and feeds it through a sealing device). If a hand-held tool is used to seal the bags, the tool should be supported from beneath, suspended from above, or mounted to support its weight while in use and eliminate the need for repetitive lifting. Ensure that the tool is stored around 30 in from the floor to eliminate unnecessary bending to access the tool, and that it is counterbalanced.
- (Bag Q 9.2 part 1 is a and part 2 height ≠ 42 OR part 1 is b and part 2 height ≠ 9) You indicated that sealing is performed at a nonideal height. To reduce the risk of injury, sealing should be performed at approximately elbow height (around 42 in above the ground when standing or 9 in above the seat of the chair when sitting).
- (Bag Q 9.3 yes) You indicated that the worker supports the weight of the bag during sealing. Supporting the bag can cause excessive strain on the hands and arms. Install a platform for the bags to rest on during the sealing process, or allow the sealing mechanism to move to the height of the supported bag.

- (Bag Q 9.4 b) You indicated that a pinch or wide finger grip occurs during sealing. Prolonged use of these postures can cause inflammation and pain in the hands/fingers. Ideally, the sealing process should be automated to eliminate the need for manual handling of bags. If this is not possible, encourage workers to hold the bags with a neutral hand posture (straight wrist) or use a tool that requires a power grip.
- (Bag Q 9.5 b) You indicated that wrist bending or deviating occurs during sealing. Prolonged wrist bending and deviation can cause inflammation and pain in the wrist, and may lead to repetitive trauma disorders such as carpal tunnel syndrome or tendonitis. Ideally, the sealing process should be automated to eliminate the need for manual sealing of bags. If this is not possible, encourage workers to maintain a neutral (straight) wrist whenever possible.

Module 10: Palletizing

☐ (Bag Q 10.1 part 1 is a and part 2 lowest < 10 or highest > 50) You indicated that bags are stacked onto a single pallet at an unacceptable height. All lifting should be done between 10 and 50 in, and as close to 30 in as possible. According to the revised NIOSH lifting equation, lifting capacity is highest at 30 in and decreases above and below this point; no lifting should be done above 70 in. For most people, lifting above or below 30 in can require back bending of more than 20 degrees and reaching with the arms above shoulder height, which increases risk of injury (Figure A41). The use of a lift table is recommended for palletizing tasks to keep the destination of the lifts as close to 30 in (near knuckle height, Figure A42) as possible. The lift table should be turnable, which will enable workers to reach all sides of the pallet without awkward reaching across the pallet, and self-leveling, which will eliminate the need to manually adjust the height of the lift table. If a lift table cannot be purchased, consider stacking several pallets on the floor to raise the height of the pallet being loaded. See Figure A42and Figure A43 for a recommended method for using stacked pallets.

 (Bag Q 10.1 part 1 is b and part 2 lowest < 10 or highest > 50) You indicated that bags are stacked on a raised surface at an unacceptable height. All lifting should be done between 10 and

50 in, and as close to 30 in (near knuckle height, Figure A42) a possible. According to the revised NIOSH lifting equation, lifting capacity is highest at 30 in and decreases above and below this point; no lifting should be done above 70 in. For most people, lifting above or below 30 in can require back bending of more than 20 degrees and reaching with the arms above shoulder height, which increases risk of injury (Figure A41). The use of a lift table is recommended for palletizing tasks to keep the destination of the lifts as close to 30 in as possible. The lift table should be turnable, which will enable workers to reach all sides of the pallet without awkward reaching across the pallet, and self-leveling, which will eliminate the need to manually adjust the height of the lift table. If a lift table cannot be purchased, consider stacking several pallets on the floor to raise the height of the pallet being loaded. See Figure A42, Figure A43, and Figure A44 for a recommended method for using stacked pallets.

- (Bag Q 10.1 part 1 is a or b and part 2 lowest ≥ 10 or highest ≤ 50) You indicated that bags are stacked at an acceptable range of heights. However, all lifting should be done as close to 30 in as possible. According to the revised NIOSH lifting equation, lifting capacity is highest at 30 in (near knuckle height, Figure A42) and decreases above and below this point. For most people, lifting above or below 30 in can require back bending of more than 20 degrees and reaching with the arms above shoulder height, which increases risk of injury (Figure A41). The use of a lift table is recommended for palletizing tasks to keep the destination of the lifts as close to 30 in as possible. The lift table should be turnable, which will enable workers to reach all sides of the pallet without awkward reaching across the pallet, and self-leveling, which will eliminate the need to manually adjust the height of the lift table. If a lift table cannot be purchased, see Figure A42, Figure A43, and Figure A44 for a recommended method for using stacked pallets.

- (Bag Q 10.1 part 1 is c and part 2 lowest $<$ 10 or highest $>$ 50) You indicated that bags are stacked on an adjustable-height surface at an unacceptable height. All lifting should be done between 10 and 50 in, and as close to 30 in (near knuckle height, Figure A42) as possible. According to the revised NIOSH lifting equation, lifting capacity is highest at 30 in and decreases above and below this point; no lifting should be done above 70 in. For most people, lifting above or below 30 in can require back bending of more than 20 degrees and reaching with the arms above shoulder height, which increases risk of injury (Figure A41). Ensure that workers know how to properly adjust the height of the lift table, and that it is adjusted such that bags are placed at approximately 30 in. The lift table should be turnable, which will enable workers to reach all sides of the pallet without awkward reaching across the pallet, and self-leveling, which will eliminate the need to manually adjust the height of the lift table.

 (Bag Q 10.1 part 1 is c and part 2 lowest ≥ 10 or highest ≤ 50) You indicated that bags are stacked on an adjustable-height surface at an acceptable range of heights. However, all lifting should be done as close to 30 in (near knuckle height, Figure A42) as possible. According to the revised NIOSH lifting equation, lifting capacity is highest at 30 in and decreases above and below this point. For most people, lifting above or below 30 in can require back bending of more than 20 degrees and reaching with the arms above shoulder height, which increases risk of injury (Figure A41). Ensure that workers know how to properly adjust the height of the lift table, and that it is adjusted such that bags are placed at approximately 30 in. The lift table should be turnable, which will enable workers to reach all sides of the pallet without awkward reaching across the pallet, and self-leveling, which will eliminate the need to manually adjust the height of the lift table.

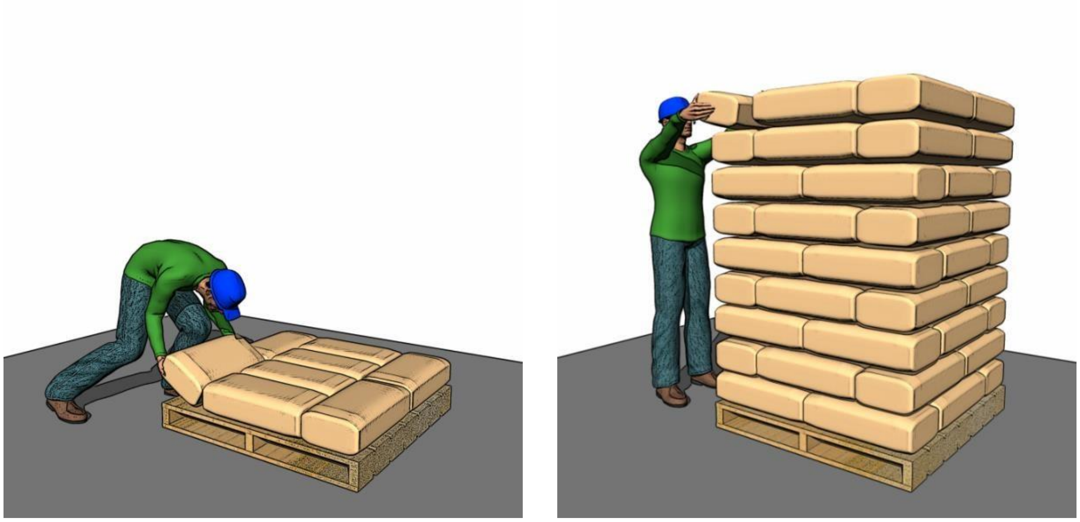


Figure A41. Awkward back and arm postures during palletizing: back bending forward (left), arm reaching forward with elbow raised above chest height (right).

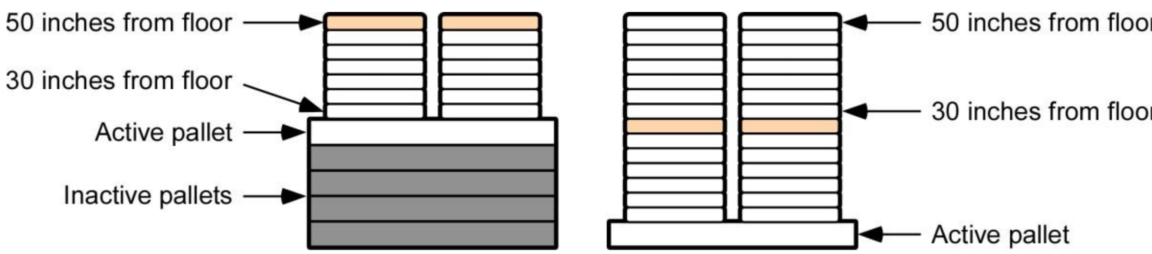


Figure A42. Method for using stacked pallets to improve postures during palletizing when a lift table is not possible. Step 1: Use 4 inactive pallets (shaded gray) to raise the height of the active pallet that is loaded so that the height of the first layer of bags is around 30 in. Load the active pallet until the top layer of bags is around 50 in (end of step 1 shown on left).

Step 2: Use a forklift to move the active pallet from the top of the stack of inactive pallets to the ground and continue loading until midpoint of top layer of bags is around 50 in (end of step 2 shown on right; top bag at end of step 1 is shaded tan.

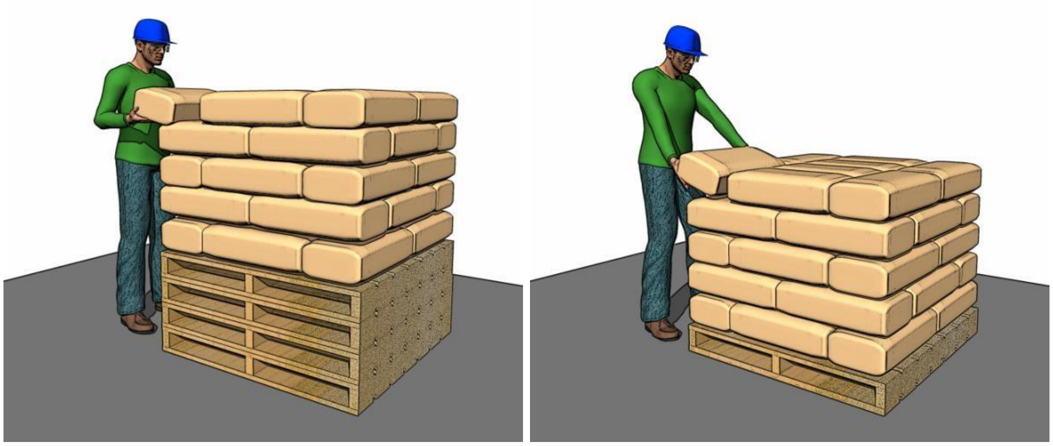


Figure A43. Method for using stacked pallets. Active pallet (fourth up from the ground on left) is placed on stack of inactive pallets and loaded until the top layer of bags is at 50 in from the ground (left), and pallet is moved by forklift to ground (right) and loading continues. Pallet on right should be loaded until the top layer of bags is 50 in from the ground.

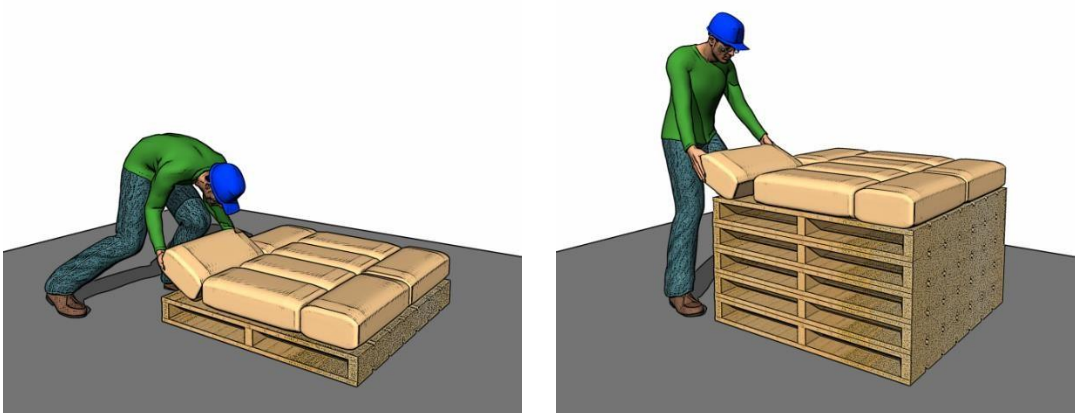


Figure A44. Loading a pallet on the floor can require extreme back bending (left), which is reduced using the stacked pallet method (right).

- (Bag Q 10.2 b) You indicated that empty pallets are positioned manually. Ideally, a forklift should be used to place pallets in position for loading to eliminate manual handling of pallets. If it is not possible to use a forklift, ensure that pallets are stored around 30 in from the floor and reduce the distance that a worker must travel while carrying the pallet. In addition, consider requiring multiple workers to lift the pallets together.

- (Bag Q 10.3 height ≠30) You indicated that bags are lifted from the conveyor at a nonideal height. Set the conveyor height as close to 30 in as possible from the ground and add an adjustable tilt end (Figure A45) to the conveyor that can be easily adjusted to knuckle height (Figure A42) for each worker. For most people, lifting above or below 30 in can place workers at greater risk for arm and back injuries. If two workers are lifting from the same conveyor, set the conveyor height to the average of the two workers' knuckle height.

Figure A45. Worker standing at conveyor belt with an adjustable tilt end.

- (Bag Q 10.3 height = 30) You indicated that bags are lifted from the conveyor at an acceptable height. To improve posture, an adjustable tilt end should be added to the conveyor so that the conveyor can be adjusted to knuckle height for each worker (approximately middle knuckle height, A42).

 (Bag Q 10.4 b) You indicated that the pallet is located to the side of the worker when the worker is facing the conveyor belt. Ideally, pallets should be placed in front of workers (Figure A46 and Figure A47). This will reduce the amount of twisting required to lift and place bags, which can reduce the risk of injury (Figure A48).

 (Bag Q 10.4 c) You indicated that the pallet is located behind the worker when the worker is facing the conveyor belt. Ideally pallets should be placed in front of workers (Figure A46 and Figure A47). This will reduce the amount of twisting required to lift and place bags, which can reduce the risk of injury (Figure A48). If it is not possible to place the pallet in front of workers, the pallet can be placed beside the worker.

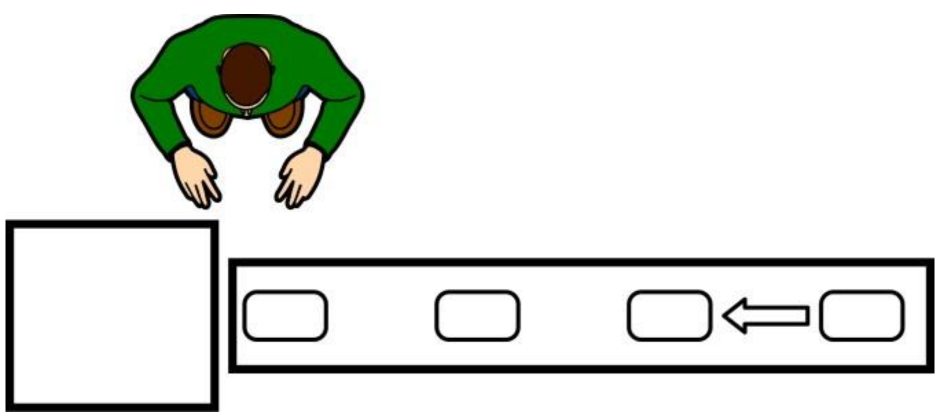


Figure A46. Pallet is in front of worker.

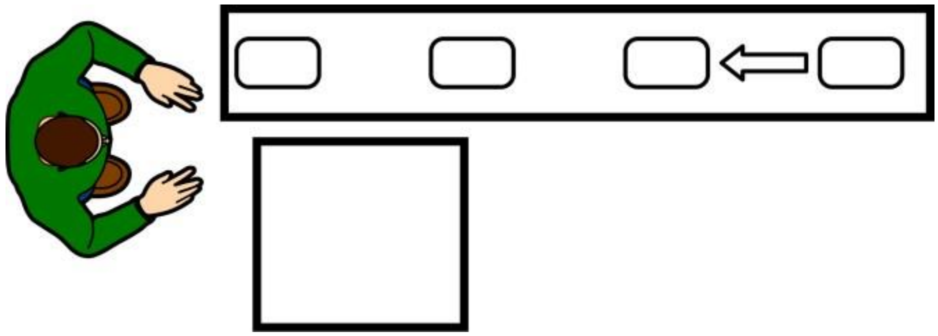


Figure A47. Pallet is in front of worker.

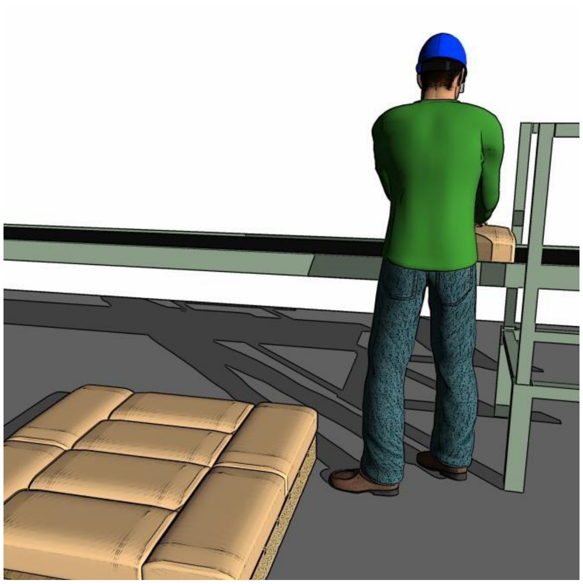


Figure A48. Worker is twisting to the side to pick up a bag from the conveyor belt.

 (Bag Q 10.5 no) You indicated that a turnable lift table is not used. Ideally, a turnable lift table should be used for all palletizing. Turnable lift tables can prevent awkward arm postures required to reach across a pallet (Figure A49), which can reduce the risk of injuries.

Figure A49. Awkward arm posture during palletizing.

 (Bag Q 10.6 no) You indicated that a lift-assist tool is not used to lift the bags. Ideally, a vacuum hoist or other lift-assist tool should be used to help in moving the bags. Using a lift-assist tool can reduce repetitive lifting, which increases risk of musculoskeletal disorders. One study reported a 39% reduction in peak spine loads when performing palletizing activities using a vacuum hoist (http://pro.sagepub.com/content/55/1/1002.short). Even with a vacuum hoist, the height of work is still important to reduce awkward postures, and all lifting should occur around 30 in.

 (Bag Q 10.7 yes) You indicated that workers slide bags on the conveyor before the bags are lifted. Ideally, a multidirectional roller table should be used to aide in sliding bags toward the worker. Make sure the sliding surface is maintained (waxed, clean, and free of debris) to reduce the amount of friction and allow bags to slide more easily.

- (Bag Q 10.8 yes) You indicated that barriers are present that prevent the worker from keeping bags close to the body. Remove any barriers that prevent the worker from getting as close to the bag as possible and ensure that workers are able to lift and lower bags directly in front of them without needing to reach to the front or side of the body. Barriers can require workers to adopt awkward arm and back postures, which can increase risk of injury.

- (Bag Q 10.10 yes) You indicated that workers bend their backs or reach with their arms while palletizing with a corner frame. A corner frame can limit access to lower layers of the pallet that sit close to the frame, which can increase reach required to place bags in those areas. Consider placing a lift table inside the corner frame to reduce awkward postures required during palletizing.

- (Bag Q 10.11 b) You indicated that wrist bending or deviating occurs during palletizing.

  Encourage workers to keep the wrist in a neutral posture whenever possible (e.g., Figure A50). Prolonged wrist bending and deviation when lifting can cause inflammation and pain in the wrist, and may lead to musculoskeletal disorders such as carpal tunnel syndrome or tendonitis.

Figure A50. Ideal hand and wrist posture while carrying bag.

 (Bag Q 10.12 b) You indicated that pinch or wide finger grips occur during palletizing. Encourage workers to avoid using pinch and wide finger grips whenever possible (e.g., Figure A50); these grips can contribute to hand injuries.

BULK BAG MODULES

Module 11: Hanging, Opening, and Filling

 (Bag Q 11.1 b) You indicated that pallets are moved into position for loading manually. Ideally, a forklift should be used to place pallets in position for loading to eliminate manual handling of pallets. If it is not possible to use a forklift, ensure that pallets are stored between 10 and 50 in from the floor and reduce the distance that a worker must travel while carrying the pallet. In addition, consider encouraging two workers to lift the pallets together.

□ (Bag Q 11.2 lowest < 10 or highest > 50) You indicated that empty bags are stacked at an unacceptable height. All bags should be stored between 10 and 50 in from the ground. Place the bags in an area with no barriers that would require workers to reach or twist to retrieve them, and minimize the distance that empty bags need to be carried to the filling station. Discuss with bag manufacturer different options for delivery of bags (e.g., 40-inch-tall stacks that will fit the 10 to 50-inch range, bags stacked on their side).

□ (Bag Q 11.3 either part 1 or part 2 height < 42 or > 57 and part 2 > part 1) You indicated that the hooks/filling spouts are at a nonideal height. The hooks and filling spout should be between 42 and 57 in (between elbow and shoulder height when standing) from the surface on which the worker stands. Ideally, a filling station with adjustable height hooks/filling spout that can be lowered to attach the bag should be used (e.g., Figure A51). Alternatively, the bag hooks can be mounted on a frame that can be removed and lowered with a forklift (Figure A53). These systems would eliminate awkward postures required to attach the bag to the hooks and filling spout (Figure A55). If this is not possible, consider adding a platform for workers to stand on that is 42 to 57 in below the spout (Figure A52). If a platform is used, ensure that the horizontal distance between the worker and the hooks/filling spout is no more than 25 in; according to the revised NIOSH lifting equation (http://www.cdc.gov/niosh/docs/94-110/pdfs/94-110.pdf), no lifting should be more than 25 in horizontally from the body. If the horizontal distance is greater than 25 in, consider using rotating hooks that enable the worker to reach all hooks from one side of the bag (Figure A54). If this is not possible, consider a movable platform that can be placed underneath the hooks/filling spout. The worker should not have to step or climb on the filling machine to hang the bag or attach it to the filling spout.

(Bag Q 11.3 either part 1 or part 2 height < 42 or > 57 and part 1 > part 2) You indicated that the hooks/filling spouts are at a nonideal height. The hooks and filling spout should be between 42 and 57 in (between elbow and shoulder height when standing) from the surface on which the worker stands. Ideally, a filling station with adjustable height hooks/filling spout that can be lowered to attach the bag should be used (e.g., Figure A51). Alternatively, the bag hooks can be mounted on a frame that can be removed and lowered with a forklift (

Figure A53). These systems would eliminate awkward postures required to attach the bag to the hooks and filling spout (Figure A55). If this is not possible, consider adding a platform for workers to stand on that is 42 to 57 in below the hooks (Figure A52). If a platform is used, ensure that the horizontal distance between the worker and the hooks/filling spout is no more than 25 in; according to the revised NIOSH lifting equation (http://www.cdc.gov/niosh/docs/94-110/pdfs/94-110.pdf), no lifting should be more than 25 in horizontally from the body. If the horizontal distance is greater than 25 in, consider using rotating hooks that enable the worker to reach all hooks from one side of the bag (Figure A54). If this is not possible, consider a movable platform that can be placed underneath the hooks/filling spout. The worker should not have to step or climb on the filling machine to hang the bag or attach it to the filling spout.

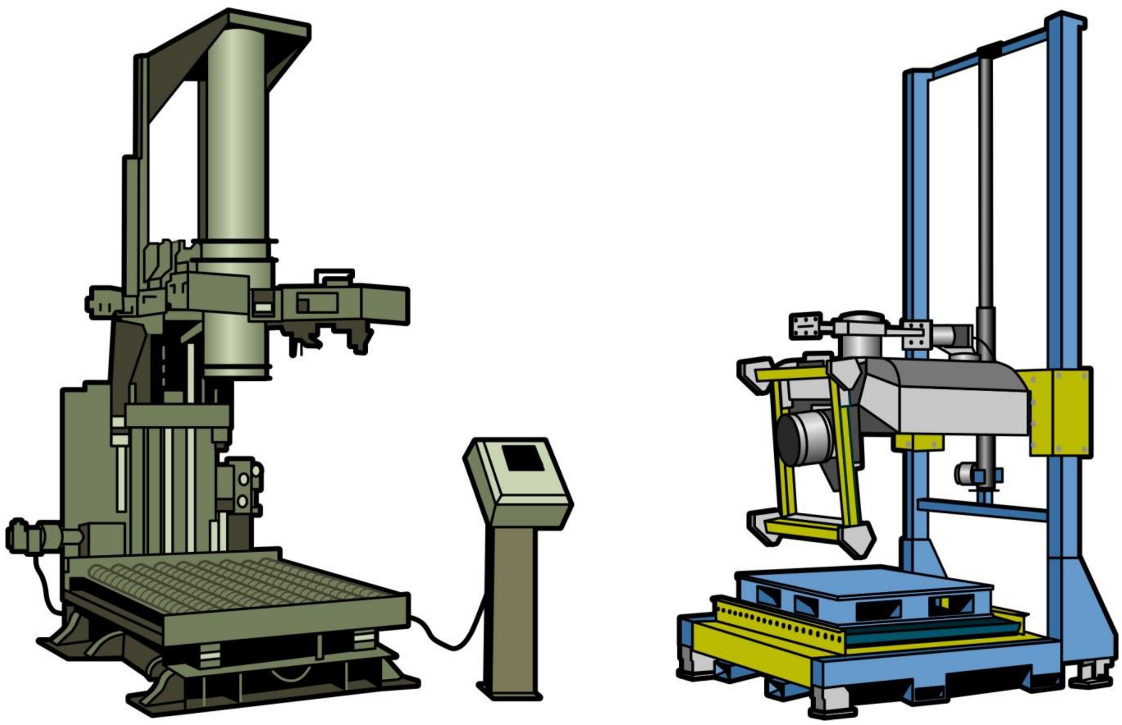


Figure A51. Examples of an adjustable height filling machine: National Bulk Equipment's cantilevered models are standard with height adjustment (left), Flexicon's SWING-DOWN® Bulk Bag Filler (right).

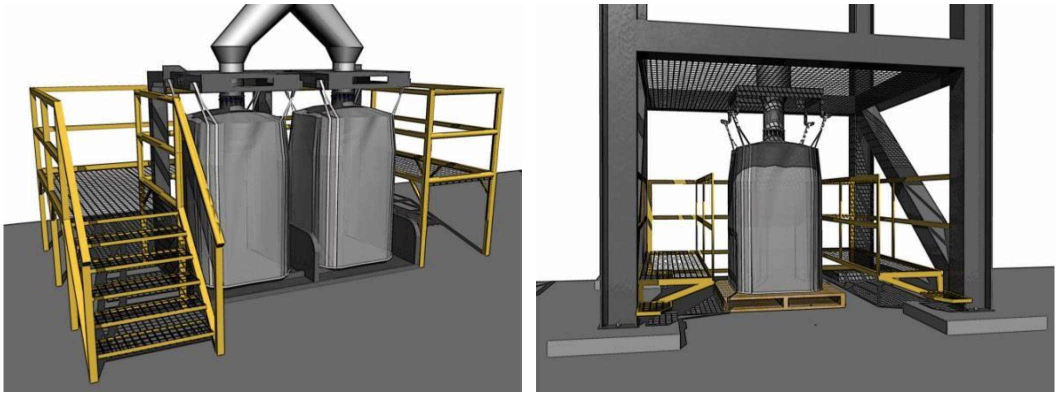


Figure A52. Platforms used to improve access to hooks and filling spout.

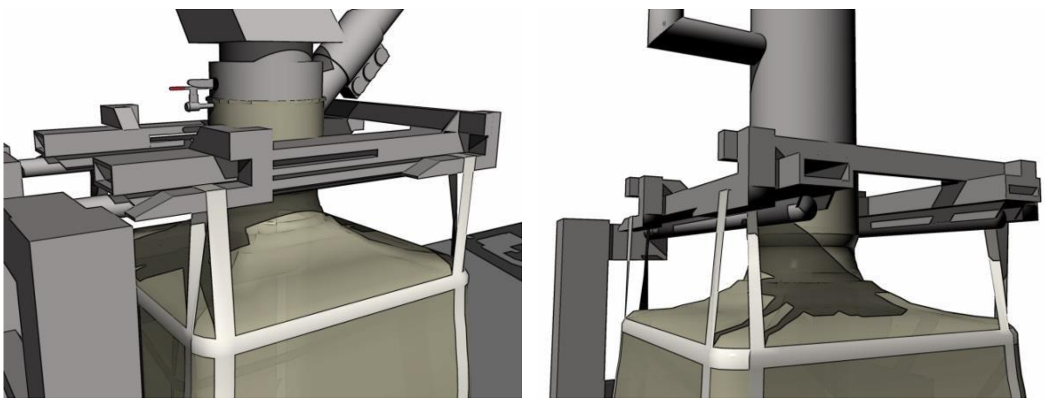


Figure A53. Bag filling stations with hooks mounted on frame that can be removed and lowered with a forklift.

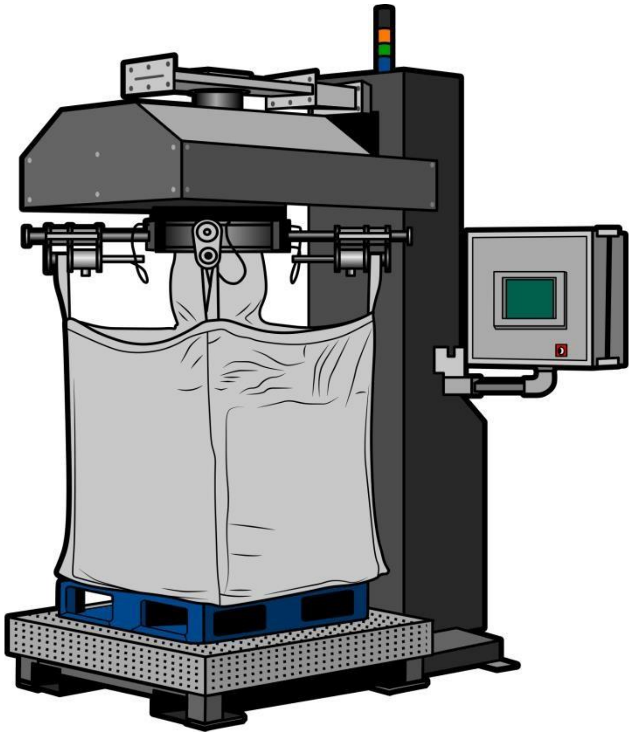


Figure A54. Example of filling station with rotating hooks.

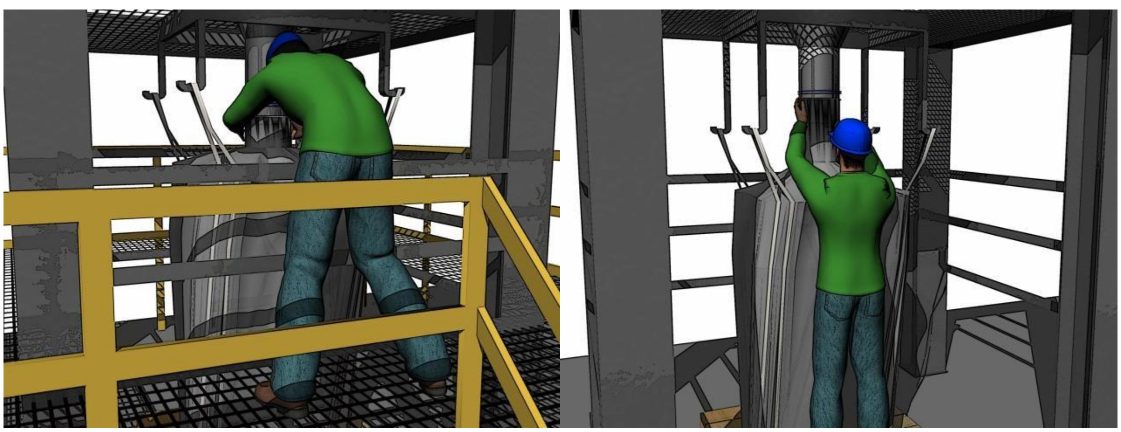


Figure A55. Filling spout is too low and worker must bend down to attach bag (left); filling spout is too high and worker must reach up to attach bag (right).

- (Bag Q 11.4 part 1 is a or f and part 2 is yes) You indicated that a hook or other mechanism is used to attach the bag to the filling spout, and that the bag sometimes separates from the filling spout during filling. Ideally, an air bladder should be used to secure the bag to the filling spout. Using an air bladder can eliminate risks associated with manually securing the bag to the filling spout, and can reduce the risk of the bag separating from the filling spout during filling. This can prevent the need for cleaning and removing spillage caused by the separation of the bag from the filling spout, and can also prevent the need to reattach a partially filled bag to the filling spout. If it is not possible to use an air bladder, consider using a clamp to secure the bag.

- (Bag Q 11.4 part 1 is b and part 2 is yes) You indicated that a clamp is used to attach the bag to the filling spout, and that the bag sometimes separates from the filling spout during filling. Ideally, an air bladder should be used to secure the bag to the filling spout. Using an air bladder can eliminate risks associated with manually securing the bag to the filling spout, and can reduce the risk of the bag separating from the filling spout during filling. This can prevent the need for cleaning and removing spillage caused by the separation of the bag from the filling spout, and can also prevent the need to reattach a partially filled bag to the filling spout. If it is not possible to use an air bladder, consider increasing the surface area of the clamp, using a clamp contoured to the filling spout, or using a hook to secure the bag (provided the bag has built-in loops at the top of the spout).

- (Bag Q 11.4 part 1 is c and part 2 is yes) You indicated that a tension cord is used to attach the bag to the filling spout, and that the bag sometimes separates from the filling spout during filling. Ideally, an air bladder should be used to secure the bag to the filling spout. Using an air bladder can eliminate risks associated with manually securing the bag to the filling spout, and can reduce the risk of the bag separating from the filling spout during filling. This can prevent the need for cleaning and removing spillage caused by the separation of the bad from the filling spout, and can also prevent the need to reattach a partially filled bag to the filling spout. If it is not possible to use an air bladder, consider using hooks or a clamp to secure the bag. If you choose to continue using a tension cord, ensure that the tension of the cord is the lowest possible tension that will securely attach the bag to reduce the amount of force required by workers to attach it.
- (Bag Q 11.4 part 1 is d and part 2 is yes) You indicated that an air bladder is used to attach the bag to the filling spout, and that the bag sometimes separates from the filling spout during filling. Check bladder size/pressure to ensure that the bag is being secured properly.

- (Bag Q 11.4 part 1 is e and part 2 is yes) You indicated that the bag is not secured to the filling spout, and that the bag sometimes separates from the filling spout during filling. Ideally, an air bladder should be used to secure the bag to the filling spout. Using an air bladder can eliminate risks associated with manually securing the bag to the filling spout, and can reduce the risk of the bag separating from the filling spout during filling. This can prevent the need for cleaning and removing spillage caused by the separation of the bag from the filling spout, and can also prevent the need to reattach a partially filled bag to the filling spout. If it is not possible to use an air bladder, consider using hooks or a clamp to secure the bag.

- (Bag Q 11.4 part 1 is c and part 2 is no) You indicated that a tension cord is used to attach the bag to the filling spout. Ideally, an air bladder should be used to secure the bag to the filling spout. Using an air bladder can eliminate risks associated with manually securing the bag to the filling spout. If you choose to continue using a tension cord, ensure that the tension of the cord is the lowest possible tension that will securely attach the bag to reduce the amount of force required by workers to attach it.
- (Bag Q 11.6 a and answered a or b to 1.2.3 (use spout or cone-top bag)) You indicated that you open bags manually prior to filling. Consider using a tool that produces forced air (e.g., compressed air, leaf blower) to open the bags. This will reduce awkward bending and reaching required when opening the bags (
- Figure A56). Ideally, the tool should be supported from beneath, suspended from the ceiling or mounted to support its weight while in use and should eliminate the need for repetitive lifting

(e.g., Figure A57). Ensure that tools are stored around 30 in from the floor to eliminate unnecessary bending to access the tool and that tools are counterbalanced so workers do not need to support the tool’s weight.

- (Bag Q 11.6 a and answered c to 1.2.3 (use duffle or open-top bag)) You indicated that you open bags manually prior to filling. Consider using a tool that produces forced air (e.g., compressed air, leaf blower) or a tool such as a broom or hockey stick that the worker can put in the bag and move around to help open the bag. Ensure that tools are stored around 30 in from the floor to eliminate unnecessary bending to access the tool and, ideally, the tool should be counterbalanced, supported from beneath, suspended from the ceiling, or mounted to support its weight while in use and to eliminate the need for repetitive lifting. The tool should not require the worker to bend to reach the bottom of the bag when standing upright.
- (Bag Q 11.6 b) You indicated that you use a tool to open bags prior to filling. Ensure that tools are stored around 30 in from the floor to eliminate unnecessary bending to access the tool and that the tools are counterbalanced. Further, tools should be supported from beneath, suspended from the ceiling or mounted to support its weight while in use and should eliminate the need for repetitive lifting (e.g., Figure A57). The tool should not require the worker to bend to reach the bottom of the bag when standing upright.

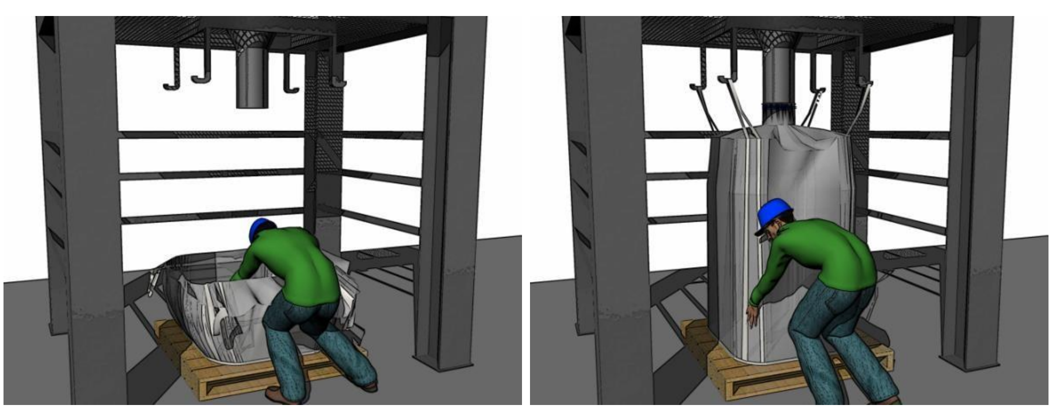


Figure A56. Worker is bending forward to reach inside and open the bag manually (left); worker is bending down to spread out the bottom corners of the bag during filling (right).

Figure A57. A leaf blower is used to force air into the bag to open it. The leaf blower is supported from beneath and is at a height that allows the worker to control it without bending over.

- (Bag Q 11.7 a) You indicated that bag filling is controlled using automatic release/stoppage (e.g., push button or foot pedal). If a push button is used, it should be located around 42 in from the floor and the worker should be able to reach it without bending, reaching, climbing, or twisting. Foot pedals should be protected from accidental activation using a cover and should not be a tripping hazard.
- (Bag Q 11.7 b) You indicated that bag filling is controlled using manual release/stoppage (e.g., hand lever). Ideally, the filling system should be automated, such as through a push button or foot pedal, to eliminate the need to manually control the release of material. This is particularly important if a large amount of force is required to open and close the valve (e.g., with coarse product). If it is not possible to automate the system, ensure that the pull lever is located around 42 in from the floor

(around elbow height) and that the worker doesn't need to bend or twist to operate the lever or read weight information. This level can also be mechanized (e.g., hydraulics) to reduce the force requirement of the worker.

- (Bag Q 11.8 a) You indicated that bags are adjusted during filling to prevent folds in the bag. If the bag isn't opening properly during filling because of folds in the bag, consider opening the bag using forced air before attaching the bag to the filling station. If this is not possible, consider pausing filling when less than 10% of product has entered the bag and adjusting the bag. This will reduce the weight of the product in the bag while it is adjusted and may reduce the need to adjust the bag for the remainder of the filling process.

- (Bag Q 11.8 b) You indicated that bags are adjusted during filling because the product isn't evenly filling the bag. If the product doesn't fill the bag properly due to product piling in center during filling (also referred to as a high angle of repose; Figure A58), consider using a cone-top bag. The shape of the cone-top bag allows for it to be filled completely with product of this type, and will require less adjusting to the product to flatten out the surface.

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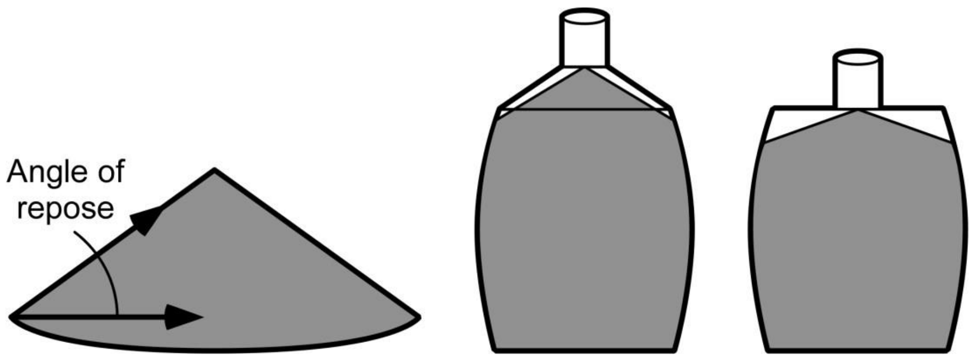


Figure A58. The angle of repose refers to the angle between a horizontal line and the surface of product (also referred to as the natural slope; left). A product with a high angle of repose will evenly fill a cone-top bag (center), but will leave unused space at the top corners of a spout-top bag and will require adjusting to evenly fill the bag (right).

 (Bag Q 11.8 c) You indicated that bags are adjusted during filling due to placement on the pallet. If the bag is loaded while on the pallet, ensure that bags are placed properly on the pallet before filling is started. Check placement of the pallet after less than 10% of the product has entered the bag and make adjustments if necessary. If the bag is suspended during loading, adjust the placement of the pallet before lowering the bag onto the pallet. Pallets should be sized such that the bottom of the bag is approximately the same size as the pallet and when filled bags are placed side by side, the sides of the bags should touch, but the sides of the pallets should not touch (Figure A59). This will increase the stability of the bags in packing containers or trailers. Adding markings to the floor beneath the filling spout to serve as a pallet placement guide will also improve pallet placement.

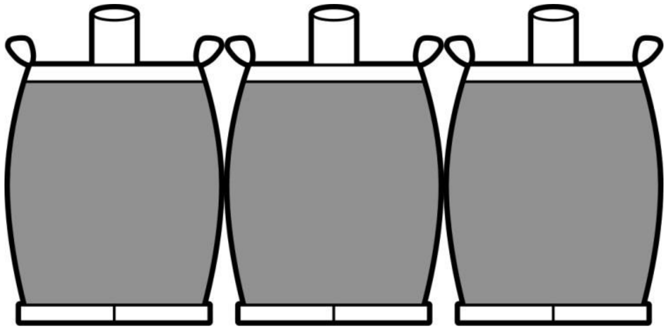
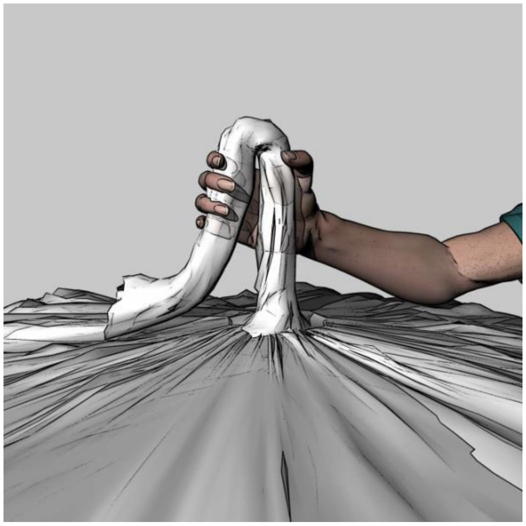


Figure A59. Example sizing of pallets for bulk bags: Pallets are approximately the same size as the bottom of the bag, and when placed side by side the filled bags touch (and the pallets do not touch).

Module 12: Closing and Sealing

- (Bag Q 12.1 height < 42 or > 57) You indicated that the hands are raised above or reach below acceptable limits during closing and sealing. Make sure the maximum hand height is between 42 and 57 in (between elbow and shoulder height). Consider adding a platform on which the worker could stand to improve access to the top of the bag.
- (Bag Q 12.2 yes) You indicated that the liner is closed separately from the outer bag. If the liner must be closed separately from the outer bag, consider if folding the liner is sufficient for closing. Closing both the outer bag and liner will increase overall physical demands during bag closing.
- (Bag Q 12.3 a) You indicated that the bag is closed using the snaking method. Closing the bag using the snaking method increases the amount of effort required by the hands and arms to close the bag which may increase risk of injury to the hands and arms when compared to the flowering method. Unless the bag needs to be sealed using the snaking method (e.g., to keep moisture out of the bag), consider using the flowering method (Figure A60).
- (Bag Q 12.3 c) You indicated that the bag is not closed using the flowering method. Using another method of closing the bag may increase risk of injury to the hands and arms. Unless the bag needs to be closed using another method, consider using the flowering method (Figure A25).
- (Bag Q 12.3 c) You indicated that the bag is closed using a method other than snaking or flowering. Consider closing bags using the flowering method (Figure A60);

this method requires a minimal amount of physical effort, which may help decrease risk of injury to the hands and arms.



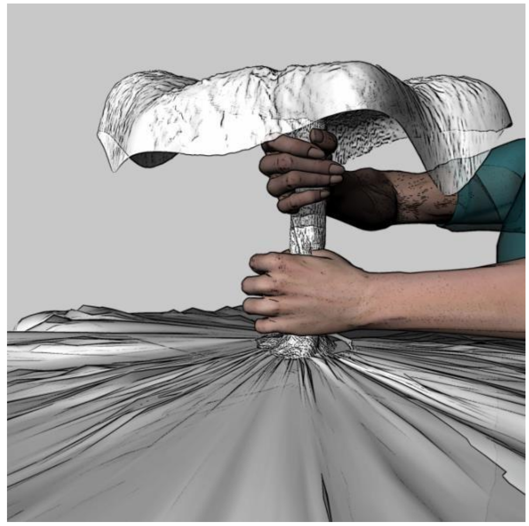


Figure A60. Snaking the liner of a bag (left) and flowering the liner (right).

 (Bag Q 12.4 a, b, d, e, f, or g) You indicated that you use a method other than a pneumatic cable tie gun to seal bags. Consider using a pneumatic cable tie gun instead of your current method (Figure A61); research shows that this method requires less exertion of the hands and arms, which may help decrease the risk of injury. Research also shows that pneumatic cable tie guns are perceived to be easier and more comfortable to use, and overall are preferred over other methods.

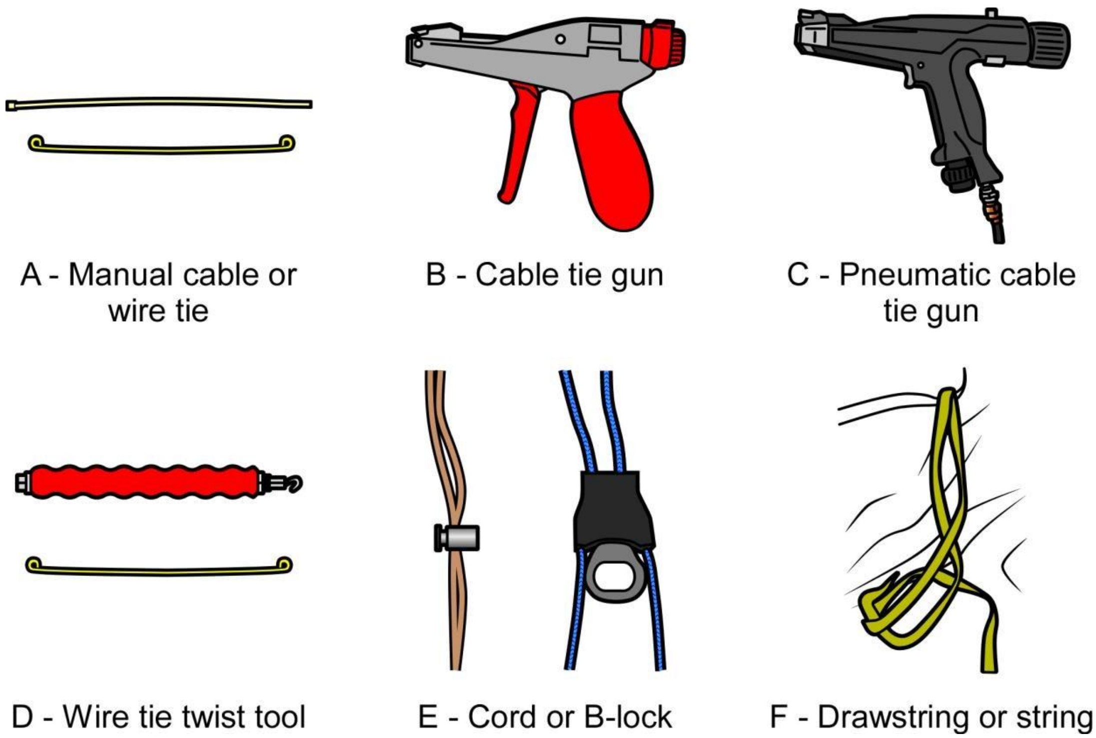


Figure A61. Methods of sealing bulk bags.

SMALL AND BULK BAGS

Module 13: Stretch and Shrink Wrapping

 (Bag Q 13.2 a, b, c, or d) You indicated that you use stretch wrap held by hand, hand saver, extended core, or mechanical brake to stretch wrap (Figure A62). Ideally, the stretch wrapping process should be automated to eliminate exposure to awkward arm and back postures associated with manual stretch wrapping. If this is not possible, the most ideal tool to use is a portable stretch wrapper. This type of tool eliminates the awkward postures required to apply stretch wrap to the bottom portion of the pallet and also eliminates manual handling of the stretch wrap. If this is not possible or if the pallet is too tall for the portable stretch wrapper, consider using a pole wrapper. A pole wrapper enables the worker to walk around the pallet and adjust the height of the wrap on the pole, eliminating the need to bend the back to wrap the bottom portion of the pallet. If none of these options are possible, discuss obtaining lighterweight stretch wrap with your supplier.

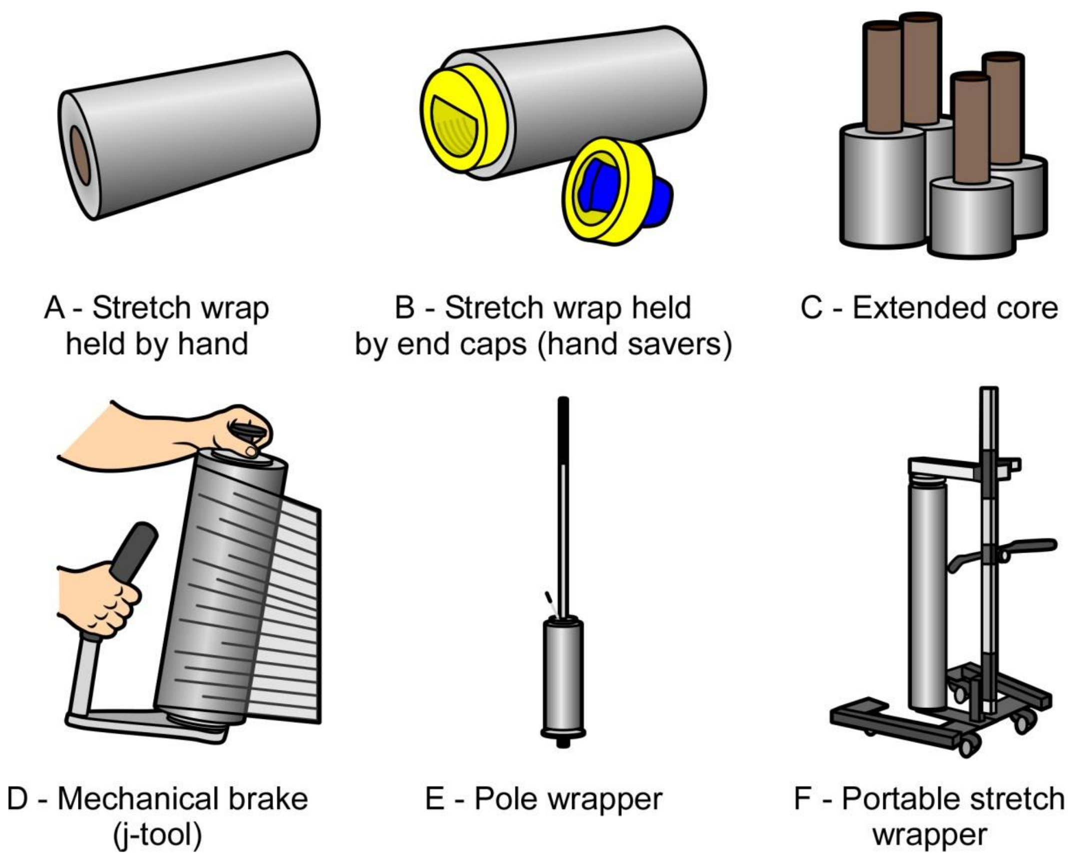


Figure A62. Tools used for stretch wrapping.

☐ (Bag Q 13.2 e) You indicated you use a pole wrapper to stretch wrap. Ideally, the stretch wrapping process should be automated to eliminate exposure to awkward arm and back postures associated with manual stretch wrapping. If this is not possible, consider using a portable stretch wrapper. This type of tool eliminates manual handling of the pole and stretch wrap. If the pallet is too tall for the portable stretch wrapper, the pole wrapper you currently use is a good alternative.

- (Bag Q 13.2 f) You indicated you use a portable stretch wrapper for stretch wrap. Consider automating the stretch wrapping process to eliminate the need to manually push the stretch wrap around the pallet.

- (Bag Q 13.3 yes) You indicated awkward arm or back postures are used when applying shrink wrap. Manually applying the shrink wrap can require awkward arm and back postures to lift and place the shrink wrap. Encourage workers to apply the wrap without reaching with the arms or bending/twisting the back (Figure A63). To encourage this, a forklift can be used to raise the pallet while workers hold the corners of the shrink wrap over the pallet (Figure A64). As the pallet is raised, the shrink wrap is pulled down over the stack of bags. If this method is used, ensure that workers stay clear from the area underneath the pallet, and that the hand/arm closest to the forklift is clear of any moving parts. Opening the shrink wrapping using a tool (e.g., leaf blower) may also help reduce exposure to awkward postures. If a tool is used, it should be supported from beneath, suspended from the ceiling, or mounted to support its weight while in use and eliminate the need for repetitive lifting.

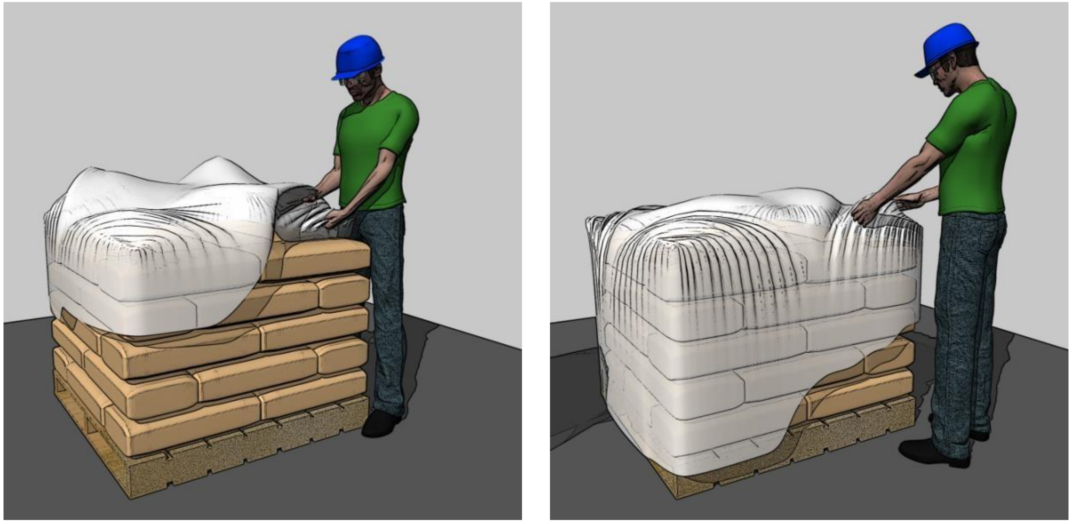


Figure A63. Worker is applying shrink wrap without awkward reaching with the arms or extreme bending/twisting of the back.

Figure A64. Forklift is used to raise pallet while worker stands still holding corners of shrink wrap.

As the pallet is raised, the shrink wrap is pulled down over the stack of bags (beginning of process is shown on left; end is shown on right). As shown, this method does not require awkward reaching with the arms or bending/twisting the back.

- (Bag Q 13.4 a) You indicated that you use gas or propane heat for shrink wrapping. Ensure that the wand used to apply the heat is long enough that workers do not have to bend forward to reach the bottom of the pallet (Figure A65).
- (Bag Q 13.4 b) You indicated you use electric heat for shrink wrapping. Ensure that the heat applicator is long enough that workers do not have to bend forward to reach the bottom of the pallet (Figure A65). Also, ensure that the cord is not a tripping hazard. See hand tool checklist in Module 14 of Maintenance and Repair Audit.

Figure A65. Short wand requires worker to bend forward to reach bottom of pallet (left). Long wand enables worker to reach bottom of pallet without bending forward (right).

- (Bag Q 13.5 a) You indicated that the worker carries the gas tank. Ideally, the gas tank should not need to be manually handled. Consider storing the gas tank in an area close to where pallets are shrink-wrapped and use a long gas line to eliminate the need to move the tank. If this approach is used, ensure that the gas line does not become a tripping hazard. Consider using a self-retracting wheel to keep the line taut, or mount the gas line overhead to remove it from the walking area and prevent it from becoming a tripping hazard. If this is not possible, consider using a rolling cart to support the weight of the gas tank while it is moved.

- (Bag Q 13.5 b) You indicated that the worker uses a rolling cart to move the gas tank. Ideally, the gas tank should not need to be manually handled. Consider storing the gas tank in an area close to where pallets are shrink-wrapped and using a long gas line to eliminate the need to move the tank. If this approach is used, ensure that the gas line does not become a tripping hazard. Consider using a self-retracting wheel to keep the line taut, or mount the gas line overhead to remove it from the walking area and prevent it from becoming a tripping hazard.
- (Bag Q 13.6 a) You indicated that the worker carries the gas tank while shrink wrapping. Ideally, the gas line should be long enough to allow the tank to stay in one place to eliminate the manual handling associated with carrying the tank. If this approach is used, ensure that the gas line does not become a tripping hazard. Consider using a self-retracting wheel to keep the line taut, or mount the gas line overhead to remove it from the walking area and prevent it from becoming a tripping hazard. If this is not possible, consider using a rolling cart to support the weight of the gas tank while shrink wrapping is performed (Figure A66).

Figure A66. Worker carrying gas tank while shrink wrapping pallets (left). Manual handling is reduced by placing the gas tank on wheeled cart (right).

- (Bag Q 13.6 b) You indicated that the worker uses a rolling cart to move the gas tank while shrink wrapping. Ideally, the gas line should be long enough that the worker does not need to move the gas tank during shrink wrapping. If this approach is used, ensure that the gas line does not become a tripping hazard. Consider using a self-retracting wheel to keep the line taut, or mount the gas line overhead to remove it from the walking area and prevent it from becoming a tripping hazard.

- (Bag Q 13.6 c) You indicated that the gas tank uses a gas line long enough for the tank to stay in one place during shrink wrapping. Ensure that the gas line does not become a tripping hazard. Consider using a self-retracting wheel to keep the line taut, or mount the gas line overhead to remove it from the walking area and prevent it from becoming a tripping hazard.

12. Appendix C: Raw Respirable Dust Results from SAS

Obs	time	dust
1	a	2.1203
2	a	2.4651
3	a	2.0326
4	a	2.8134
5	a	1.9519
6	a	6.9078
7	a	2.3330
8	a	2.3330
9	a	2.0875
10	a	1.9519
11	a	2.1716
12	a	2.4769
13	a	2.3539
14	a	2.4534
15	a	2.4769
16	a	2.2073
17	a	2.1037
18	a	2.3330
19	a	2.3228
20	a	2.3228
21	a	2.3330
22	a	1.7603
23	a	2.3026
24	a	2.5903
25	a	5.8091
26	a	2.7806
27	a	2.8473
28	a	2.6593
29	a	3.2968
30	a	2.8647
31	b	1.7720
32	b	1.2140
33	b	1.9878
34	b	1.7720
35	b	1.7720
36	b	2.1628
37	b	2.0956
38	b	2.1804

Obs	time	dust
39	b	1.9105
40	b	1.7373
41	b	2.5770
42	b	1.9241
43	b	2.8134
44	b	4.1352
45	b	2.0794
46	b	2.0956
47	b	1.7545
48	b	2.0956
49	b	2.0794
50	b	2.0956
51	b	2.0956
52	b	1.3863
53	b	2.0956
54	b	2.0875
55	b	2.0956
56	b	2.0402
57	b	2.0956
58	b	2.0956
59	b	2.0025
60	b	2.0956
61	b	2.0956
62	b	2.1120
63	b	2.0956
64	b	2.0956
65	b	2.2538
66	b	2.2443
67	b	2.0794
68	b	2.0479
69	b	2.0326
70	b	2.0956
71	b	2.0956
72	b	1.0024
73	b	2.0956
74	b	2.0956
75	b	2.1037
76	b	2.1037

Obs	time	dust
77	b	2.1037
78	b	2.1037
79	b	2.1037
80	b	2.1037
81	b	1.6094
82	b	2.3026
83	b	2.1037
84	b	2.3026
85	b	2.3026
86	b	2.0956
87	b	2.0956
88	b	2.9004
89	b	6.9078
90	b	2.9004
91	b	2.8134
92	b	2.7334
93	b	3.3814
94	b	2.2828
95	b	2.5010
96	b	2.9759
97	b	6.9078
98	b	2.7646
99	b	0.9676
100	b	6.9078
101	b	6.9078
102	b	2.6451
103	b	6.9078
104	b	1.9379
105	b	2.6736
106	b	2.2073
107	b	4.4228
108	b	1.5702
109	b	3.6889
110	b	1.6928
111	b	3.0159
112	b	6.9078
113	b	3.6889
114	b	1.8389

Obs	time	dust
115	b	6.9078
116	b	2.3330
117	b	6.9078
118	b	2.3228
119	b	3.0159
120	b	2.8134
121	b	4.1352
122	b	3.2968
123	b	2.2256
124	b	2.0956
125	b	2.2073
126	b	2.4651
127	b	2.7969
128	b	2.1037
129	b	3.6889
130	b	3.7723
131	b	2.6311
132	b	6.9078
133	b	2.4079
134	b	3.2442
135	b	2.7969
136	b	3.0576
137	b	3.7297
138	b	2.2926
139	b	2.1893
140	b	3.9633
141	b	2.8473
142	b	2.8302
143	b	2.7646
144	b	6.9078
145	b	2.0326
146	b	2.6037
147	b	2.4534
148	b	3.3524
149	b	3.7297
150	b	1.6820
151	b	1.9951
152	b	2.6037

Obs	time	dust
153	b	2.3228
154	b	4.4228
155	b	3.7297
156	b	1.9951
157	b	2.6173
158	b	2.6173
159	b	2.6037
160	b	2.3026
161	b	2.1203
162	b	2.7969
163	b	2.4769
164	b	2.4304
165	b	2.4769
166	b	2.6593
167	b	2.2256
168	b	3.2968
169	b	2.6173
170	b	2.5639

The UNIVARIATE Procedure Variable: dust
Time= a

Moments			
N	30	**Sum Weights**	30
Mean	2.64876	**Sum Observations**	79.4628
Std Deviation	1.06810225	**Variance**	1.14084241
Skewness	3.23023332	**Kurtosis**	10.6987196
Uncorrected SS	243.562316	**Corrected SS**	33.08443
Coeff Variation	40.3246141	**Std Error Mean**	0.1950079

Basic Statistical Measures			
Location		**Variability**	
Mean	2.648760	**Std Deviation**	1.06810
Median	2.333000	**Variance**	1.14084
Mode	2.333000	**Range**	5.14750
		Interquartile Range	0.48770

Tests for Location: Mu0=0				
Test	**Statistic**		**p Value**	
Student's t	**t**	13.58283	**Pr > |t|**	<.0001
Sign	**M**	15	**Pr >= |M|**	<.0001
Signed Rank	**S**	232.5	**Pr >= |S|**	<.0001

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.562346	**Pr < W**	<0.0001
Kolmogorov-Smirnov	**D**	0.319891	**Pr > D**	<0.0100
Cramer-von Mises	**W-Sq**	0.864689	**Pr > W-Sq**	<0.0050
Anderson-Darling	**A-Sq**	4.704143	**Pr > A-Sq**	<0.0050

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	6.90780
99%	6.90780
95%	5.80910
90%	3.08075
75% Q3	2.65930
50% Median	2.33300

The UNIVARIATE Procedure Variable: dust
Time= a

Quantiles (Definition 5)	
Level	**Quantile**
25% Q1	2.17160
10%	1.99225
5%	1.95190
1%	1.76030
0% Min	1.76030

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
1.7603	22	2.8473	27
1.9519	10	2.8647	30
1.9519	5	3.2968	29
2.0326	3	5.8091	25
2.0875	9	6.9078	6

The UNIVARIATE Procedure Variable: dust
Time= b

Moments			
N	140	Sum Weights	140
Mean	2.75469143	Sum Observations	385.6568
Std Deviation	1.31262761	Variance	1.72299125
Skewness	2.24032913	Kurtosis	4.67312628
Uncorrected SS	1301.86127	Corrected SS	239.495784
Coeff Variation	47.6506225	Std Error Mean	0.11093728

Basic Statistical Measures			
Location		Variability	
Mean	2.754691	Std Deviation	1.31263
Median	2.297600	Variance	1.72299
Mode	2.095600	Range	5.94020
		Interquartile Range	0.72620

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	24.83107	Pr > |t|	<.0001
Sign	M	70	Pr >= |M|	<.0001
Signed Rank	S	4935	Pr >= |S|	<.0001

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.693303	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.236163	Pr > D	<0.0100
Cramer-von Mises	W-Sq	2.587387	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	14.95881	Pr > A-Sq	<0.0050

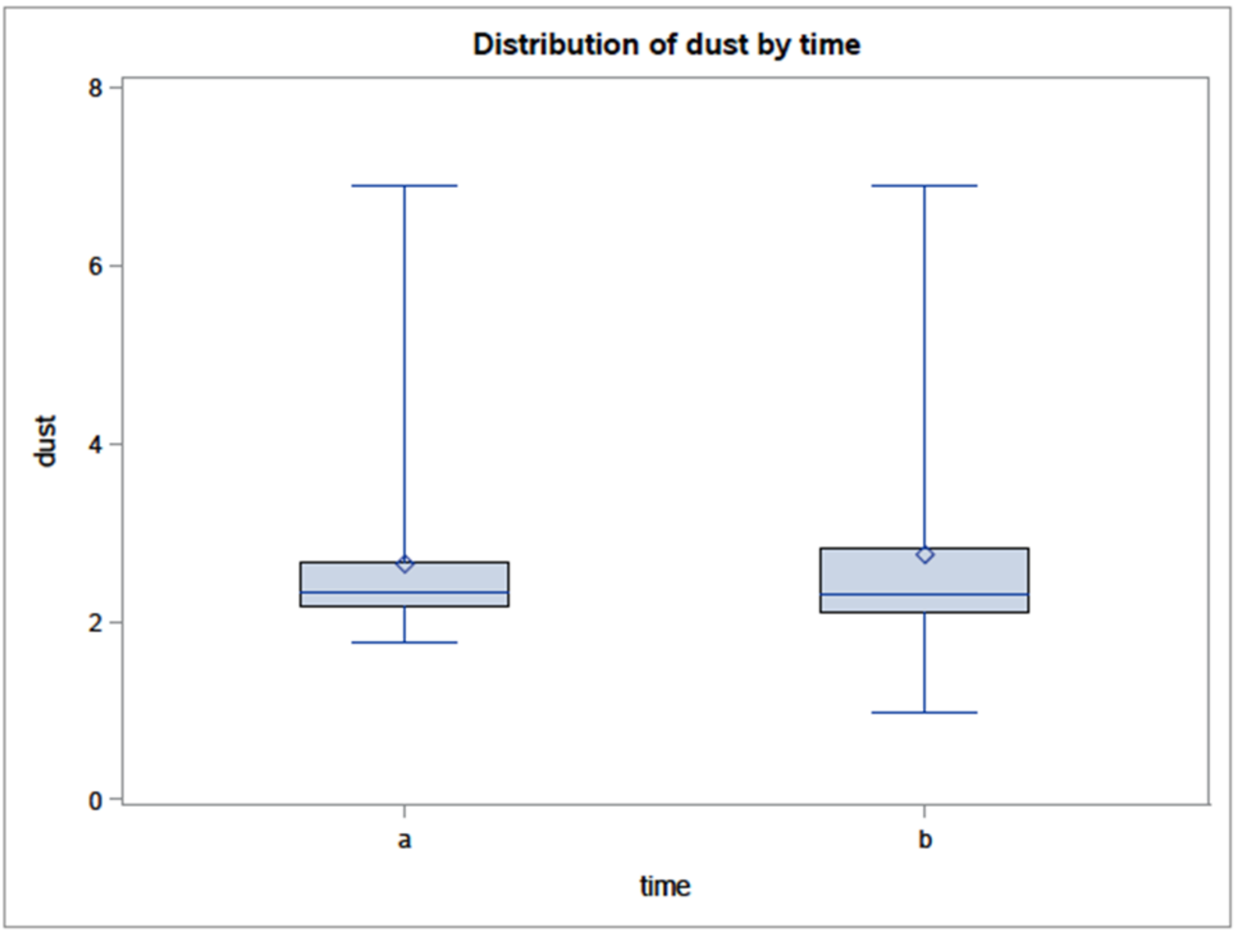
Quantiles (Definition 5)	
Level	Quantile
100% Max	6.90780
99%	6.90780
95%	6.90780
90%	4.04925
75% Q3	2.82180
50% Median	2.29760

The UNIVARIATE Procedure Variable: dust

Time= b

Quantiles (Definition 5)	
Level	**Quantile**
25% Q1	2.09560
10%	1.87470
5%	1.68740
1%	1.00240
0% Min	0.96760

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
0.9676	99	6.9078	112
1.0024	72	6.9078	115
1.2140	32	6.9078	117
1.3863	52	6.9078	132
1.5702	108	6.9078	144



The TTEST Procedure
Variable: dust

time	N	Mean	Std Dev	Std Err	Minimum	Maximum
a	30	2.6488	1.0681	0.1950	1.7603	6.9078
b	140	2.7547	1.3126	0.1109	0.9676	6.9078
Diff (1-2)		-0.1059	1.2738	0.2563		

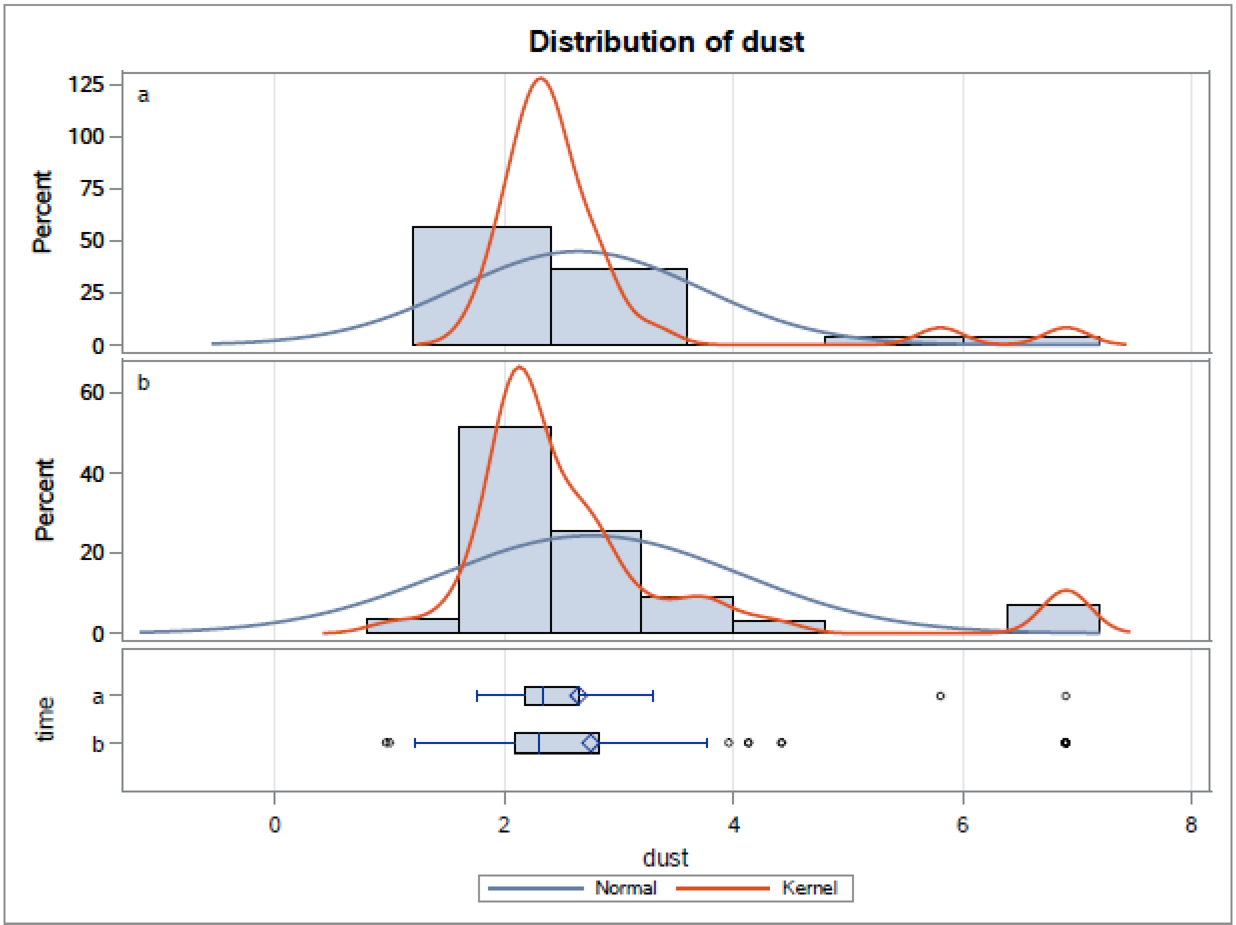
time	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
a		2.6488	2.2499	3.0476	1.0681	0.8506	1.4359
b		2.7547	2.5353	2.9740	1.3126	1.1748	1.4874
Diff (1-2)	Pooled	-0.1059	-0.6118	0.4000	1.2738	1.1509	1.4262
Diff (1-2)	Satterthwaite	-0.1059	-0.5566	0.3448			

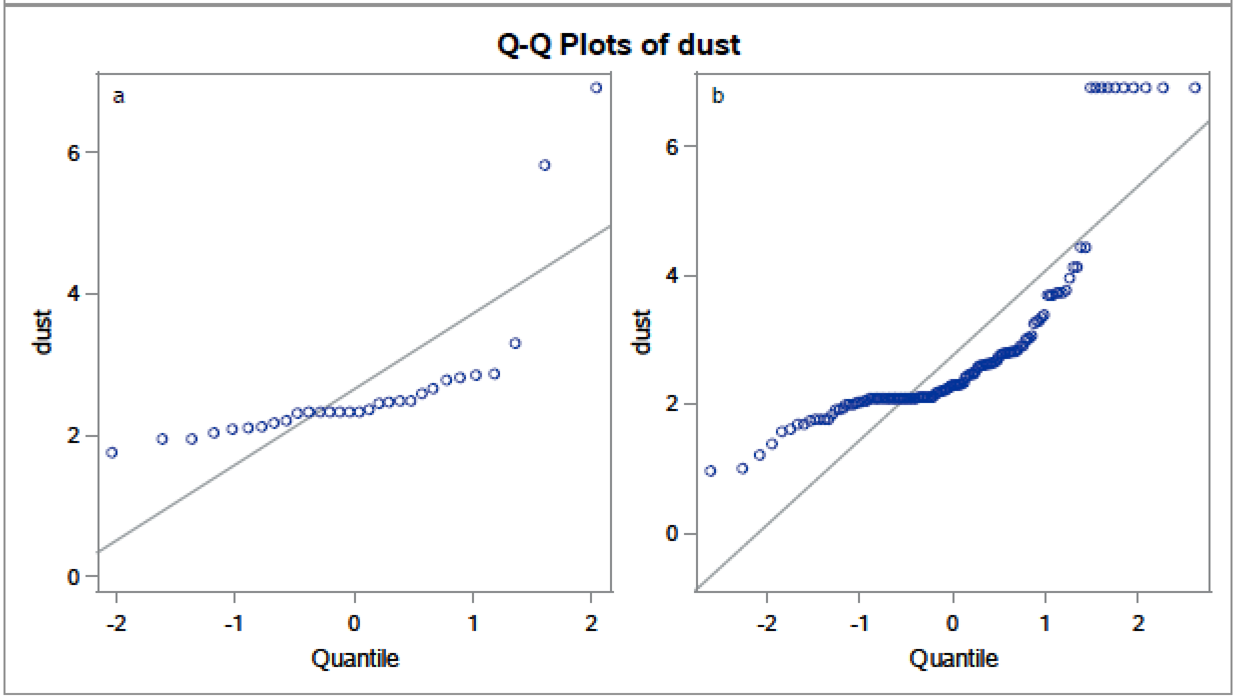
Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	168	-0.41	0.6799
Satterthwaite	Unequal	49.722	-0.47	0.6389

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	139	29	1.51	0.1951

The TTEST Procedure

Variable: dust





N P AR1WAY

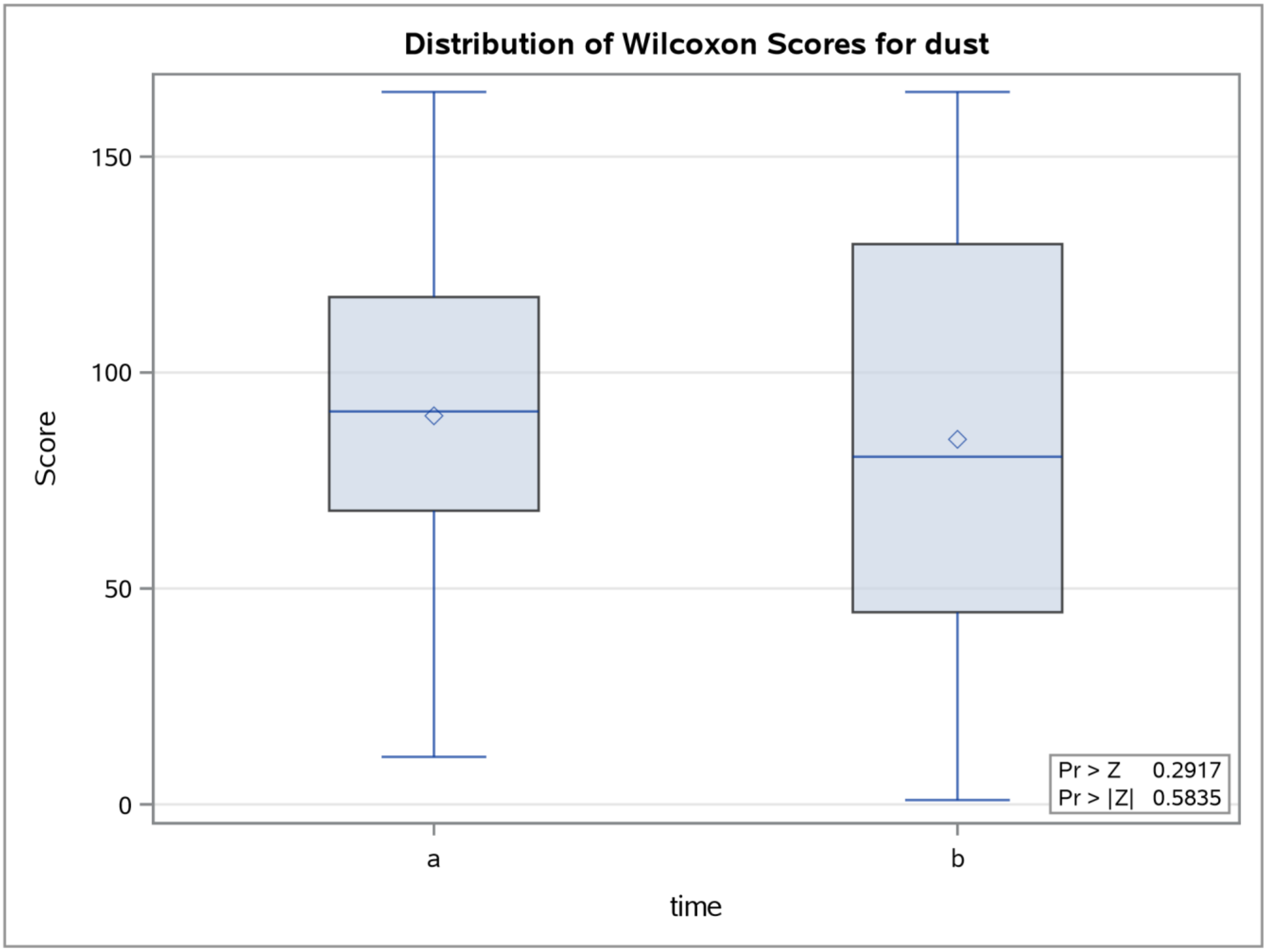
The NPARWAY1 Procedure

Wilcoxon Scores (Rank Sums) for Variable dust Classified by Variable time					
time	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
a	30	2699.50	2565.0	244.374444	89.983333
b	140	11835.50	11970.0	244.374444	84.539286
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	2699.5000
Normal Approximation	
Z	0.5483
One-Sided Pr > Z	0.2917
Two-Sided Pr > |Z|	0.5835
t Approximation	
One-Sided Pr > Z	0.2921
Two-Sided Pr > |Z|	0.5842
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	0.3029
DF	1
Pr > Chi-Square	0.5821

NPAR1WAY


Distribution of Wilcoxon Scores for dust
150
100
50
0
Score
a
b
time
Pr > Z 0.2917
Pr > |Z| 0.5835

13. Appendix D: Raw Respirable Crystalline Silica Results from SAS

Obs	time	lnresp
1	a	-5.80914
2	a	-4.01738
3	a	-3.72970
4	a	-5.80914
5	a	-4.34281
6	a	-5.80914
7	a	-4.13517
8	a	-3.41125
9	a	-3.38139
10	a	-3.32424
11	a	-3.07911
12	a	-3.96332
13	a	-3.81671
14	a	-5.11600
15	a	-4.42285
16	a	-4.07454
17	a	-4.50986
18	a	-4.26870
19	a	-4.82831
20	a	-4.71053
21	a	-3.91202
22	a	-3.57555
23	a	-4.60517
24	a	-4.50986
25	a	-5.80914
26	a	-4.60517
27	a	-4.96185
28	a	-5.80914
29	a	-5.80914
30	a	-5.80914
31	b	-4.60517
32	b	-3.21888
33	b	-4.60517
34	b	-3.21888
35	b	-4.60517
36	b	-4.60517
37	b	-4.60517
38	b	-3.91202

Obs	time	lnresp
39	b	-3.91202
40	b	-4.60517
41	b	-4.60517
42	b	-1.96611
43	b	-4.60517
44	b	-4.60517
45	b	-4.60517
46	b	-4.60517
47	b	-4.60517
48	b	-2.99573
49	b	-3.50656
50	b	-2.99573
51	b	-3.50656
52	b	-3.50656
53	b	-3.21888
54	b	-3.50656
55	b	-4.60517
56	b	-4.60517
57	b	-4.60517
58	b	-3.50656
59	b	-3.21888
60	b	-4.60517
61	b	-4.60517
62	b	-4.60517
63	b	-3.21888
64	b	-4.60517
65	b	-4.60517
66	b	-4.60517
67	b	-3.50656
68	b	-4.60517
69	b	-3.50656
70	b	-4.60517
71	b	-4.60517
72	b	-2.99573
73	b	-4.60517
74	b	-4.60517
75	b	-3.50656
76	b	-4.60517

Obs	time	lnresp
77	b	-3.21888
78	b	-4.60517
79	b	-4.60517
80	b	-3.50656
81	b	-2.81341
82	b	-3.91202
83	b	-3.68888
84	b	-3.91202
85	b	-3.91202
86	b	-3.50656
87	b	-3.57555
88	b	-3.50656
89	b	-5.80914
90	b	-3.64966
91	b	-3.64966
92	b	-3.91202
93	b	-5.80914
94	b	-3.50656
95	b	-3.64966
96	b	-5.80914
97	b	-5.80914
98	b	-5.80914
99	b	-3.41125
100	b	-5.80914
101	b	-5.80914
102	b	-3.81671
103	b	-5.80914
104	b	-3.17009
105	b	-4.42285
106	b	-3.41125
107	b	-5.80914
108	b	-3.68888
109	b	-5.80914
110	b	-3.38139
111	b	-5.80914
112	b	-5.80914
113	b	-5.80914
114	b	-2.93746

Obs	time	lnresp
115	b	-5.80914
116	b	-4.60517
117	b	-5.80914
118	b	-3.32424
119	b	-5.80914
120	b	-3.81671
121	b	-5.80914
122	b	-5.80914
123	b	-4.96185
124	b	-3.72970
125	b	-2.76462
126	b	-4.34281
127	b	-5.52146
128	b	-3.47377
129	b	-5.80914
130	b	-5.80914
131	b	-3.17009
132	b	-5.80914
133	b	-3.57555
134	b	-5.80914
135	b	-3.64966
136	b	-5.80914
137	b	-5.80914
138	b	-3.77226
139	b	-3.81671
140	b	-5.80914
141	b	-3.91202
142	b	-4.60517
143	b	-5.80914
144	b	-5.80914
145	b	-4.26870
146	b	-4.19971
147	b	-5.80914
148	b	-5.80914
149	b	-5.80914
150	b	-2.97593
151	b	-3.41125
152	b	-5.80914

Obs	time	lnresp
153	b	-3.64966
154	b	-5.80914
155	b	-5.80914
156	b	-3.86323
157	b	-3.54046
158	b	-5.80914
159	b	-3.50656
160	b	-5.80914
161	b	-5.80914
162	b	-4.60517
163	b	-5.11600
164	b	-4.13517
165	b	-4.07454
166	b	-5.80914
167	b	-5.80914
168	b	-5.80914
169	b	-4.34281
170	b	-4.13517

The UNIVARIATE Procedure
Variable: lnresp
Time=a

Moments			
N	30	Sum Weights	30
Mean	-4.5321823	Sum Observations	-135.96547
Std Deviation	0.86604242	Variance	0.75002948
Skewness	-0.2628333	Kurtosis	-1.0296268
Uncorrected SS	637.971156	Corrected SS	21.750855
Coeff Variation	-19.108729	Std Error Mean	0.15811699

Basic Statistical Measures			
Location		Variability	
Mean	-4.53218	Std Deviation	0.86604
Median	-4.46636	Variance	0.75003
Mode	-5.80914	Range	2.73003
		Interquartile Range	1.20398

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	-28.6635	Pr > |t|	<.0001
Sign	M	-15	Pr >= |M|	<.0001
Signed Rank	S	-232.5	Pr >= |S|	<.0001

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.918382	Pr < W	0.0244
Kolmogorov-Smirnov	D	0.163156	Pr > D	0.0407
Cramer-von Mises	W-Sq	0.085947	Pr > W-Sq	0.1713
Anderson-Darling	A-Sq	0.76221	Pr > A-Sq	0.0436

Quantiles (Definition 5)	
Level	Quantile
100% Max	-3.07911
99%	-3.07911
95%	-3.32424
90%	-3.39632
75% Q3	-3.91202
50% Median	-4.46636

The UNIVARIATE Procedure
Variable: lnresp
Time=a

Quantiles (Definition 5)	
Level	**Quantile**
25% Q1	-5.11600
10%	-5.80914
5%	-5.80914
1%	-5.80914
0% Min	-5.80914

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
-5.80914	30	-3.57555	22
-5.80914	29	-3.41125	8
-5.80914	28	-3.38139	9
-5.80914	25	-3.32424	10
-5.80914	6	-3.07911	11

The UNIVARIATE Procedure
Variable: lnresp
Time=b

Moments			
N	140	Sum Weights	140
Mean	-4.4575476	Sum Observations	-624.05666
Std Deviation	1.00151623	Variance	1.00303476
Skewness	-0.1053068	Kurtosis	-1.169952
Uncorrected SS	2921.18408	Corrected SS	139.421831
Coeff Variation	-22.467875	Std Error Mean	0.08464357

Basic Statistical Measures			
Location		Variability	
Mean	-4.45755	Std Deviation	1.00152
Median	-4.60517	Variance	1.00303
Mode	-5.80914	Range	3.84303
		Interquartile Range	2.28563

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	-52.6626	Pr > |t|	<.0001
Sign	M	-70	Pr >= |M|	<.0001
Signed Rank	S	-4935	Pr >= |S|	<.0001

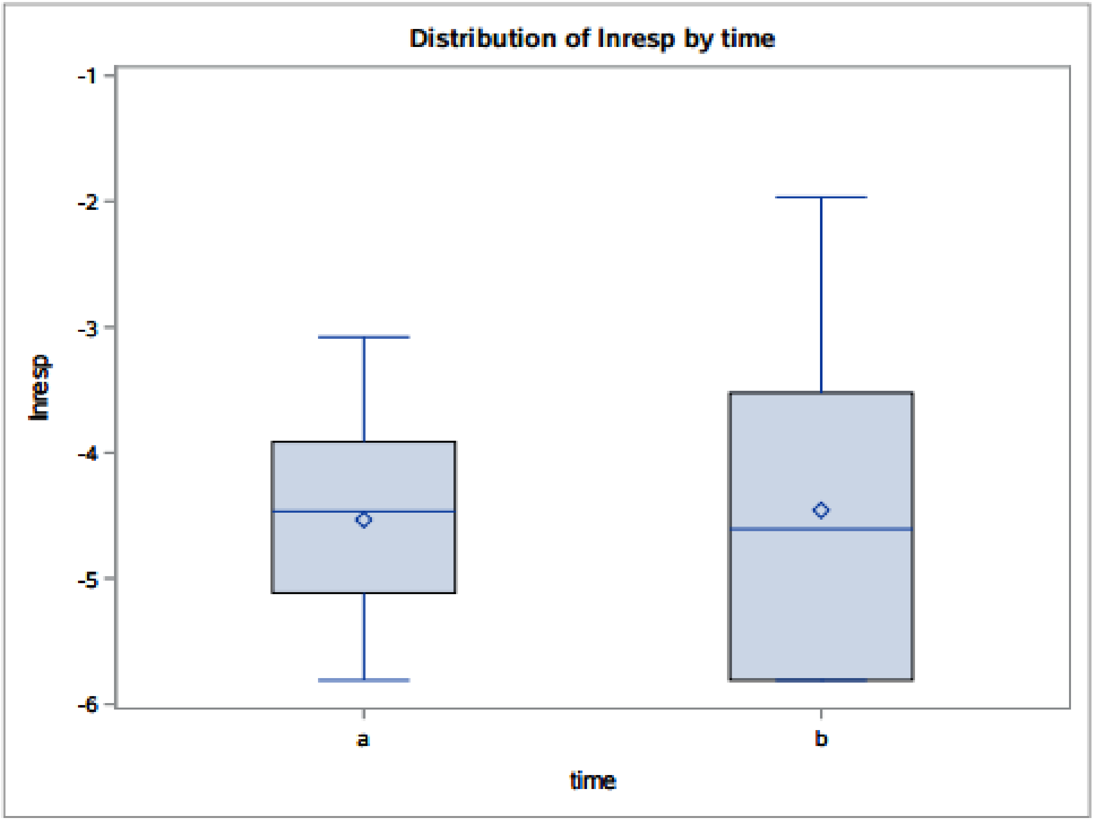
Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.89249	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.189991	Pr > D	<0.0100
Cramer-von Mises	W-Sq	0.761761	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	5.605919	Pr > A-Sq	<0.0050

Quantiles (Definition 5)	
Level	Quantile
100% Max	-1.96611
99%	-2.76462
95%	-2.99573
90%	-3.21888
75% Q3	-3.52351
50% Median	-4.60517

The UNIVARIATE Procedure
Variable: lnresp
Time=b

Quantiles (Definition 5)	
Level	**Quantile**
25% Q1	-5.80914
10%	-5.80914
5%	-5.80914
1%	-5.80914
0% Min	-5.80914

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
-5.80914	168	-2.97593	150
-5.80914	167	-2.93746	114
-5.80914	166	-2.81341	81
-5.80914	161	-2.76462	125
-5.80914	160	-1.96611	42



Distribution of lnresp by time
-1
-2
-3
-4
-5
-6
lnresp
a
b
time

The TTEST Procedure Variable: ln resp

time	N	Mean	Std Dev	Std Err	Minimum	Maximum
a	30	-4.5322	0.8660	0.1581	-5.8091	-3.0791
b	140	-4.4575	1.0015	0.0846	-5.8091	-1.9661
Diff (1-2)		-0.0746	0.9795	0.1971		

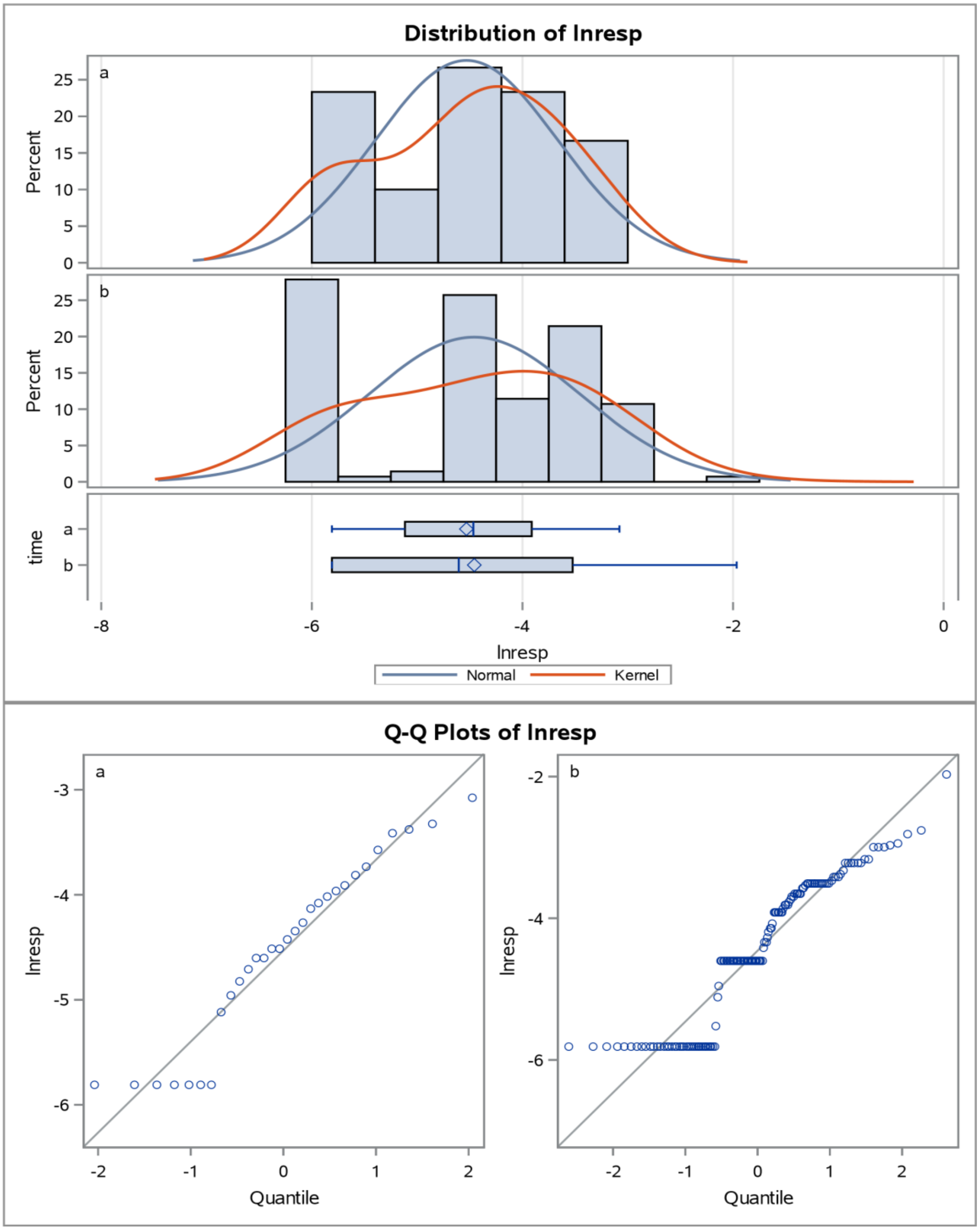
time	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
a		-4.5322	-4.8556	-4.2088	0.8660	0.6897	1.1642
b		-4.4575	-4.6249	-4.2902	1.0015	0.8964	1.1349
Diff (1-2)	Pooled	-0.0746	-0.4637	0.3144	0.9795	0.8850	1.0967
Diff (1-2)	Satterthwaite	-0.0746	-0.4354	0.2861			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	168	-0.38	0.7054
Satterthwaite	Unequal	47.194	-0.42	0.6792

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	139	29	1.34	0.3639

The TTest Procedure

Variable: lnresp



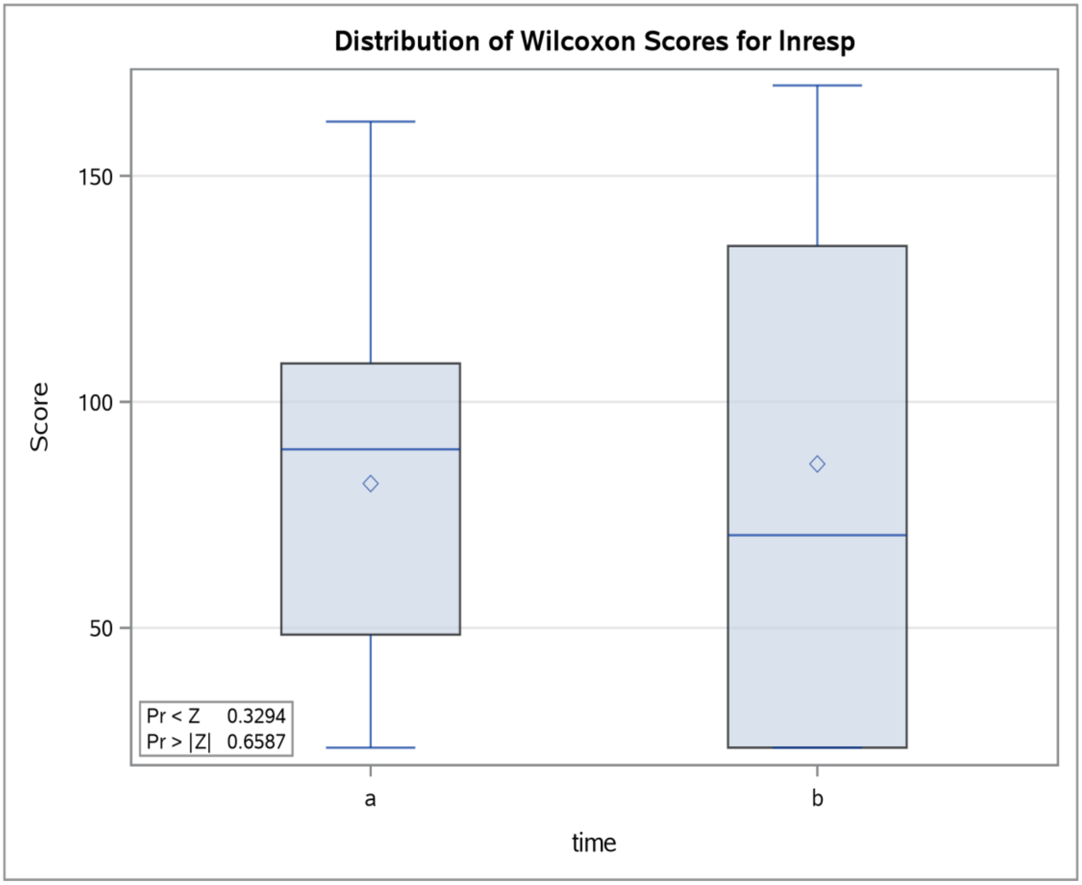
The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable lnresp Classified by Variable time					
time	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
a	30	2458.0	2565.0	241.135172	81.933333
b	140	12077.0	11970.0	241.135172	86.264286
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	2458.0000
Normal Approximation	
Z	-0.4417
One-Sided Pr < Z	0.3294
Two-Sided Pr > |Z|	0.6587
t Approximation	
One-Sided Pr < Z	0.3296
Two-Sided Pr > |Z|	0.6593
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	0.1969
DF	1
Pr > Chi-Square	0.6572

The NPAR1WAY Procedure



14. Appendix E: Raw Noise Results from SAS

Obs	time	noise
1	a	67.8
2	a	71.4
3	a	62.8
4	a	69.1
5	a	81.0
6	a	63.1
7	a	62.8
8	a	69.4
9	a	73.6
10	a	69.4
11	a	66.7
12	a	69.6
13	a	65.7
14	a	68.7
15	a	69.4
16	a	65.3
17	a	66.3
18	a	66.7
19	a	70.4
20	a	78.8
21	a	71.4
22	b	84.0
23	b	79.0
24	b	79.0
25	b	82.0
26	b	60.6
27	b	74.7
28	b	74.2
29	b	86.9
30	b	77.0
31	b	85.2
32	b	74.4
33	b	0.0
34	b	85.8
35	b	87.6
36	b	79.5
37	b	84.9
38	b	78.6

Obs	time	noise
39	b	72.1
40	b	82.3
41	b	73.6
42	b	71.4
43	b	86.4
44	b	57.6
45	b	71.4
46	b	73.7
47	b	76.1
48	b	64.1
49	b	65.3
50	b	84.9
51	b	65.6
52	b	71.1
53	b	79.3
54	b	66.5
55	b	71.2
56	b	72.5
57	b	67.0
58	b	70.8
59	b	86.0
60	b	71.2
61	b	65.1
62	b	68.6
63	b	73.5
64	b	63.9
65	b	66.8
66	b	50.3
67	b	76.5
68	b	64.9
69	b	75.2
70	b	69.2

The UNIVARIATE Procedure
Variable: noise
Time= a

Moments			
N	21	Sum Weights	21
Mean	69.0190476	Sum Observations	1449.4
Std Deviation	4.64323368	Variance	21.559619
Skewness	1.08106446	Kurtosis	1.56437126
Uncorrected SS	100467.4	Corrected SS	431.192381
Coeff Variation	6.72746705	Std Error Mean	1.01323666

Basic Statistical Measures			
Location		Variability	
Mean	69.01905	Std Deviation	4.64323
Median	69.10000	Variance	21.55962
Mode	69.40000	Range	18.20000
		Interquartile Range	4.10000

Tests for Location: Mu0=0				
Test	Statistic		p Value	
Student's t	t	68.1174	Pr > |t|	<.0001
Sign	M	10.5	Pr >= |M|	<.0001
Signed Rank	S	115.5	Pr >= |S|	<.0001

Tests for Normality				
Test	Statistic		p Value	
Shapiro-Wilk	W	0.905206	Pr < W	0.0442
Kolmogorov-Smirnov	D	0.164501	Pr > D	0.1412
Cramer-von Mises	W-Sq	0.09754	Pr > W-Sq	0.1159
Anderson-Darling	A-Sq	0.657526	Pr > A-Sq	0.0779

Quantiles (Definition 5)	
Level	Quantile
100% Max	81.0
99%	81.0
95%	78.8
90%	73.6
75% Q3	70.4
50% Median	69.1

The UNIVARIATE Procedure
Variable: noise
Time=a

Quantiles (Definition 5)	
Level	**Quantile**
25% Q1	66.3
10%	63.1
5%	62.8
1%	62.8
0% Min	62.8

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
62.8	7	71.4	2
62.8	3	71.4	21
63.1	6	73.6	9
65.3	16	78.8	20
65.7	13	81.0	5

The UNIVARIATE Procedure
Variable: noise
Time=b

Moments			
N	49	**Sum Weights**	49
Mean	72.3979592	**Sum Observations**	3547.5
Std Deviation	13.4380134	**Variance**	180.580204
Skewness	-3.3387578	**Kurtosis**	17.1674584
Uncorrected SS	265499.61	**Corrected SS**	8667.8498
Coeff Variation	18.5613152	**Std Error Mean**	1.9197162

Basic Statistical Measures			
Location		Variability	
Mean	72.39796	**Std Deviation**	13.43801
Median	73.60000	**Variance**	180.58020
Mode	71.20000	**Range**	87.60000
		Interquartile Range	12.30000

Note: The mode displayed is the smallest of 4 modes with a count of 2.

Tests for Location: Mu0=0				
Test	**Statistic**		**p Value**	
Student's t	**t**	37.71284	**Pr > |t|**	<.0001
Sign	**M**	24	**Pr >= |M|**	<.0001
Signed Rank	**S**	588	**Pr >= |S|**	<.0001

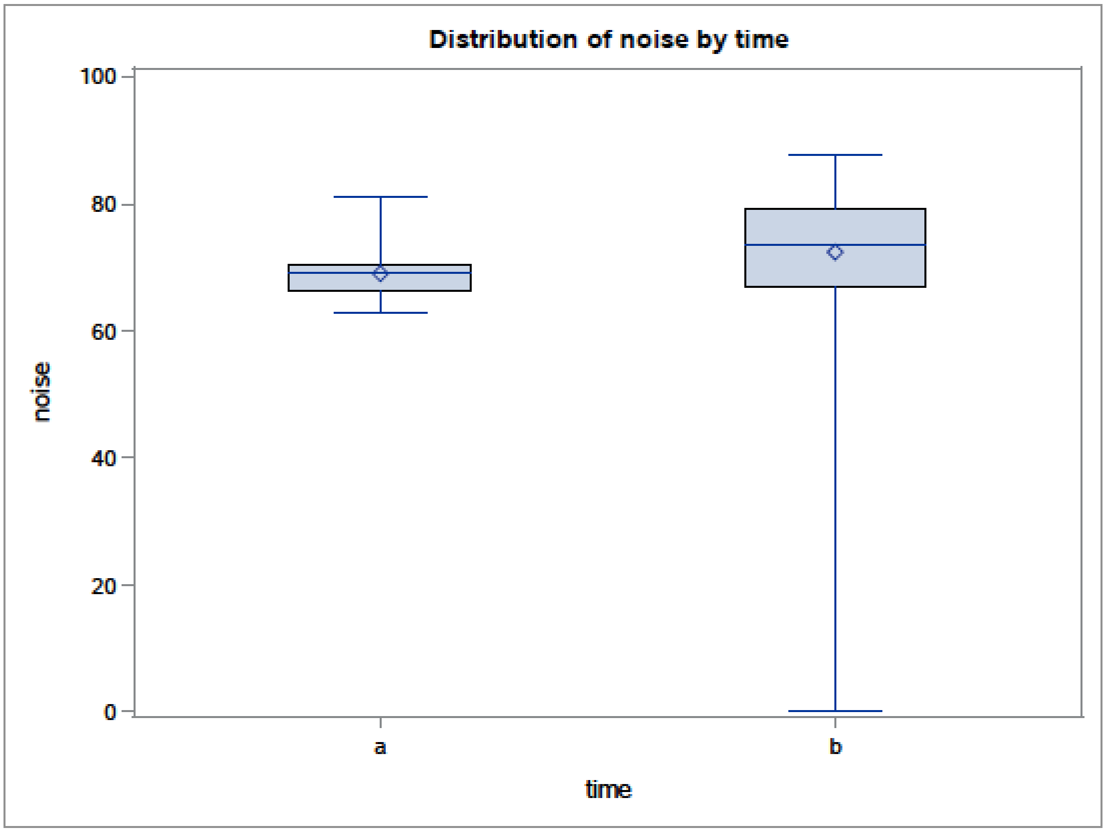
Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	**W**	0.713791	**Pr < W**	<0.0001
Kolmogorov-Smirnov	**D**	0.181936	**Pr > D**	<0.0100
Cramer-von Mises	**W-Sq**	0.342723	**Pr > W-Sq**	<0.0050
Anderson-Darling	**A-Sq**	2.385654	**Pr > A-Sq**	<0.0050

Quantiles (Definition 5)	
Level	**Quantile**
100% Max	87.6
99%	87.6
95%	86.4
90%	85.8
75% Q3	79.3

The UNIVARIATE Procedure
Variable: noise
Time=b

Quantiles (Definition 5)	
Level	**Quantile**
50% Median	73.6
25% Q1	67.0
10%	63.9
5%	57.6
1%	0.0
0% Min	0.0

Extreme Observations			
Lowest		**Highest**	
Value	**Obs**	**Value**	**Obs**
0.0	33	85.8	34
50.3	66	86.0	59
57.6	44	86.4	43
60.6	26	86.9	29
63.9	64	87.6	35


Distribution of noise by time
noise
100
80
60
40
20
0
a
b
time

The TTEST Procedure Variable: noise

time	N	Mean	Std Dev	Std Err	Minimum	Maximum
a	21	69.0190	4.6432	1.0132	62.8000	81.0000
b	49	72.3980	13.4380	1.9197	0	87.6000
Diff (1-2)		-3.3789	11.5676	3.0171		

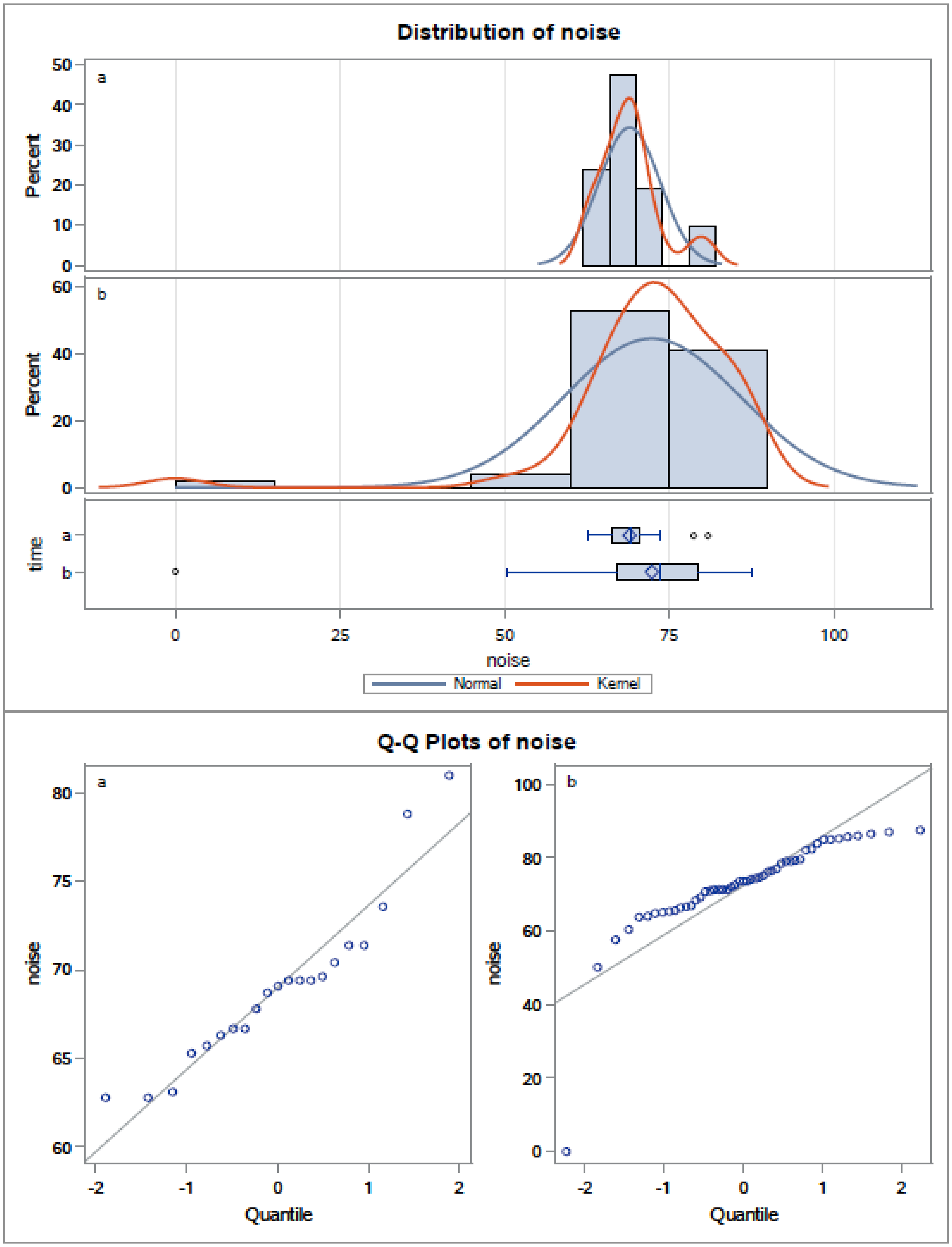
time	Method	Mean	95% CL Mean		Std Dev	95% CL Std Dev	
a		69.0190	66.9055	71.1326	4.6432	3.5523	6.7052
b		72.3980	68.5381	76.2578	13.4380	11.2062	16.7881
Diff (1-2)	Pooled	-3.3789	-9.3994	2.6415	11.5676	9.9080	13.9003
Diff (1-2)	Satterthwaite	-3.3789	-7.7127	0.9549			

Method	Variances	DF	t Value	Pr > |t|
Pooled	Equal	68	-1.12	0.2667
Satterthwaite	Unequal	66.148	-1.56	0.1243

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	48	20	8.38	<.0001

The TTEST Procedure

Variable: noise



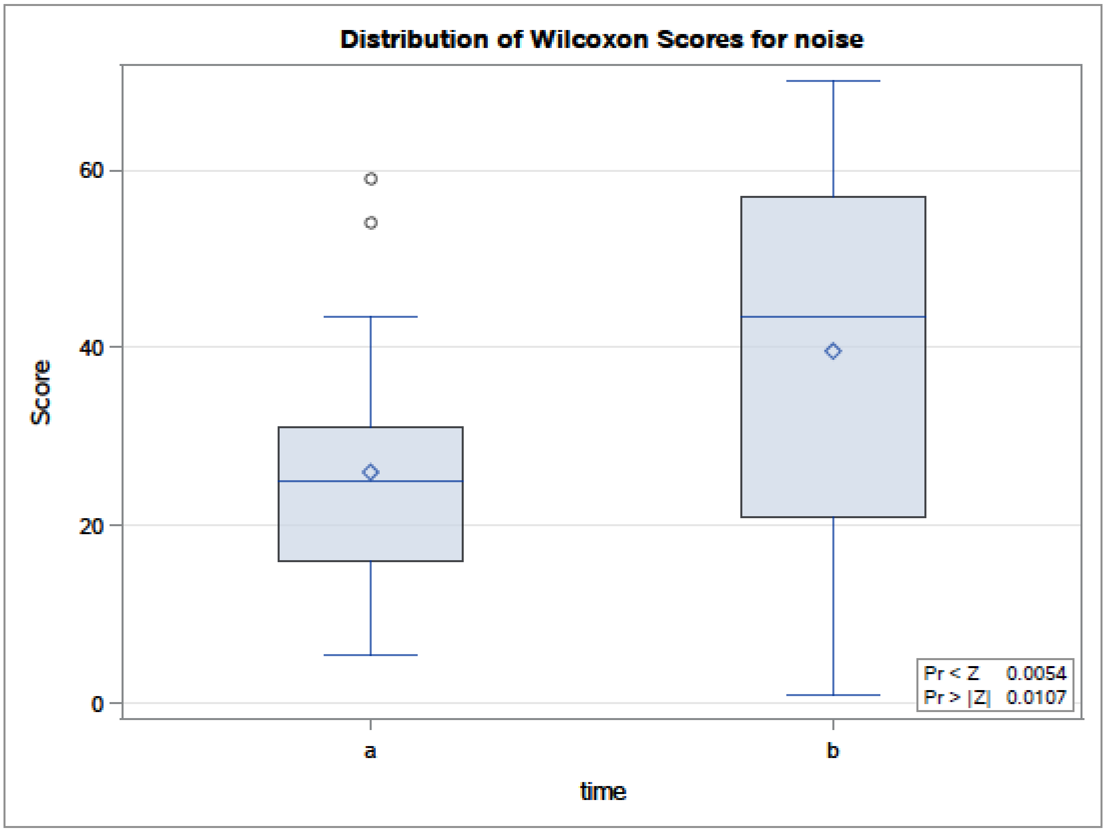
The NPAR1WAY Procedure

Wilcoxon Scores (Rank Sums) for Variable noise Classified by Variable time					
time	N	Sum of Scores	Expected Under H0	Std Dev Under H0	Mean Score
a	21	546.0	745.50	78.012903	26.000000
b	49	1939.0	1739.50	78.012903	39.571429
Average scores were used for ties.					

Wilcoxon Two-Sample Test	
Statistic	546.0000
Normal Approximation	
Z	-2.5509
One-Sided Pr < Z	0.0054
Two-Sided Pr > |Z|	0.0107
t Approximation	
One-Sided Pr < Z	0.0065
Two-Sided Pr > |Z|	0.0130
Z includes a continuity correction of 0.5.	

Kruskal-Wallis Test	
Chi-Square	6.5396
DF	1
Pr > Chi-Square	0.0105

The NPAR1WAY Procedure



15. Appendix D: Corporate Dust Sampling Program

POLICY

Corporate dust sampling program addresses two primary types of dust – respirable and total. Respirable dust is a term that describes the aerodynamic size of dust particles - generally ≤

10 μm in aerodynamic diameter. Respirable dust particles may penetrate into the gas exchange region of the respiratory system and may be too small to be removed by the lung's defense mechanisms, making them more likely to be retained. Retained respirable dust particles, particularly if they are composed of crystalline silica, may cause deleterious health effects. Conversely, total dust is any airborne dust particulate, regardless of aerodynamic diameter, and is generally considered to be less hazardous than respirable dust.

Corporate Dust Sampling Program includes two basic sampling techniques. The first is known as **personal** sampling where samples are obtained by placing the dust-collecting filter within an individual's breathing zone. The second technique is known as **area** sampling. Here the dust-collecting filter is placed at a stationary, designated general work area. Personal sample results are characteristic of the amount of dust that an individual is exposed to during the course of a work period. Area sample results are characteristic of the amount of ambient dust within a specific area of a facility. Both sampling techniques are valid and necessary for a complete evaluation of the workplace environment.

Personal sampling is conducted to determine if dust exposures of corporate employees are within either government approved exposure limits or internal objective limits. Federal inspectors collect personal samples and the subsequent analysis of these samples will be used to determine whether or not a facility will be cited for violating permissible exposure limits.

Area samples are used as a supplement to personal sampling to evaluate individual processes or a group of processes and the associated workplace dust emissions. Area sampling is also used to document the effectiveness of dust control devices or procedures.

Although personal and area samples can be collected at the discretion of plant management, an annual sampling plan for both area and personal sampling will be established in coordination with the Safety & Health Department. The number of samples and their locations will vary by facility, but the objective is to characterize individual employee exposures and operational workplace emissions. For operational workplace emissions, area samples will be collected repeatedly, over time, at the same designated locations. Sampling plans will be evaluated by plant and Safety & Health personnel prior to the start of each calendar year.

PROCEDURES

Personal Sampling

When conducting respirable dust sampling, a size-selective sampling device (cyclone) is used. When conducting total dust sampling, a cyclone assembly is not used within the sampling train. Whether sampling for respirable or total dust, the filter will be placed in the employee's breathing zone, usually by attaching the unit to the wearer’s collar or upper lapel. The pump should be attached to the employee's body in such a way as to not interfere with the typical movement patterns associated with his/her work. Once the employee has been selected, and the pump has been prepared [assure that the oversize reservoir (nylon piece at bottom of cyclone that screws off) is emptied prior to sampling if performing respirable dust sampling] and calibrated, the instructions listed below should be reviewed with the employee.

1. Inform the employee that the pump should not interfere with normal work procedure;

2. Instruct the employee not to cover the inlet of the cyclone nor tamper with the cassette. The employee is also to be instructed not to remove the sampler unless approved by the Safety & Health Supervisor and if removed, the sample train should not be inverted nor laid down on its side
3. Emphasize the need for the employee to continue to work in their normal **routine** manner and to report any unusual occurrences during the sampling period, especially if they may have encountered visible dust;
4. Instruct the employee to accurately complete the Activities Log for Dust Pump Testing (Exhibit G1-1) if another person is not present to do so;
5. Explain to the employee what is being accomplished, what the sampling device does, and the reason for taking the sample; and
6. Inform the employee when and where the sampler will be removed. The employee should also be told how to contact the Safety & Health Supervisor should a problem arise during sampling.

When obtaining a personal sample, it is imperative to describe the employee's activities completely and accurately during the sampling period. This should be done using the Activities Log for Dust Pump Testing (Exhibit G1-1). In addition to noting the individual's activity during the particular sampling period, it is necessary to note if this is a normal work period or if the employee normally does something different. A complete description of an individual's activities is necessary to enable an evaluation of possible causes for elevated sample results. For example, if an employee with elevated sample results notes that he/she spent three (3) hours cleaning a screen and previous area sample results from that process demonstrates high emissions, we can focus on the most likely cause of the elevated personal sample results. When completing the

Activities Log it is important to note activities and the associated time spent doing the activities, such as cleaning screens, cleaning floors/beams, time in control rooms, time repairing suspected sources of dust, time bagging, time loading pallets, time on top of rail cars, etc. The purpose is to note the activity and associated time where elevated as well as minimal dust exposures can be encountered. A concise description of events taking place during the sampling day should be included in the comments section of the dust sample record when entered into ONLINE. Dust sampling data stemming from regulatory sampling shall be entered into ONLINE to provide additional dust exposure information in the corporate dust exposure database.

The steps listed below will be followed for all personal samples that are obtained in the breathing zone of employees. Appropriate results should be recorded in the Pump Calibration Record (Exhibit G1-2):

1. Only use a fully charged sampling pump and ensure that the sampling train has been calibrated properly – 1.7 liters per minute (lpm) for respirable dust sampling and 2.0 lpm for total dust sampling;
2. The battery powered sampling pump will be attached to the employee's person, usually on a belt about the waist;
3. Start the pump and record the time; and
4. Check the flow rate of the sampling pump at the end of the first half-hour and periodically (approximately every two hours) thereafter to ensure proper flow rate. Note the time the test is terminated. The flow rate using a calibrator should also be checked at the end of the test and should be within five (5) percent of the beginning flow rate. Both the before and after flow rates should be recorded on G1-2.

Select one unused filter per batch of samples as a control filter or blank. This means that if your plant collected 10 samples as a batch over the period of a week, then the lab should receive 11 filters – 10 samples and one blank. Regardless of the number of samples being submitted to the laboratory for analysis, a blank must always accompany the sample. Filters should be sent to the laboratory in a timely manner, so avoid accumulating filters from multiple testing dates

The blank or control filter will be used to determine the amount of weight change on the filter due to outgassing from the filter or cassette. The amount of outgassing is related to the temperature fluctuation in the environment. The control filter must be exposed to the same time, temperature, and handling conditions as the ones that you are using for sampling. You should carry the control filter in your shirt pocket while making rounds to check on the samples and treat the control the same as the exposed filters when you are in the office or laboratory. **DO NOT REMOVE THE FILTER CASSETTE END CAPS OF CONTROL FILTERS.**

When sampling has been completed, the filter must remain in the cassette. Remove the filter cassette from the sampling train and place a stopper in the openings of each end of the filter cassette. Package the cassettes securely in a suitable container that will maintain their integrity while you arrange for the transfer of the samples to the laboratory for analysis.

Area Sampling

When obtaining a general work area sample, it is important to make sure that the sample location is representative of the general working area occupied by employees and the pump is not placed in a location where it is likely to be damaged as a result of normal work operations.

In some instances this will mean fastening the dust pump to a stationary or rigid object. Particular care should also be exercised in ensuring that the height of the dust pump approximates that of the breathing zone of the employees in the area. If conducting respirable dust sampling, ensure that the oversize reservoir (nylon piece at bottom of cyclone that screws off) is emptied prior to sampling.

Area samples are to be collected in accordance with an approved sampling plan developed cooperatively between each plant and the Safety & Health Department. Once established, area sample locations should not be moved, as this will affect the long-term dust emission database. Normally, additions and deletions of sampling locations would only occur with the addition or deletion of process operations. Area samples not related to the sampling plan can be obtained by plants for their internal information. Such situations could include the modification of a process and the resultant dust emission change; noted deterioration of a process where excessive emissions are suspected; or routine quality control reasons.

Direct Reading Sampling

A sampling device, other than the traditional dust sampling train, is available for evaluating workplace dust concentrations. Here, all respirable size dust concentrations are provided via direct reading devices - laboratory analysis is not required. The hand-held meter is placed in the desired sampling site and an instantaneous reading of all respirable dust is provided. A frequently used meter of this type is called a pDR (Personal Data Recorder). These devices are highly effective detective tools used for determining, for example, sources of dust emissions. Because of the direct read-out capability, the device can be moved around in an area to locate "hot spots", thereby permitting further evaluation of the dust source.

Note that these meters are not acceptable by most regulators for compliance sampling although they are used by regulators as diagnostic tools. In addition, since these meters only provide data for all respirable dust, they do not provide data concerning the allowable dust limit at the sampled location since there is no meter capability for determining the amount of crystalline silica within the dust sampled.

Sampling Frequency

The number of PERSONAL dust samples to be collected within each existing job position within a facility is a function of the size of the work force, uniformity of dust exposures, and magnitude of exposures. Facilities with larger workforces, greater variability in exposures, and/or higher exposures will collect a greater number of personal samples, and vice versa.

The American Industrial Hygiene Association (AIHA) has determined that between six (6) and ten (10) personal samples are required to adequately characterize exposures for an individual job position, and Corporate subscribes to this approach.

Over time, the vast majority of corporate job positions have had far more than six personal samples collected and are accurately characterized. As such, sampling frequencies for these types of job positions are well established and only require minor changes from time to time.

However, job positions within facilities that are newly acquired, constructed, or that have undergone significant additions or modifications, require increased initial evaluation. In order to ensure accurate exposure characterization for job positions within these types of settings, a minimum of six (6) personal samples will be collected for each potentially affected job position. Such samples will be collected within six months of facility or process start-up. The establishment of a schedule for these baseline exposures will be developed in coordination with Safety & Health staff.

Sampling schedules for job positions already characterized are to be determined for each facility on an annual basis. This information is entered on a sampling plan developed cooperatively by each plant and the Safety & Health Department. Each plant will submit an annual sampling plan to Safety & Health for review and approval, following approval by the Plant Manager. Such schedule will be submitted during December of the calendar year preceding the plan year. An example sampling plan is provided at Exhibit G1-3.

The sampling plan ~~is~~ need not specify individuals being sampled, but should be organized by job description or job function. As with noise exposure, if a number of people perform the same function, a representative of the group can be sampled; the results therefore being characteristic of the others working at the same function. Sampling must be rotated among employees such that eventually personal samples will have been obtained for each person exposed to dust. Employees may perform the same task but their exposures can be greatly different because of individual work practices.

Samples Exceeding Permissible Exposure Limits

All operations will undertake a root cause analysis to determine the cause of all personal dust sample results that exceed permissible exposure limits when the cause(s) of the overexposure is unknown. Dust samples collected during root cause analysis will not be used for calculating the plant’s compliance with the dust objective. However, the sample that initiated the root cause process will be included in compliance calculations.

Dust sampling and resultant analysis is a scientific and expensive process, and each sample is considered to be important to the plant and to the corporation. Therefore, if a personal sample, either obtained by a regulator or by the plant, exceeds the permissible dust exposure limit and the reason for the overexposure is unknown, the following action must be taken:

If the result was an anomaly, such as an upset condition, the comments section of the Silica Data Entry Screen in ONLINE shall be edited to include such information, and additional sampling will not be required.

If the sample result is not an anomaly; then root cause analysis will begin, including additional sampling, to determine the reason(s) for the initial overexposure and should include a plan for subsequent mitigation. The procedure involves an analysis of the employee's activities that occurred during the initial sampling. If poor work practices or faulty process controls were involved, correct these and repeat dust sampling with the same employee doing essentially the same procedures but with identified corrections in place. If the result of this sample is within permissible exposure limits, two additional samples will be obtained under the same circumstances to statistically validate the results. The end result of this repetitive process will be three consecutive sample results that are within permissible exposure limits. Whenever feasible, a supervisor should periodically observe the individual being sampled. Root cause analysis should begin as soon as feasible after receipt of the initial report indicating an over exposure situation. A detailed activity log will be completed for each sample obtained and the results/findings of the root cause analysis shall be provided to Safety & Health via ONLINE. A Root Cause Analysis form is provided as Exhibit G1-4.

During root cause analysis, both work practices and equipment aspects should be evaluated as to their relationship, individually or in combination, to the cause for the excessive exposure. Once cause is determined, remedies can be instituted.

As used above, the word "Process" means: faulty engineering controls, lack of engineering controls, holes in ducts, bin leaks, excessive conveyor discharge, and loose screen covers, changes in the plant process, etc.

As used above, the term "Work Practices" includes: practices such as dry sweeping, throwing bags on pallets, removing bags too soon from loading spouts, not cleaning areas of silica prior to performing maintenance. Poor work practices also include driving mobile equipment indoors over silica that has spilled onto floors, letting sand accumulate within plants so that wind can cause it to become airborne, not removing or not correctly removing silica dust from one's clothing, etc. See Exhibit G1-8 for a listing of work practices.

Employee Notification of Dust Sample Results

General Area Dust Sample Result Notification

Within 15 days of receiving the results of laboratory analysis via ONLINE, general area dust sample results are to be posted conspicuously (e.g. lunchroom bulletin boards) for worker review.

Personal Dust Sample Result Notification

Within 15 days of receiving the results of laboratory analysis via ONLINE, personal ~~area~~ dust sample results are to be provided to the affected worker via Exhibit G1-9 entitled "Employee Notification of Dust Sample Results".

Sampling Techniques

It is imperative to practice good sampling techniques when obtaining personal samples since the minutest quantity of dust can lead to a sample exceeding the PEL. The filter assembly must be placed near the wearer's breathing zone (BZ) - attached at or near the collar lapel. A filter located away from the BZ i.e., stomach level or hanging loose so that it moves about when bending, etc., will not provide a good representation of the individual's exposure. Because of the nature of plant work, the further away the filter is from the breathing zone, the increased likelihood of a higher filter reading. Ensure that the wearer's clothing is free of dust prior to attaching the filter assembly and remove the filter before cleaning dust from clothing. If your facility has an approved clothes cleaning booth, make sure the sampling device is removed and left outside the booth during cleaning, being careful not to invert or lay the sampling train on its side. Body movement can cause dust on clothing to become airborne and the process of removing dust from clothing also cause it to become airborne and thus available for entry into the filter. Ensure that the air inlet to the filter assembly is pointing out and away from the wearer. Treat the filter assembly with care and avoid rough handling that could cause dust particles to enter either the assembly air inlet or the filter opening (when removing the filter from the assembly). If a wearer removes the sampling assembly during the course of sampling, ensure that it is put in a clean, dust-free, place until it is put on again. The importance of proper sampling techniques and wearer's responsibilities must be conveyed to all personnel being sampled

Pump Calibration

Since the results of dust surveys may be required in legal proceedings, it is imperative that dust pumps be properly maintained and calibrated. The results of all calibration tests will be recorded on the Pump Calibration Record form, Exhibit G1-2. When using the cyclone collection system, it is very important to calibrate the system as close to the required flow rate as possible; the acceptable range is +/- 5%.

It is recommended that electronic airflow calibrators be used as the primary means of calibration. Electronic calibration devices generally measure the time for a frictionless soap film to travel in a fixed volume from one point to another using infrared light beams. The measured flow rate is provided via a direct digital readout (e.g. 1.7 liters per minute, or whatever the desired flow rate was to be). Electronic airflow calibrators are fast, rugged, small, transportable and easy to use. An alternative to the electronic calibrator is the manual bubble/burette method. Both methods are traceable to the National Institute of Standards and Technology and thus ensure the accuracy of a primary standard for calibration. Both methods are described in Exhibit G1-5.

Pump calibration shall be performed before and after each use of the sampling pump to ensure the accuracy of flow rates throughout the sampling period. Calibration shall follow the selected method found in G1-5. Both calibration methods require that the entire sampling train be used which consists of the cyclone assembly with a filter cassette and requires the use of a calibration jar that can be easily fabricated or purchased.

Plants shall run duplicate side-by-side personal dust samples with any regulatory authority conducting personal samples. In the event the plant does not have enough sampling pumps to conduct duplicate side-by-side samples with each individual being sampled by the regulator, the position(s) having the greatest likelihood of an overexposure should be sampled. Because regulators typically do not provide advance notice of dust sampling activities, each site must have its own means to perform proper calibration of their dust sampling pumps described above. Several models of electronic calibrators are available from Buck, Gilian (Gilabrator) and MSA.

Dust Survey Analysis

Dust samples are analyzed by the DCM Science Laboratory located in Wheat Ridge, CO. Upon completion of a dust sample, sample data is to be provided to Safety & Health via the

ONLINE silica data entry page (https://www.corporatesafety.com/scripts/silica.asp). Sampling data must be entered into the ONLINE system ***prior*** to the filters being shipped to DCM. Exhibit G1-7 is the aforementioned data entry screen.

The information provided via the ONLINE data entry page are, in combination with the analytical results, used to generate a Dust Sampling Summary (Exhibit G1-6). The summary can be generated from the ONLINE Dust Sampling Data Page found at https://www.corporatesafety.com/scripts/silica.asp. The information contained in the Summary is to be used by plants for the operation of their dust prevention programs. For clarity, each of the headings is described:

ID: This is a unique record identifier automatically generated by ONLINE upon record entry.

Plant Name: Corporate plant where samples were obtained.

Country: Country in which the plant is located.

Sample Date: Date when samples were obtained.

Sample Number: Number that appeared on the particular filter cassette.

Last Name: The last name of the employee sampled.

Sample Type: This will indicate whether the sample was a personal (PS) or general area (GA) sample.

Contaminant: This column will indicate what contaminant was sampled for.

Job Classification: Area or job where the sample was obtained. Not necessarily the permanent job of an individual but what or where the individual was or was doing when the sample was obtained.

Job Title: The job title of the person who was sampled.

Silica Conc. (mg/m^3): The concentration of respirable quartz of the sample determined by dividing the weight of respirable quartz in milligrams by the volume of air sampled in cubic meters.

Dust Conc. (mg/m^3): The concentration of respirable dust of the sample determined by dividing the weight of respirable dust in milligrams by the volume of air sampled in cubic meters.

Variance: The variance of the sample determined by dividing the concentration of respirable dust by the Permissible Exposure Limit (PEL). A value that exceeds unity (i.e. >1.0) means an overexposure has occurred. A value that does not exceed unity (i.e. $\leq$1.0) means the sample was within the allowable limits.

PEL: The MSHA Permissible Exposure Limit. The time-weighted average workday exposure above which people should not be exposed. Exposures above this limit, if collected by MSHA, will normally result in MSHA citations. The

PEL, in milligrams per cubic meter, is based on the formula: 10/(% quartz + 2).

Exposure Category: Exposure category is based on the sample result in terms of the respirable silica (quartz) concentration. Category I means the sample concentration was less than 50 ug/m^3 (micrograms per cubic meter) respirable silica. Category II means the concentration was 50-99 ug/m^3. Category III means the concentration was 100-200 ug/m^3 and Category IV means the concentration was more than 200 ug/m^3.

Upset: This column will indicate whether any anomalies (i.e. upsets) were identified during the sampling period.

Root Cause: This column will indicate whether the sample was associated with a root cause analysis.

In order to maintain an accurate history of an employee's exposure to dust, it is necessary to track the different positions he/she has held at the plant. It is also important to track breaks in service such as lost time due to injury and/or layoff. The Personal Change Authorization (PCA) process accomplishes this.

The database for dust results requires standardization to be meaningful. Therefore, the following, and only the following, job classifications are to be used for describing the location of area samples and the location of an individual that was sampled. If the data entered on the Personnel Change Authorization does not conform to these descriptors because of accounting terminology, enter the correct descriptor in the "Remarks Section" box of the Personnel Change Authorization.

Administrative

Bagging

Crushing

Drying

Loadout

Maintenance

Milling ***Mining***

Screening ***Wet Process***

Sample Submission

Dust samples shall be submitted directly to DCM Laboratories. The address is:

DCM Laboratories

12421 W. 49th Avenue, Unit #6 Wheat Ridge, CO 80033

Our point of contact at DCM is Cindy Mefford (cindymeff@aol.com) who can be reached by phone at (800) 852-7340 or 303-463-8270; fax 303-463-8267.

Other than Dust Sampling

There may be instances when the Safety & Health Supervisor has questions concerning employee exposure to contaminants other than dust. The supervisor should contact the Safety & Health Department for assistance since this department has the capability and contract laboratory support to sample for a variety of contaminants, as well as otherwise evaluate employee exposures. The Safety & Health Department should be provided with basic information such as the reason for concern (visible emissions, employee complaints, etc.), the suspected material, and other information or circumstances that would aid in an initial evaluation.

16. Appendix E: Corporate Hearing Conservation Program

POLICY

The purpose of this Hearing Conservation policy is to prevent hearing loss, especially from occupational exposure to noise. Procedures detailed in this policy encompass a Hearing Conservation Program (HCP) and are based primarily on the requirements set forth in 30 CFR Part 62.

The procedures outlined below are to be considered minimum requirements for any Corporation facility. Where the Corporation procedures outlined below are more stringent than local laws or regulations, Corporation procedures shall be applied. Where local laws or regulations are more stringent than the Corporation procedures outlined below, local laws and regulations shall be applied.

PROCEDURE

Inclusion in a Hearing Conservation Program ("HCP") - Each Corporation operation will develop a local HCP for those employees, who during the course of employment, could be exposed to an 8 hour average noise level of 85 dBA or greater (equivalently 50% with an 8 hour PEL of 90 dBA). This value of 85 dBA or 50% of the allowable dose is referred to as the Action Level ("AL"). Employees exposed to noise at or above the AL will be included in a HCP.

Employees not included in a HCP will receive an audiogram at initial employment and every two years thereafter as part of Corporation's medical surveillance program. The inclusion of employees with noise exposures less than 50% of the allowable dose is optional. All employees and visitors will use hearing protectors when in areas where signage requires their use.

Permissible Exposure Level - The Permissible Exposure Level (PEL) for noise is a time weighted eighthour average (TWA8) exposure of 90 dBA. No employee will be exposed to noise exceeding a time weighted average exposure over a calculated period of 8 hours of 90 dBA during any workshift, or equivalently a dose of 100%. Allowable exposure periods for noise levels greater than 90 dBA are provided in Exhibit F2-1, page 7. An upper noise level limit, or ceiling value, of 115 dBA has been established and no employee is to be exposed to noise levels exceeding 115 dBA. A single impact sound, such as a hammer blow, will not violate this ceiling value. Personal exposure levels measured are evaluated without regard to the protection provided by hearing protectors.

Noise Monitoring - Noise exposure determinations must first be made in order to determine whom, if any, of an operation's employees are to be enrolled in a HCP. When evaluating a person's noise exposure, operations should consider the possibility that an individual could work as a substitute at a work position where the exposure would exceed the Action Level.

When determining which employees are exposed to 8-hour time weighted noise levels of 85 dBA or greater (or equivalently a dose of 50% or more of the permissible exposure level) the dosimeter will be set on A scale, slow response, and integrating noise levels from 80 dB to 130 dB. Employees with 8-hour time weighted noise levels of 85 dBA or greater (or equivalently a dose of 50% or more of the permissible exposure level) will be included in the plant's hearing conservation program. They will also wear hearing protectors when in areas where the noise level is 85 dBA or greater.

When determining if an individual's noise exposure is in excess of the Permissible Exposure Level of 90 dBA for an 8-hour time weighted exposure (or equivalently a dose of

100%), the dosimeter will be set on the A scale, slow response, and integrate noise levels from 90 dBA to 140 dBA. Dosimeters inherently account for exposure periods other than the normal eight hour workday and the dose, a percentage of that allowed, as shown on the dosimeter will be the actual dose for the period of time the meter was in operation. Persons exposed at or in excess of the Permissible Exposure Level will wear hearing protectors and efforts will be made to reduce their noise exposure to below the PEL.

Exposure is normally determined by attaching noise dosimeters on individuals for their workshift. For those workplaces with low noise levels, administrative decisions can be made as to inclusion in the hearing conservation program based on hand-held meter readings. Dosimeters can be used as hand-held noise survey meters (sound level meters) where noise levels are read directly from the meter. Plants, or areas of plants, having low noise levels can be evaluated using the dosimeter in the sound level meter mode. Here the meter readings would be obtained at each work area of the individual in question (those areas where the individual would work throughout his/her workshift). If all values were less than 85 dBA, there would not be a requirement for full workshift dosimeter determinations for that individual. These readings must, however, be recorded since regulators generally have access to all noise data. If it is determined that full workshift dosimetry is necessary, sampling should begin by job description and work down to each individual employee. In addition, sampling should begin with those job descriptions where the noise exposure is thought to be the greatest. Dosimeters should be positioned with the microphone affixed at the shoulder/collar area, as close to the ear as feasible. Noise sampling should not be necessary for office staff.

Dosimetry sampling shall be conducted annually at each operation on all job classifications and should be representative of the work normally done by each employee sampled. It may be necessary to sample an individual more than once if he/she works in or around a high noise area in order to obtain a representative sample. Be conservative and include individuals in the hearing conservation program even if only a few of their samples obtained exceed the Action Level. All dosimetry data (collected by a Corporation employee or by a regulator) must be entered into the Corporation Safety Information System (ONLINE) to ensure that accurate records of employee exposure are maintained.

The determination of which, if any, of your employees should be included in a hearing conservation program is the plant's decision. That decision should be made based on documented noise data; either sound level meter readings or dosimetry data.

Exposures Exceeding the PEL - If an employee's noise exposure exceeds the PEL, all feasible engineering and administrative controls will be used to reduce the employee's noise exposure to or below the PEL. If these controls are not feasible or do not sufficiently reduce the noise exposure, then hearing protectors will be used. These employees will also be included in the hearing conservation program. Dual hearing protection (plugs and muffs) will be used if an employee's noise exposure equals or exceeds a TWA8 of 105 dBA during any workshift, or equivalently a dose of 800%.

Contents of a Hearing Conservation Program - A HCP consists of: monitoring and documentation of employee noise exposures; employee written notification of noise exposure; employee training; audiometric testing (baseline and annual thereafter), employee notification and follow-up; recordkeeping; reduction of excessive noise exposure; and the selection, fitting and use of hearing protectors. See Exhibit F2-1 for detailed information.

Responsibilities - The safety and health supervisor (unless otherwise designated by the plant manager) is responsible for day-to-day operation of the plant HCP. It is management responsibility to reduce employee noise exposures through engineering and administrative means wherever feasible. Supervisors are responsible for ensuring employees under their control properly care for and use hearing protectors and otherwise comply with this policy. Employees are responsible for proper care and use of hearing protectors as well as compliance with appropriate aspects of this policy.

Signage - For any work area where the noise level exceeds 85 dBA or has an impact noise level exceeding 140 dB, the area shall be conspicuously posted as requiring hearing protection. Signage may read:

CAUTION: HEARING PROTECTION MUST BE WORN IN THIS AREA.

Observation of Monitoring - Affected employees or their representatives will be afforded an opportunity to observe noise exposure monitoring. Management will provide advance notice of the date and time of intended exposure monitoring to affected miners and their representatives.

Records -

Access- Regulators generally have access to all records associated with noise monitoring.

Noise Records to be Maintained - The following records are to be retained by plants:

Noise exposure measurement records and notifications. All exposure determinations that generate written worker notification (above Action Level, the PEL, the dual hearing protection level, or the ceiling level) shall be maintained along with the worker notification documents. These will be maintained for the duration of the worker’s exposure above the action level and for at least 6 months thereafter.

Training records. The most recent certified training record for each worker will be maintained for as long as the worker is exposed to a noise level of 85dBA or greater and for at least 6 months thereafter.

Audiometric records. All audiograms, records of examinations and evaluations by physicians, audiologists or other health care providers relating to hearing loss, and individual worker audiometric notifications will be maintained for each individual for the duration of employment plus at least six months. All audiometric equipment certifications provided by the audiometric testing service will be maintained.

Regulator hearing loss reports. Regulator reports for noise-induced hearing loss shall be maintained for the duration of employment with copies provided to the Corporate Safety & Health Department.

Plants will maintain a copy of each person's baseline audiogram and a copy of the most current audiogram. Originals of all audiograms will be sent to the Corporate Safety and Health Department where they will be retained for 30 years beyond employment of each employee. Training and employee notification records will be maintained at plants. Noise measurement data will be entered in ONLINE.

Program Evaluation - Corporation operations will periodically review employee noise exposures and their HCP. Changes in process equipment, wear and tear of equipment, and the addition of process equipment can result in the addition of persons to the HCP, depending on the resulting measured individual noise doses. These changes should be evaluated as they occur. Noise exposures of existing persons within the HCP should be determined on a periodic basis, sufficient in frequency for plant management to be assured that the worker's exposure has not increased or decreased. An increased exposure could result in reduced exposure time to the high noise level. A major decrease could allow the person to be removed from the HCP.

SIGNATURE PAGE

This is to certify that the thesis prepared by Lindsie Wilson entitled "Evaluation of Automated vs. Manual Bagger Exposures to Ergonomics, Dust, and Noise at A Sand Mine Processing Plant" has been examined and approved for acceptance by the Department of Safety Health and Industrial Hygiene, Montana Tech of The University of Montana, on this 11th day of December, 2015.

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