Recommendations to Improve Safety in Potato Harvesting and Packing in Southern Colorado HHE-980172


Richard Unger and Kim Cornelius of the NIOSH Pittsburgh Research Laboratory (PRL) traveled to the San Luis Valley in Colorado at the request of the NIOSH Denver Field Office to provide assistance on a study related to injuries in the potato production and packing industry. This work was conducted under an agricultural HHE requested by Colorado State University which involves defining the extent and nature of injuries in the industry and advising farmers and packers about effective controls to reduce the risk of injury. PRL researchers, along with Jane McCammon, NIOSH, and Lori Berberet, CSU, visited a number of harvesting and packing operations. During the walk-throughs, the team collected data and provided verbal suggestions concerning equipment modifications to reduce the risk of hand and back injuries. This is a summary report with specific recommendations for the industry.

Issues:

- Lifting
- Personal Protective Equipment
- Stairs Walkways and Ladders
- Workstation Design

An shorter version of this report, Recommendations to Improve Safety in Potato Production and Packing in Southern Colorado, (1600K - all the movies are missing) can be viewed and printed in Adobe Acrobat (PDF) format. To read and print publications in this format, you must first install the *free* Adobe Acrobat Reader from Adobe Systems, Inc.

Information about the authors of this report can be found in Contact Information. Definitions of some of the more technical terms found in the report are listed in the Glossary.

Lifting

The spine is a sensitive mechanism. Over time, improper lifting can cause irreversible damage that can lead to permanent injury.

Issue - High load weights, repetitive lifting of heavy loads and improper workstation design

- At some facilities, workers were required to lift 100 pound sacks of potatoes. *This weight is well above the threshold of what one person can lift safely.* There is concern that handling these weights is putting these workers at a significant risk of developing cumulative trauma injuries as well as acute back injuries. The risk to the worker is increased due to the unstable nature of heavy loads packaged in sacks. The workstation design requires workers to lift loads above their shoulders and below their knees which also increases the risk of both cumulative and acute injuries.

- Workers were observed making repetitive lifts of 50 pound boxes at a workstation that exposes them to risk of injury. Workers were observed lifting 50 pound boxes of potatoes from roller belt lines only 16 to 19 inches from the ground. The lifting height of the box is below the knee height of most workers. These boxes were lifted and placed on pallets that were stacked to heights above the workers' heads. *This task puts workers at risk of back and shoulder injury*.

  The NIOSH lifting equation is a tool used to assess a lifting task and given the conditions, determine a Recommended Weight Limit (RWL) for the task. The RWL is calculated using the equation which starts with a lifting constant of 51 pounds and takes into account characteristics of the load and the lifting conditions such as, horizontal (H) and vertical (V) location of load, the distance the load will be moved (D), asymmetry (A), frequency of the lift (F), hand coupling for the load (C), and the length of time during which the lifting will take place. The starting point of 51 pounds is discounted by these variables resulting in a lower weight suited for the conditions. Thus, the recommended weight that should not be exceeded assuming *ideal* lifting conditions and techniques is 51 pounds. Ideal conditions are not realistic when calculating a recommended weight limit for most tasks, thus 51 pounds will invariably be reduced to a lower weight.

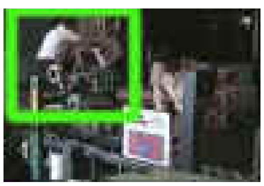
  The following examples illustrate what the recommended weight limit for the conditions under which the task is being performed.

Situation 1

The worker is lifting a bag from a starting vertical height of 34 inches and placing the box at a vertical destination above the shoulders, approximately 65 inches high. The box is held reasonably close to his body (use best case of 10 inches). The shape of the box is good, but there are no cut-outs or handles for the hands, so the hand-to-container coupling classification is fair. The worker is performing the lift with little asymmetry. The worker handles approximately 4 boxes per minute and is lifting these 50 pound boxes throughout his eight hour shift. The variables used in the NIOSH equation, in this case, H=10 inches, V=34 inches, D=29 inches, A= 1, coupling classification is fair, frequency is 4 lifts/minutes and the duration is 8 hours.

With these conditions, the recommended weight limit (RWL) is 20 pounds at the origin and 15 pounds at the destination. The lifting index (LI) is 2.6 at the origin and 3.4 at the destination. An LI value of greater than 1 indicates the task is hazardous for some portion of the population and a value greater than 3 indicates the job is likely to be a problem for much of the population.

Situation 2



This worker is lifting 50 pound boxes coming down a line that is about mid-thigh height, approximately 28 inches from the ground. The worker holds the box reasonably close to his body (10 inches) when he retrieves it, however, when he places it at the destination, the box is away from his body (24 inches) as he places it behind another box on the pallet. The vertical height is approximately 30 inches at the boxes destination. Hand coupling is fair and asymmetry is minimal. Specifically in this case, H=10 inches at origin (24 inches at destination), V=28 inches, D=2 inches, A= 1, coupling classification is fair, frequency is 3 lifts/minutes and the duration is 8 hours.

Using this situation, the RWL is 28 pounds at the origin and only 12 pounds at the destination, giving the task a lifting index of 1.8 at the origin and 4.3 at the destination.

Note that for both situations, as the pallets are loaded with boxes of potatoes, the destination height will increase and placement of the box will vary, however, the origin remains constant. Thus, even though these workers are doing this job over the course of their shift, the numbers will vary slightly. Although these examples may demonstrate extreme situations (one worker placing the box about head height, and the other reaching far away from his body), this task is still of concern. For instance, the extreme situation in both cases is at the destination. The box origin for the lift is not too extreme and yet the RWL is 20 pounds for situation 1 and 28 for situation 2. This is due to the repetition involved and the task being carried out over an eight hour shift.

The **Army's MIL-STD-1472**, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, addresses lifting, and it was examined to confirm recommended lifting limits. Using just a single lift evaluation (not repetitive, as is the case with these workers) for a lift performed by the male only population, a lift from the floor to a surface not greater than 5 feet above the floor is 56 pounds (not much more than these potato boxes). However, when you take into consideration the frequency of the lifts (if the worker is lifting 4 per minute), this number is reduced to *37 pounds*. At three lifts per minute, the maximum load under these conditions is *42 pounds*!

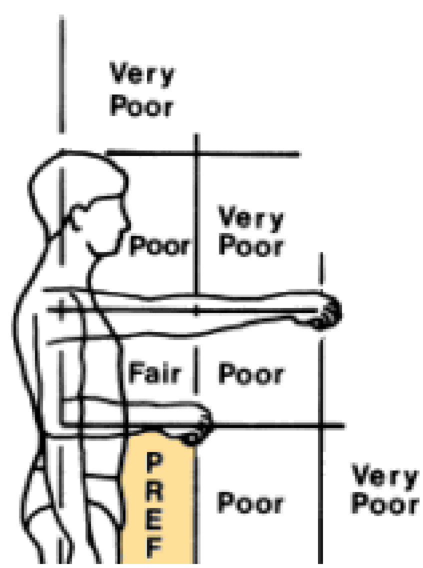
Issue - Back Belts

- At some facilities, workers were observed wearing back belts. In those cases, it appeared that the belts had been distributed to workers across the board. Currently, evidence on the effectiveness of back belts is inconclusive and is currently being researched by NIOSH. Providing back belts to all employees is not recommended; they should be distributed only on a case by case basis. It is more effective to assess the lifting task to ensure that it can be accomplished without exceeding the capabilities of the worker and make appropriate changes. Wearing a back belt is a band aid approach where the real problem may not be addressed. When workers are given back belts, they may attempt to lift more weight than they would without it. NIOSH recommends that employers and workers minimize their risk of back injury by developing and implementing a comprehensive ergonomics program. See NIOSH's SELECTED TOPICS Ergonomics and Musculoskeletal Disorders to learn more on the current back belts information available from NIOSH, including Back Belts - FACTS: June 1997, Back Belts -- Do They Prevent Injury? and Workplace Use of Back Belts Review and Recommendations.

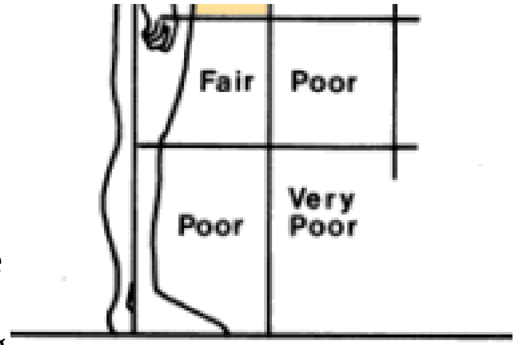
Recommendations

Both the NIOSH lifting equation and the Army standards indicate that these lifts are outside the recommended safe lifting guidelines. At this point, administrative and engineering controls are appropriate and need to be implemented to reduce the risk of injury to the workers. The following recommendations are made:

First, the potato harvesting manufacturers should discontinue packing potatoes in 100 pound sacks because it places their workers at risk. Then, the distributors should be informed that it is not to their benefit to request 100 pound bags because it places their workers at an increased risk of injury when handling these heavy loads. Lifting a 100 pound object is a two person lift. As a repetitive task, this is not suitable for workers to be handling and would only be acceptable if transported by machines. It is strongly recommended that the potatoes packaged in 100 pound sacks no longer be used. Sacks should be avoided due to the potential for the load to shift while handling. If there is a concern that distributors want 100 pound bags then it is important to educate the



distributors to the fact that their workers are at risk too.



Second, the optimal vertical lifting height for handling heavy materials is between the shoulder and knees of the worker. The figure at the right (Pheasant, 1996) illustrates the preferred area for handling materials and categorizes zones which are not preferred. Note that the worst scenario is above shoulders, below knees and anything more than a forearm length distance from the body. Workers should avoid bending low or lifting high to reduce the risk of injury. Boxes rolling off the line should be channeled to a height approximately 33 inches from the ground. This would put the boxes about hip height for most workers. Boxes should be piled on pallets no higher than shoulder height, approximately 50 inches. Additional benefit would be gained from using a spring loaded lift for the pallets to keep the workers from bending over or stooping to ground level. These changes to the workstations where 50 pound boxes are handled would help to reduce the risk of injury to workers. However, a long term goal should be to set the standard of the weight of packaging potatoes to a lesser amount. There is no basis for why the boxes need to be 50 pounds. And rather than arbitrarily select a new number, a thorough analysis of the task would need to be conducted to determine an appropriate weight for these boxes.

Finally, a Materials Handling Checklist may be useful to employers and employees to help reduce the risk of developing back injuries in the workplace.

Note: an Applications Manual for using the NIOSH Lifting Equation is available online and should be consulted before using the formulas for designing tasks.

NIOSH has a guide, Elements of Ergonomics Programs that provides basic information useful for employers, workers, and others in designing effective programs to prevent work-related musculoskeletal disorders (WMSDs).

Materials Handling Checklist

This checklist was developed using material from two sources: Lifting Checklist for Employers (taken from A Guide to Manual Materials Handling, by A. Mital, A.S. Nicholson and M.M. Ayoub, Taylor & Francis Inc. Bristol, PA, 1993) and a checklist developed by American College of Occupational and Environmental Medicine.

Employer checklist

Lifting

- Provide mechanical assist devices, table or pallets to allow waist-height lifting
- Encourage employees to get assistance in moving bulky/ heavy loads
- Make loads smaller
- Eliminate risk of sudden movement or shifting load
- Reduce lifting and lowering distances
- Reduce carrying distances
- Schedule regular rest breaks for employees doing heavy physical work; ensure breaks are taken

Awkward Postures

- Examine workstations to ensure the equipment and work area allow workers to perform tasks in safest positions and postures
- Create good workplace design to minimize unnecessary bending, twisting, or reaching
- Eliminate space constraints that prevent good posture

Working Environment

- Provide clean workplace free of obstacles, spills, and elevation changes with good lighting and traffic patterns for materials movement
- Provide non-skid, cushioned floors
- Regularly review accident and injury records to identify problem areas and eliminate hazards

- Encourage early evaluation and treatment of injuries

Employee checklist

Lifting

- Keep lifted objects close to body at hip or waist level
- Evenly balance load with both arms
- Get help if load is too bulky or heavy to lift alone or split into smaller, lighter loads
- Take rest breaks and stretch
- Avoid twisting, bending, and reaching while lifting

Awkward Postures

- Monitor workstation and habits to incorporate improved ways to sit/ stand/ move
- Make sure work surface is at comfortable height
- Alternate between sitting and standing tasks
- Use a chair with good back support

Working Environment

- Maintain firm footing and wear comfortable, low-heeled, closed toe, non-slip shoes
- Reports and/ or work to eliminate hazards in the workplace
- See a doctor if you have a back injury or other illness

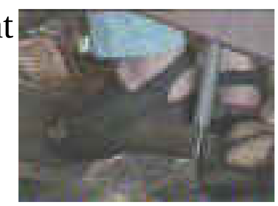
Personal Protective Equipment (PPE)

Personal protective equipment is not a substitute for good engineering, work practice, and administrative controls, but should be used in conjunction with these controls to provide for a safe and healthy workplace.

Issue - Personal Protective Equipment was not standardized and was often inappropriate for the work being performed.

- Most employees performing sorting operations wore gloves. However, many were observed wearing gloves that were too big, or too wide at the top opening. Many wore loose fitting rubber gloves.

- Shoes were variable as well. Many were observed wearing sneakers, and at least one employee wore open-toe shoes while working in the packing plant.



- Loose fitting clothing was common among employees working around conveyors and other moving machinery.

Recommendations - Personal Protective Equipment should be in good repair, correctly sized for the worker, and appropriate for the task. OSHA has some very good guidelines available online entitled Personal Protective Equipment, with information on choosing and using PPE. **These guidelines should be used as a reference to determine the PPE needs for each job involving potato harvesting and packing.**

A single free copy of the guidelines can be obtained from the U.S. Department of Labor, OSHA/OSHA Publications, P.O. Box 37535, Washington DC 20210 by sending a self-addressed mail label with your request.

Some general information about the various types of PPE available is listed below:

Safety Glasses And Goggles

Protective eye wear is required when flying particles, dusts, fumes, vapors or harmful rays are apt to expose the worker to potential eye injury.

- Safety Glasses - Standard safety glasses look very much like normal glasses, but are designed to protect against flying particles. Safety glasses have lenses that are impact resistant and frames that are far stronger than regular eyeglasses. Safety glasses must meet the standards of the American National Standards Institute (ANSI). Safety glasses are also available in prescription form for those persons who need corrective lenses. Safety glasses can be equipped with side shields, cups, or tinted lenses to offer additional protection.
- Safety Goggles, like safety glasses, are impact resistant and are available in tinted lenses. Goggles provide a secure shield around the entire eye area to protect against hazards coming from many directions.

Protective Hats

Head injuries are caused by falling or flying objects, or by bumping the head against a fixed object. Head protectors, in the form of protective hats, must resist penetration and absorb the shock of a blow. The shell of the protective hat is hard enough to resist the blow and the headband and crown straps (suspension unit) keep the shell away from the wearer's skull. Protective hats can also protect against electrical shock.

Protective hats are made in the following types and classes:

- Type I - Helmets with a full brim.
- Type 2 - Brimless helmets with a peak extending forward from the crown.
- Class A - General service, limited voltage. Intended for protection against impact hazards. Used in mining, construction, and manufacturing.
- Class B - Utility service, high voltage. Used by electrical workers.
- Class C - Special service, no voltage protection. Designed for lightweight comfort and impact protection. Used in certain construction, manufacturing, refineries, and where there is a possibility of bumping the head against a fixed object.

Safety Shoes And Boots

There are many types and styles of protective footwear and it is important to realize that a workers job may require additional protection other than listed here. Whatever the specific requirements are, ensure that the footwear meets established safety standards by checking for the American National Standards Institute (ANSI) label inside each shoe.

- Steel-Reinforced Safety Shoes - These shoes are designed to protect feet from common machinery hazards such as falling or rolling objects, cuts, and punctures. The entire toe box and insole are reinforced with steel, and the instep is protected by steel, aluminum, or plastic materials. Safety shoes are also designed to insulate against temperature extremes and may be equipped with special soles to guard against slip, chemicals, and/or electrical hazards.

- Safety Boots - Safety boots offer more protection when splash or spark hazards (chemicals, molten materials) are present.

When working with corrosives, caustics, cutting oils, and petroleum products, neoprene or nitrile boots are often required to prevent penetration. Foundry or "Gaiter" style boots feature quick-release fasteners or elasticized insets to allow speedy removal should any hazardous substances get into the boot itself. When working with electricity, wear special electrical hazard boots which are designed with no conductive materials other than the steel toe (which is properly insulated).

Gloves

Work gloves cannot prevent hand accidents - only safe and conscientious work practices can do that. But, choosing the right work gloves for the job can help protect from unnecessary injury and disability if an accident should occur. When protective hand wear is required for the job, make sure that the gloves fit well, are comfortable to wear, are rated to guard against the particular hand hazards present, and are checked often for degradation.

The following is a guide to the most common types of protective work gloves and the types of hazards they can guard against.

- **Disposable** - Disposable gloves, usually made of light-weight plastic, can help guard against mild irritants.
- **Fabric** - Made of cotton or fabric blends are generally used to improve the workers grip when handling slippery objects. They also help insulate hands from mild heat or cold.
- **Leather** - These gloves are used to guard against injuries from sparks or scraping against rough surfaces. They are also used in combination with an insulated liner when working with electricity.
- **Metal Mesh** - These gloves are used to protect hands from accidental cuts and scratches. They are used most commonly by persons working with cutting tools or other sharp instruments.
- **Aluminized** - Gloves made of aluminized fabric are designed to insulate hands from intense heat. These gloves are most commonly used by persons working molten materials.
- **Chemical Resistance** - These gloves may be made of rubber, neoprene, polyvinyl alcohol or vinyl, etc. The gloves protect hands from corrosives, oils, solvents.

Respiratory Protection

Respiratory protective equipment limits exposure to atmospheric concentrations of hazardous dusts, mists, vapors, fumes, and gases when engineering controls cannot eliminate the hazard. Respirator types include self-contained breathing apparatus, supplied air, and chemical cartridge.

Hearing Protection

Hearing protection, including plugs and muffs, should be worn in noisy environments.

Stairs, Walkways and Ladders

In a single or multi person work area, it is necessary to provide adequate access spaces, passageways and stairs.

Issue - The walkways and stairs that workers use to reach their workstations were unsafe in some places.

- In this example, the stairs consist of a piece of expanded metal bent into the configuration of steps. The angle of the steps is such that slips are likely and the expanded metal treads flex when they are stepped on, making for an unstable climbing surface.

- On this elevated platform, there is no guard rail to prevent the worker from stepping or tripping from the platform.

- Here, the platform surface is uneven due to matting installed to improve the comfort of the workers. The uneven surface increases the tripping hazard.

Recommendations - Special catwalk, ladder and stair design requirements are often associated with heavy mobile equipment or complex plant machinery. Planning for the ingress, egress or mounting of these special vehicles or workstations should occur *before* basic designs make it more difficult to create a suitable catwalk/ladder/stair and handrail system. The designer should integrate the catwalks, ladders, stairs and handrails into the overall machine or facility concept early enough so that the driver or worker will have a safe approach to the workstation and back again to the ground or floor. The relationships between the catwalks, steps or ladders and the associated handholds or handrails are particularly critical to the safety of the person using them.

Follow the principles in Basic Design Recommendations for Stairs, Walkways and Ladders, which are based on the published literature, in considering the design of these special types of entry devices.

Design Recommendations for Catwalks, Ladders and Stairs

Jump to: Open Catwalks Ladders and Stairs Catwalk References OSHA 3124 1997 (Revised)

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Open Catwalks

The floor of catwalks should have non-skid surfaces. Catwalks should have handrails on both sides, a mid-rail, and a toe board (figure 1). Avoid rough edges, bolt ends, and other protrusions.

The minimum width of a catwalk is 12 in. This minimum width requires walking "cat-fashion" (steps aligned fore-and-aft, figure 2). When used for emergency evacuation, or where personnel must carry a load, a minimum 16 in. width is preferable.(2)

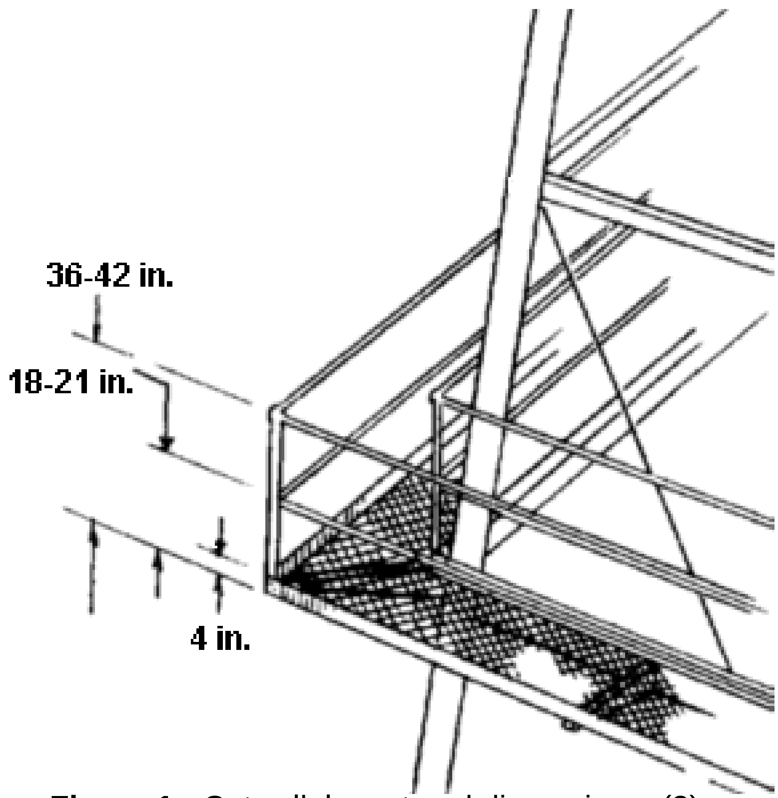

Figure 1 - Catwalk layout and dimensions. (3)

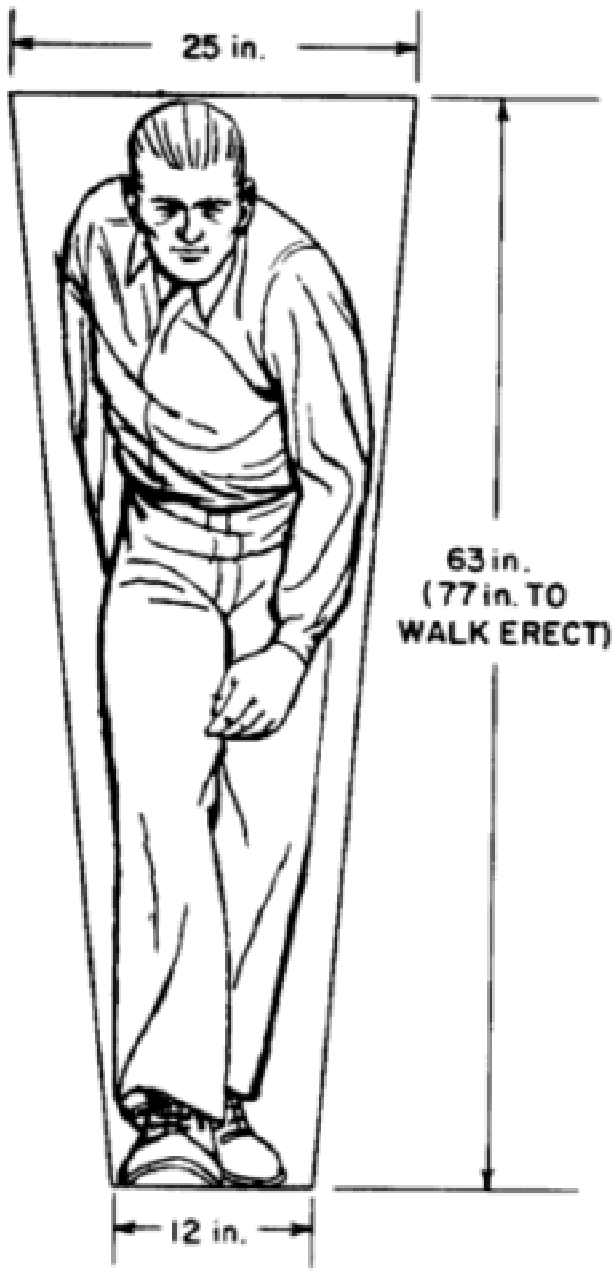

Figure 2 - Minimum catwalk widths. (2)

Ladders and Stairs

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Note: Additional information on Stairway and Ladder design is available online from the U.S. Department of Labor Occupational Safety and Health Administration OSHA 3124 1997 (Revised).

Use ladders where the desired rise from the horizontal is at an angle of 50° or more, or where a stairway is not practical. Use a stair ladder for inclines between 50° and 75°. Use a vertical ladder for angles greater than 75°. Use stairs for rises between 20° and 50°. Use ramps for inclines less than 20°.

Ladder Design Principles

- The first step from the ground must be reachable by the shortest expected user, and at least two handholds must be accessible to this person while he or she is still on the ground.
- The steps or rungs must accept the user's shoe, with the shoe being placed for a firm step; i.e., the midpoint of the shoe, not just the toe, must rest solidly on the step. Each step or rung should be sufficiently wide so that the person can stop and rest both feet on it.
- Plan the position of each succeeding step and its associated handhold so that the user's final entry into the vehicle will be compatible with sitting in the seat. Remember that when a person climbs a ladder, the hand and leg that are making the next move are on opposite sides of the body. If handholds and steps are not planned to conform to this natural "climb pattern," the person will more than likely end up with the wrong foot ready to enter the workstation; i.e., usually a person cannot hold and step from the same side without swinging. Do not create a system that forces the user to step on a hubcap, tire, or other irregular surface.
- Provide sufficient clearances for a person exiting the workstation to turn around and face a vertical ladder to climb down.
- The specific contour of handrails must follow the gripping, pulling, and supporting patterns associated with both entry and exit; entry and exit are generally quite different and sometimes require more than one handrail geometry.

Non Vertical (Stair) Ladders

Non vertical ladders should have flat horizontal treads (as opposed to round rungs) and two handrails. The most familiar example of this type is the ship's ladder, which usually rises at an angle of 68° from the horizontal (50° - 60° is a preferable range), with a clearance for only one person. Use separate up and down ladders for simultaneous two-way traffic. Two-way ladders should use a maximum tilt angle of 60°, preferably with a double handrail in the center. (2)

Figure 3 shows recommended dimensions for stair ladders. The optimum height between treads is 8½ to 9 inches. Treads should be open (without risers) and provided with non-skid surfacing. The depth of the tread depends upon the angle of the ladder. As a rule, the rear of each tread should overlap the front of the tread immediately above, varying from 1 in. for a 70° ladder to 3 in. for a 50° ladder. Although portions of the shoe may extend beyond this point, this design will be in contact with the weight-bearing portion of the shoe sole. Fasten metal screening to the underside of the ladder to prevent the foot from slipping through. When two or more flights of such ladders are one above the other, solid metal sheets instead of screening will protect those on the lower ladder from falling dirt particles, etc. Provide handrails with a non slip surface on both sides of the ladder. The handrail diameter should be between 1 1/4 in. and 1 3/8 in., with a spacing of 21 in. to 24 in. (figure 4). The recommended handrail clearance from an adjacent wall is 3 in. (2)

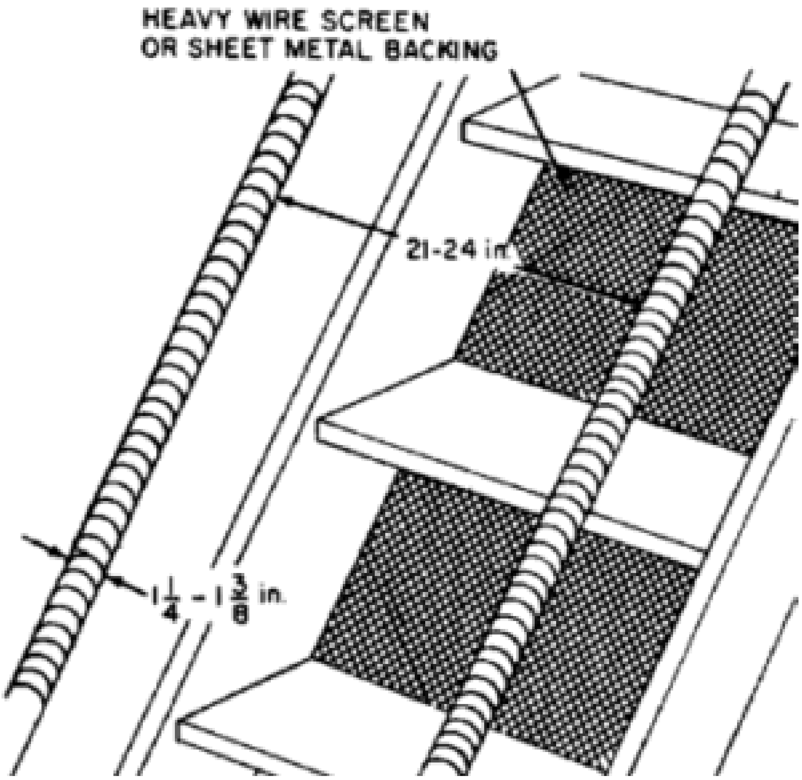

Figure 3 - Non vertical ladder dimensions. (2)

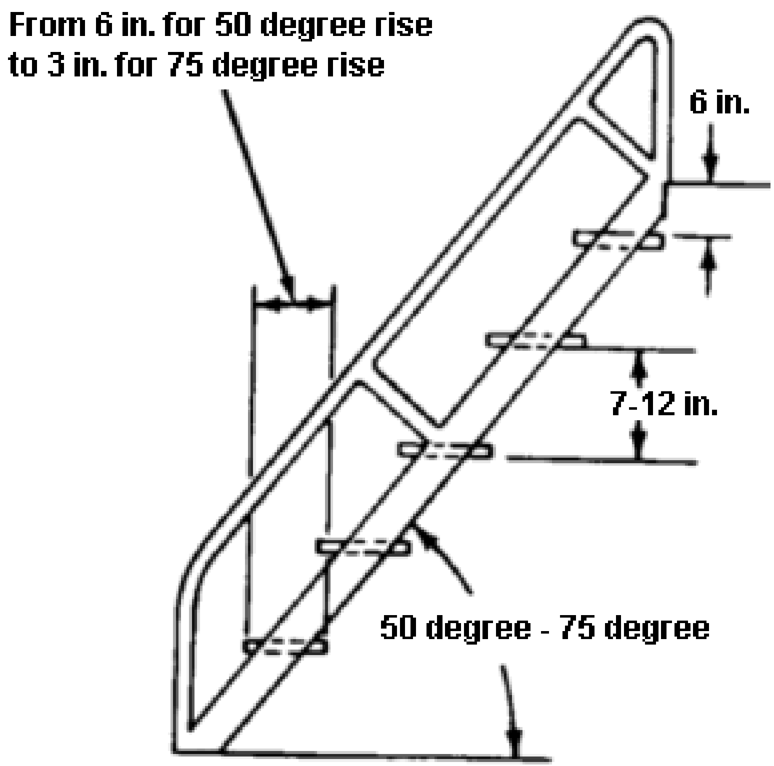

Figure 4 - Handrail arrangement. (2)

Vertical Ladders

Use round rungs to provide both hand grips and foot supports for vertical ladders (inclines between 75° and 90°). Figures 5 and 6 shows the recommended dimensions of such a ladder.

The optimum height between treads is from 11 to 12 in. The optimum width of the rungs is 18 to 21 in. Allow 30 in. (90° inclines) to 36 in. (75° inclines) of clearance on the climbing side of the ladder. Allow 6 to 8 in. on the wall (or opposite) side of the ladder. If ladders are used to provide permanent access to several levels, they should be offset at each level and protected by guardrails around the opening at the top of each ladder. (2)

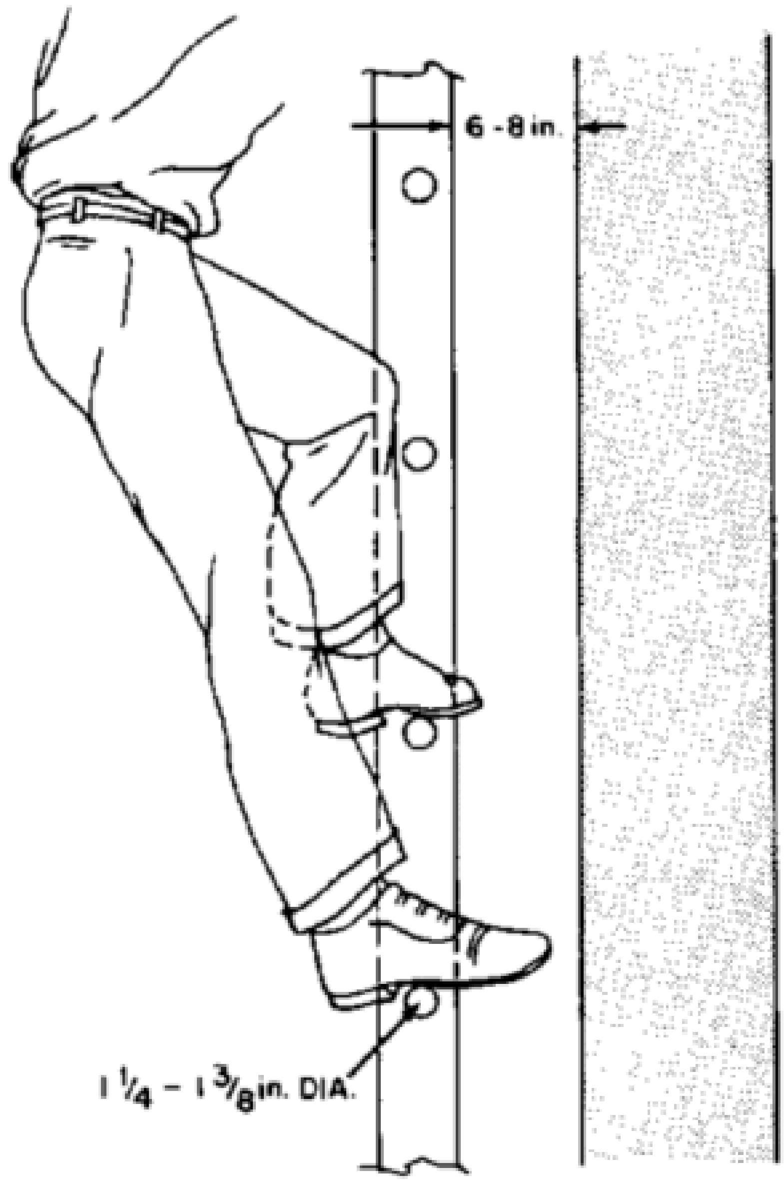

Figure 5 - Vertical ladder design. (2)

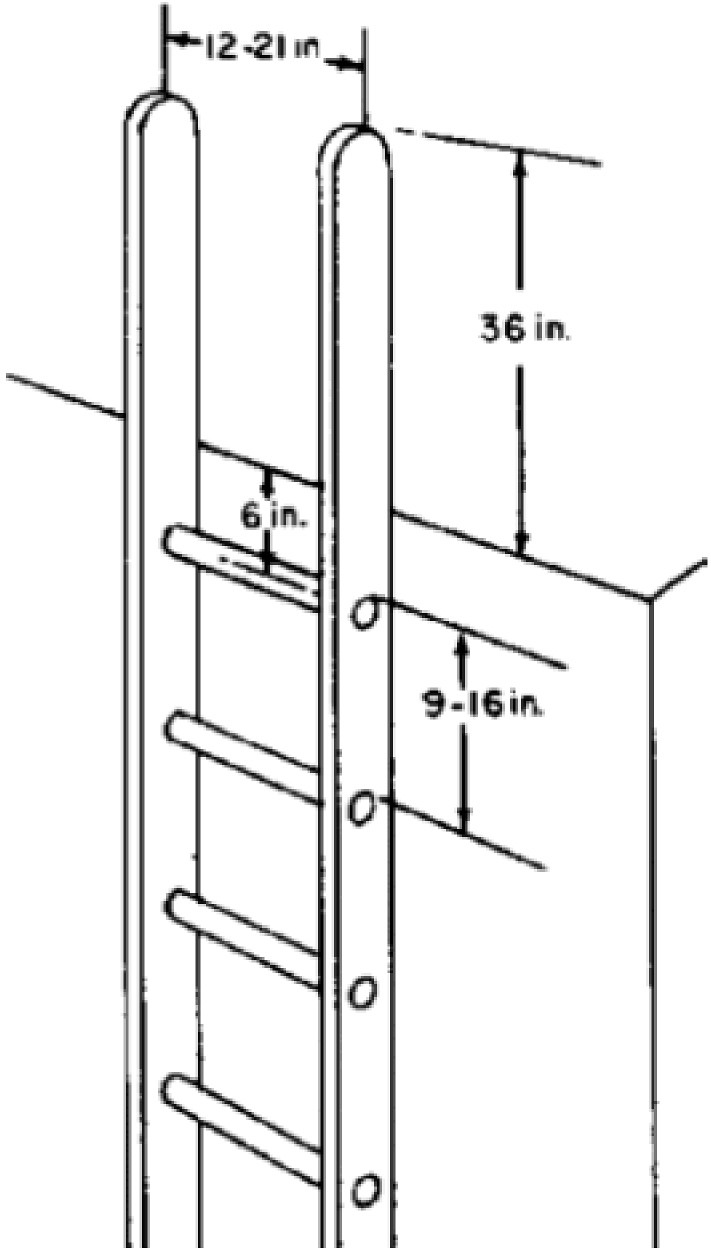

Figure 6 - Vertical ladder design. (2)

Stairs

Stairs should rise from the horizontal at an angle of between 20° and 50°. The preferred angle is between 30° and 35°. This rise angle automatically determines the ratio of riser height to tread depth, but the minimum riser height should be 5 in. (2) and the maximum 11 in. (3) Some example riser heights and tread depths are shown in table 1. The optimum tread depth is 9 1/2 in. to 10 1/2 in. plus a 1 in. to 1 1/2 in. overhang (figure 7). (2) These dimensions provide depth such that, in descending the stairs, the ball of the foot, does not extend beyond the front edge of the tread, and the heel comfortably clears the overhang of the step above.

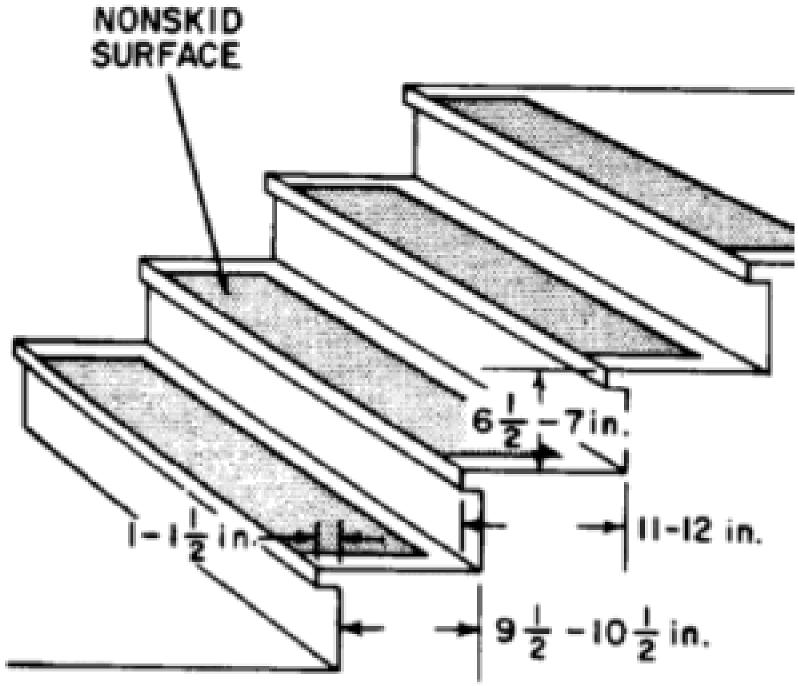

Figure 7 - Stair tread dimensions. (2)

Avoid long continuous flights of stairs. Where space permits, provide landings every 10 to 12 treads.(2) In addition, enclosed stairs should have a handrail on at least one side. (2) Figure 8 shows the recommended height of handrails. The width of stairs (between handrails or between a wall and handrail) should be as shown in figure 9.

Table 1 - Effect of stair slope on riser height and tread depth. (4)

Slope (°)	Riser Height (in.)	Tread Depth (in.)
30	6.5	11.0
35	7.2	10.2
40	8.0	9.5
45	8.8	8.8

For open stairways and landings, provide a guardrail halfway between the handrails and treads. In addition, provide screen guards between the guardrail and floor for landings where the stairway is at right angles to the landing (figure 10). (2)

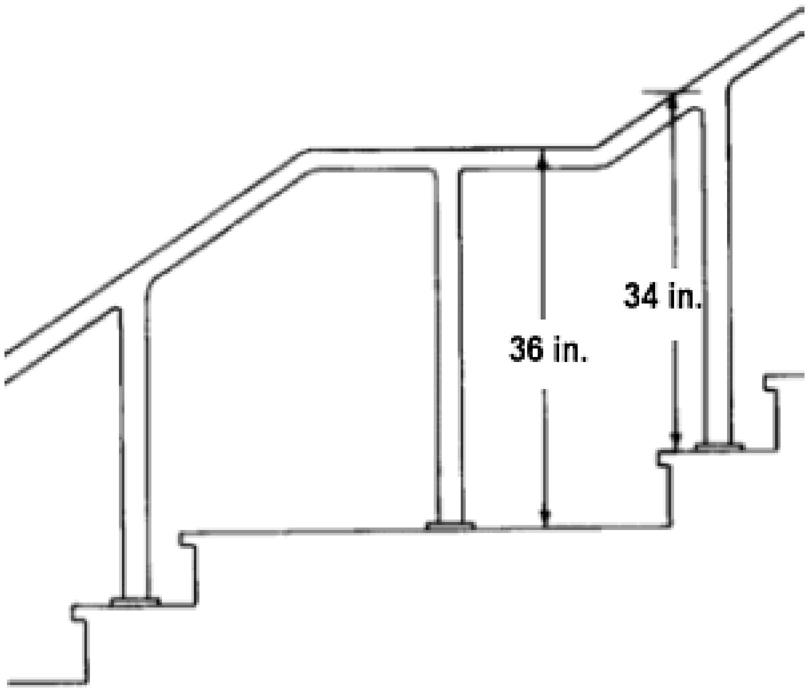

Figure 8 - Recommended handrail heights. (2)

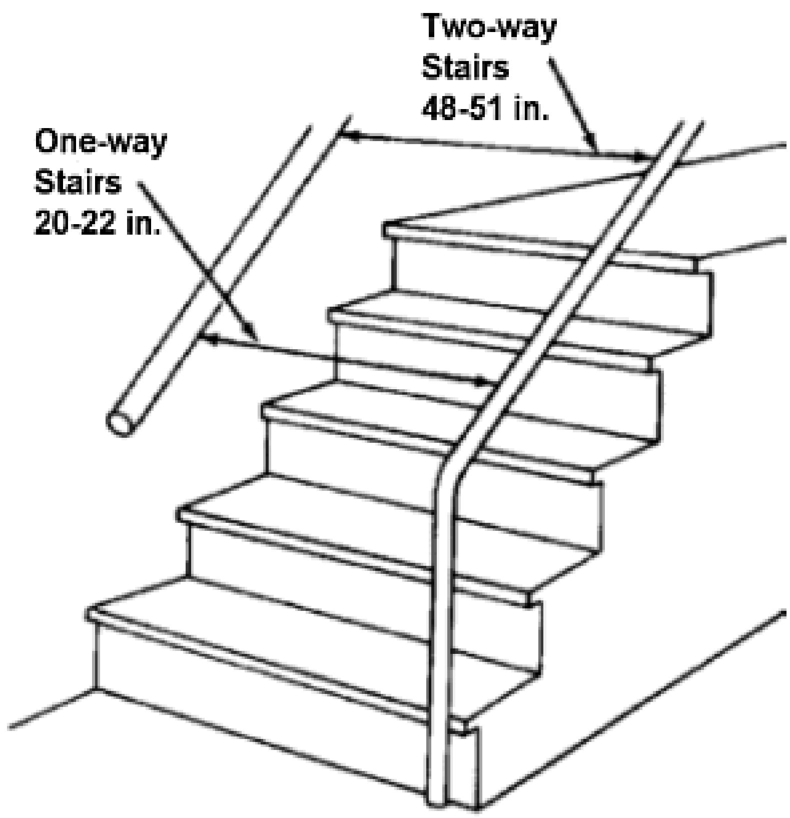

Figure 9 - Recommended stair widths between handrails. (2)

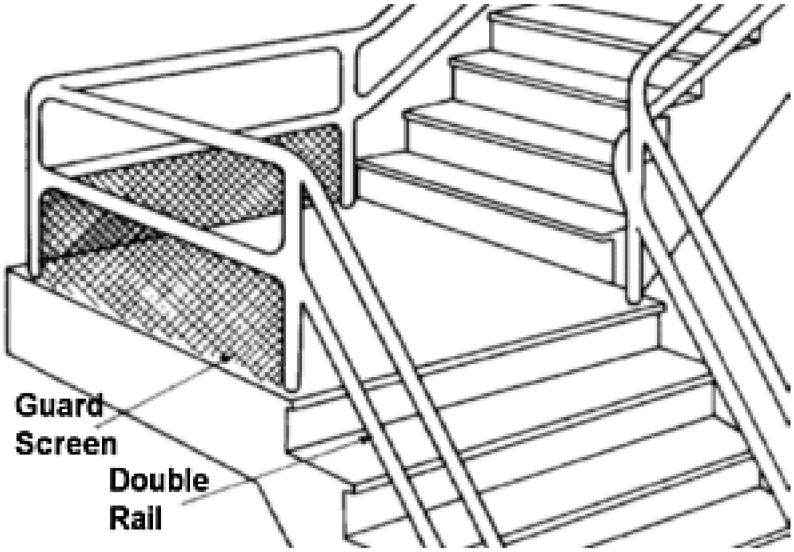

Figure 10 - Use of guards and guard rail when stair flights are at right angles. (2)

References

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1. Human Factors Design Handbook. Wesley E. Woodson, Barry Tillman, Peggy Tillman, McGraw-Hill, Inc., 1992.
2. Human Engineering Guide to Equipment Design. Joint Army-Navy-Air Force Steering Committee, Wiley-Interscience Publication, New York, 1972.
3. SAE J185 Access Systems for Off-Road Machines. Society of Automotive Engineers, Warrendale, PA, 1988.
4. Ergonomic Design for People at Work. Human Factors Section of the Eastman Kodak Company, Van Nostrand Reinhold Company, 1983.

Workstation Design

The ideal workstation is compatible with the expected user and with the performance requirements of the task.

Issue - The design of workstations was often inadequate from the standpoint of worker safety and comfort. Poor work practices contribute to musculoskeletal disorders such as sprains and strains.

- **Seating** in the packing plant was usually inadequate. The seat pictured on the left has no adjustments, and the padding is worn or nonexistent. The mounting is also dangerous in that there is no railing on the elevated platform the seat rests on.

- **Ingress and Egress** - Many times the workers had difficulty getting in and out of (ingress and egress) their workstations. The worker in this photo would have a difficult time quickly leaving the work area in case of an emergency.

- **Sorting Lines** - The sorting lines observed were staffed primarily by women. The job is repetitive and required extended reaches. Some lines required reaches up to 36 inches to access potatoes on the far side of the conveyor. In order to accommodate 95% of the users, the design of a reaching task should be such that the smallest worker (5th percentile female) can reach the object, in this case the potatoes. The reach envelope for a 5th percentile female is 25.6 inches and is the furthest distance a potato should pass in front of the worker.

  Emergency stop buttons were not available to all the workers in a work area. As shown in the picture, only one of the workers can reach the emergency stop switch mounted above the conveyor. At times, no emergency stop was located in the immediate work area.

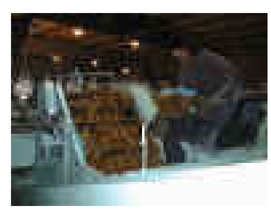
  Several of the sorting lines had sharp edges where the workers leaned in to perform sorting tasks. Some workers were observed placing a piece of cardboard across this area to protect themselves from the sharp edges.

  The discard bins for rejected potatoes sometimes were on the far side of the conveyor and other times on the side where the worker was standing. When the discard bins were across the conveyor belt, the workers had to extend their reach even further. This caused them to 'flick' their wrists to toss the potato across the conveyor. The extended reaching is stressful on the body, particularly the lower back and shoulders. This combined with the repetition and 'flicking' causes stress to the wrist and elbows and could contribute to repetitive strain injuries.

Several jobs observed in the packaging facilities require the workers to spend a significant portion of the day on their feet. This can lead to fatigue and stress to the lower extremities and back which over time can lead to injuries. At one facility, a number of employees were using a cushioned mat to stand on at their workstations. The mat was cushioned on the side that they were standing on, but the side making contact with the floor was wooden. This wood surface caused the whole pad to shift very easily putting the worker at risk to a fall.


- **Posture** - Many workers had to improvise in order to reach their work area. There were many examples of workers using boards, bricks and crates to raise themselves up to a comfortable working height. These fixes lead to an unstable work surface, increasing the chances of a slip or fall. In some cases workers had to lie on their side in order to inspect the potatoes as they went by on the conveyor. In addition to the obvious hazard of the worker falling onto the conveyor and being injured, any period of time in this awkward uncomfortable posture can lead to aches, pains, and even permanent injury as well as low employee morale.


- **Guarding** - It was common to see unguarded machinery in close proximity to workers. This, in conjunction with the unstable work surfaces mentioned above, greatly increases the chances of a severe acute injury. There were also many instances of unguarded open pits that workers had to negotiate around.



- **Work Design** - One worker was observed at a workstation with a chair mounted directly above the conveyor where he periodically reached down to sort out potatoes. This worker was at risk of getting caught or falling into the conveyor.

Recommendations - Follow the suggestions presented in [Workstation Layout] and [General Seating Recommendations] to address most of the issues listed above. In addition:

- Workers who are required to stand for long periods of time should utilize anti-fatigue mats or anti-fatigue pads in their shoes. Where appropriate, sit/stand stools may be considered. Mats used must be safe and not shift against the floor.

- Future designs of sorting lines should accommodate the reach envelope of the smallest person who could work the line, the 5th percentile female. Discard bins *next* to the worker rather than across the beltline are recommended to reduce the repetitive, extended reaches associated with this task.

Workstation Layout

Jump to: Priorities in Workstation Design
Workstation Design Guidelines

Machine designers call any location on a machine where one or more operators routinely control machine functions a workstation.

If the workstation does not have a seat, the design may require that the operator stoop, kneel, or crouch to operate the machine. If this is the case, you must pay attention to the design and placement of controls to ensure safe, efficient machine operation. If the workstation has a canopy, make sure allowances were made for operator visibility and head clearance (especially when a hard hat is worn). Finally, make sure the dimensions of the workstation are sufficient to permit free arm-to-control movements and operator ingress-egress.

If the designer followed the first principles for workstation design, they will have addressed most of the issues listed above:

Anthropometrics - The designer used anthropometric data from within the 5th- to 95th-percentile range. They considered the limits imposed by operators with shorter arms when identifying the arm reach envelope for the location of controls. For clearance requirements for the head, knees, etc., they used data from the larger members of the user population. For visual accommodation, they ensured that the entire potential range of eye positions were taken into account.

Work Design - Where practical, the design distributes the workload as evenly as possible between hands and feet. Primary controls requiring precision operation are be positioned for use by either hand. If that is not possible, preference was given to the right hand. Emergency controls are equally available to both hands.

Operator Protection - The designer anticipated all potential safety hazards and required emergency actions before starting to design.

Standardization - The design maintains the relative placement of controls and displays for similar types of equipment. This takes advantage of established habits and helps to eliminate unnecessary retraining.

Priorities in Workstation Design

Designers have many competing priorities that must be reconciled when laying out a workstation. This is especially true when they try to develop a workstation for use in restricted spaces. The following are some recommended priorities for laying out a workstation:

- **Priority 1 -** Consider the primary visual tasks. Whether it is to look at the roadway ahead or to monitor a display device, the eye position relative to the task establishes the basic layout.
- **Priority 2 -** Determine the placement of primary controls associated with a primary visual task (e.g., a steering wheel). Emergency controls are also primary items. Because primary and emergency control positions are generally related to a seat reference point, this is an appropriate time to identify that location.
- **Priority 3 -** Consider the control/display relationships. Controls should be near the displays they affect and should have a direction of movement that corresponds to the direction of movement of the display that the control affects. The act of activating the control should not obscure the display.
- **Priority 4 -** Arrange the workstation elements in their anticipated sequence of operation (usually from left to right and top to bottom).
- **Priority 5 -** Place the workstation elements according to frequency of use.

Workstation Design Guidelines

The following sections provide basic information related to workstation design. Each section corresponds to one of the previously mentioned first principles of workstation design for machinery

Anthropometrics

Of the hundreds of anthropometric measurements possible from the human body, the designer usually requires only 21 to lay out most workstations. Click HERE to see these relevant anthropometric measures and a list of additional space requirements for various items of personal protective equipment generally used in the work environment.

Enclosed Workstation Dimensions

Seated posture, cab length, control placement, and the control actions affect the width of the workstation. Shoulder breadth and hip breadth are the relevant anthropometric dimension needed for establishing seated width requirements for normally seated or supine operators. For most individuals, shoulder width provides sufficient space to accommodate small hand tools hung from the belt. For heavy individuals, hip breadth provides a starting point for determining the cab width. If operators sit cross-legged or with their knees to the chest, they require additional width.

Workstation Ingress-Egress

For fully or partially enclosed workstations, the ingress-egress opening should permit rapid, unobstructed entry and exit. The design should also incorporate the following entry design features:

- Design and locate operating controls so that the operator cannot kick, bump, or inadvertently activate them when entering or leaving the workstation.
- Provide hand grip and footholds to ease entry and exit. Be sure that the hand grips and footholds do not interfere with emergency egress.
- Protect ingress-egress opening from potential fires or mechanical hazards. Design the entries to be free of blockage or obstructions created by machine parts if there is a collision.
- Provide an emergency escape hatch, opening, or route for enclosed workstations.

Work Design

Workstation efficiency depends on the logical arrangement of tasks to enhance operator performance and reduce the chance of error. Properly associated controls and displays, logically grouping controls, and arranging controls to follow a natural sequence contribute to an efficiently operated machine.

In a well designed workstation, the designer takes into account the subtle physiological stresses that result from simple design incongruities, such as lack of postural control, improper distribution of body weight, cardiovascular restriction, and fatigue inducing activity. Physiological factors, environmental stresses, and design features all interact, as shown in the table below. When looking at this table, keep in mind that gastrointestinal and cardiovascular disturbance minimizations should take precedence over musculoskeletal considerations in systems requiring long-term operator exposure.

Relationship between operator physiological systems, environment, and workstation layout.
Rating criteria: 1 = critical, 2 = important, 3 = minor.

Considerations	Physiological Systems Affected		
	Musculo-skeletal	Cardio-vascular	Gastro-intestinal
Environment:			
Vibration	2	3	3
Oscillation	2	2	1
Acceleration	3	2	3
Impact	3	2	3
Noise	1	3	3
Workstation Layout:			
Poor distribution of operators body/limb weight	1	2	2

Improper postural support	2	2	3
Awkward body or limb positions	1	3	3
Frequent requirements to use maximum reach or force	1	3	3

Operators are better motivated if their workstation is well-organized, convenient, simple, reliable, safe, and attractive. A disorganized, inconvenient, or unattractive workstation will frustrate them. Operators' are less motivated to work if they have difficulty getting into position, or seeing or reaching controls because of poor arrangement.

Operator Protection

The following design features focus on improving protection and efficiency. These should be incorporate into the design of workstations whenever possible.

Panic Bars

Each workstation should be equipped with a panic bar, emergency cutoff switch, or button that the operator can readily activate using gross hand or foot movements. The panic bar should be installed so that entrapment cannot occur if the moving machine or a machine component (such as a swinging conveyor) could trap the operator against a structure, or side of the machine itself.

Interlock Switch

The machine should have an interlock device to prevent movement of the machine or its components if the operator has left the designated operating area.

Operator Restraint Device

The machine should have seat belts, access opening safety chains, doors, or other appropriate restraint devices to prevent the operator from falling or being thrown out of the machine while it is moving, or in case of collision.

Protection From Spillage and Workstation Cleanliness

There should be guards to protect the operator from spillage while loading, transporting, or discharging materials. Also, it is not difficult for materials to accumulate on the floor of the workstation. This buildup, if serious enough, can restrict pedal movement and lead to safety hazards and operator dissatisfaction. The floors of workstations should include grating near the pedals to prevent the buildup of dirt and debris. The wheels and tracks of vehicles should have covers to prevent road debris from being thrown at the operator.

Noise Protection

The workstation should be protected, where possible, from direct exposure to high noise sources by isolations, deflective shields, or other components. It should not entrap noise or reflect secondary sources of noise into the compartment. Sound absorption and control materials should be installed where appropriate.

If the interior sound levels cannot be reduced to permissible levels during certain machine operations, there should be signed posted conspicuously within the seated operator's primary field of view stating that noise levels exceed permissible levels during these operations and cautioning the operators to wear hearing protection.

Thermal Protection

The hydraulic fluid used in the power systems of many machines can get very hot at times, especially those not using heat exchangers. Maximum allowable temperatures should be established for exposed equipment surfaces and for any fluids conveyed in lines subject to rupture. This is especially important in the vicinity of the operator's workstation.

Warning Devices

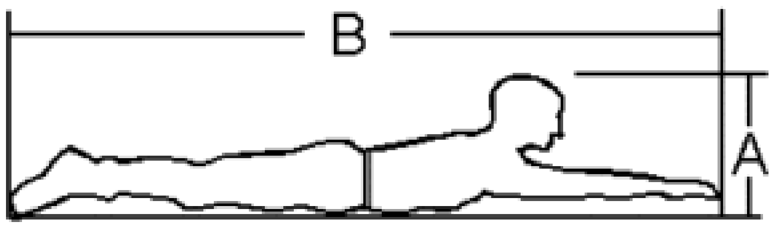
Machines that have movable appendages, such as conveyor booms or auger devices, should have audible and/or visual warning devices to signal impending movement. Sometimes it may be prudent to incorporate a short delay between the activation of the warning device and the movement of the appendage to allow time for workers to get clear of any hazards.

Standardization

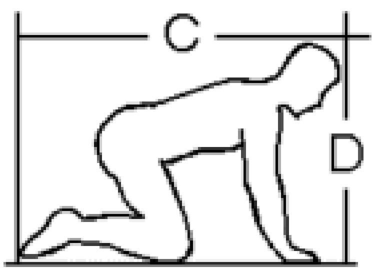
Try to be aware of previous workstation layout solutions, especially those that reflect the guidelines and specifications set out by recognized standards organizations, such as the Society of Automotive Engineers. Standardizing workstations provides several important benefits, including reduction in training time, less chance of operator error due to transferring from one machine to another, and simplified maintenance.

Workstation Layout: Relevant Anthropometric Measures

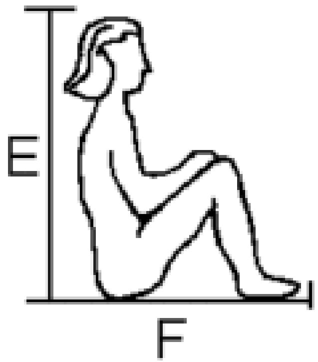
The 21 anthropometric measurements listed below are all that are needed to lay out the vast majority of workstations. The data are for the 5th-percentile female and the 95th-percentile male. The subjects are lightly clothed with no hard hat or hand tools hanging from the belt. Therefore, these values represent the minimum dimensions for each size category.



		in (cm)
A	Prone Height	18.9 (46.5)
B	Prone Length	107.9 (274.1)

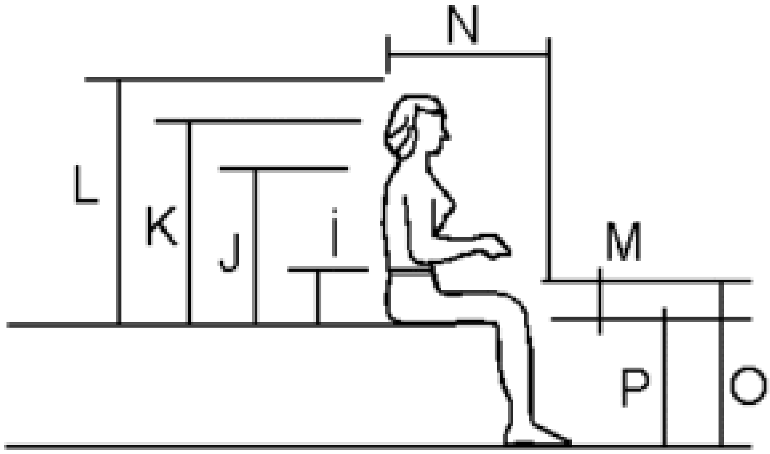


		in (cm)
C	Kneeling Length	55.5 (140.0)
D	Kneeling Height	39.4 (100.1)

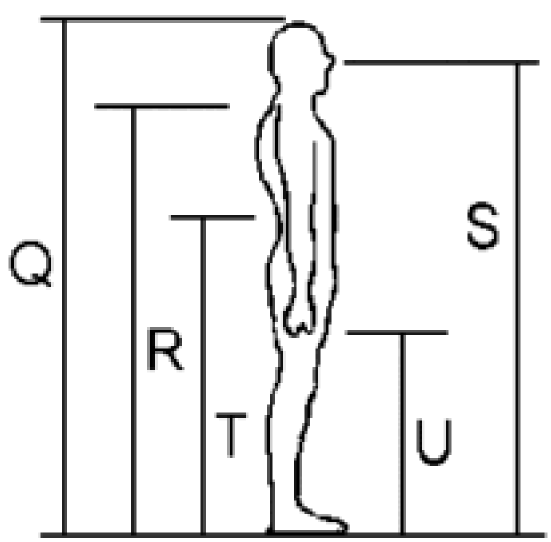


		Men in (cm)	Women in (cm)
E	Seated Height	38.3 (97.3)	33.6 (85.3)
F	Seated Length	35.4 (89.9)	34.5 (87.6)

		Men in (cm)			Women in (cm)		
		5th	**50th**	**95th**	**5th**	**50th**	**95th**
G	Shoulder Breadth	16.5 (41.9)	18.2 (46.2)	19.8 (50.3)	14.7 (37.3)	16.5 (41.9)	18.3 (46.5)
H	Hip Breadth	12.6 (32.0)	14.2 (36.1)	15.7 (39.9)	12.6 (32.0)	14.8 (37.6)	17.1 (43.4)



		Men in (cm)			Women in (cm)		
		5th	50th	95th	5th	50th	95th
I	Elbow Rest Height	7.7 (19.6)	9.4 (23.9)	11.2 (28.4)	7.4 (18.8)	9.4 (23.9)	10.6 (26.9)
J	Shoulder Height	21.6 (54.9)	23.8 (60.5)	25.9 (65.8)	20.3 (51.6)	22.4 (56.9)	24.6 (62.5)
K	Eye Height	29.3 (74.4)	31.7 (80.5)	38.0 (96.5)	27.2 (69.1)	29.4 (74.7)	31.5 (80.0)
L	Sitting Height	33.7 (85.6)	36.0 (91.4)	38.3 (97.3)	31.3 (79.5)	33.6 (85.3)	35.9 (91.2)
M	Thigh Clearance	5.0 (12.7)	6.0 (15.2)	7.0 (17.8)	4.1 (10.4)	5.5 (14.0)	6.9 (17.5)
N	Buttock-Knee Length	21.6 (54.9)	23.5 (59.7)	25.4 (64.5)	20.7 (52.6)	22.7 (57.7)	24.7 (62.7)
O	Knee Height	19.7 (50.0)	21.5 (54.6)	23.3 (59.2)	18.9 (48.0)	19.8 (50.3)	21.4 (54.4)
P	Stool Height (Popliteal Height)	14.6 (37.1)	16.3 (41.4)	18.1 (46.0)	13.4 (34.0)	15.0 (38.1)	16.7 (42.4)



		Men in (cm)			Women in (cm)		
		5th	50th	95th	5th	50th	95th
Q	Stature	64.6 (164.1)	68.9 (175.0)	73.3 (186.2)	59.8 (151.9)	64.0 (162.6)	68.1 (173.0)
R	Shoulder Height	52.1 (132.3)	56.2 (142.7)	60.2 (152.9)	48.0 (121.9)	52.1 (132.3)	56.3 (143.0)
S	Eye Height	60.1 (152.7)	64.5 (163.8)	68.9 (175.0)	55.1 (140.0)	59.4 (150.9)	63.6 (161.5)
T	Elbow Height	39.6 (100.6)	42.5 (108.0)	46.1 (117.1)	35.9 (91.2)	39.1 (99.3)	42.1 (106.9)
U	Fingertip Height	23.7 (60.2)	26.0 (66.0)	28.3 (71.9)	21.3 (54.1)	23.6 (59.9)	25.9 (65.8)

Additional space requirements for various items of personal protective equipment.

Item	Add to	Height in (cm)	Width in (cm)	Length in (cm)
Hard Hat	head	2.0 (5.1)	2.0 (5.1)	2.0 (5.1)
Leather Boots	foot	1.0-2.0 (2.5-5.1)	1.0 (2.5)	1.0 (2.5)
Rubber Boots	foot	0.25 (0.6)	0.25 (0.6)	0.25 (0.6
Light Gloves	hand	-	-	0.25 (0.6)
Heavy Gloves	hand	0.25 (0.6)	0.5 (1.3)	0.5 (1.3)

General Seating Recommendations

Jump to: Seating Design Guidelines

Seating for most industrial applications generally includes an adjustable backrest, a suspension system, a fore-and-aft track adjustment, an up-and-down seat adjustment, and sometimes an armrest and/or footrest. Some manufacturers also include devices for lumbar region support.

When purchasing a seat as part of a piece mobile machinery or stationary workstation, you should make sure the seat satisfies the guiding first principles for seating design:

- FP✓ **Seat Dimensions** - Make sure the seat is designed to fit and adjust to body dimensions, and distributes weight to relieve pressure points and support posture. In other words, the seat should be comfortable.
- FP✓ **Vibration Isolation** - The seat should have features to guard against the dynamic forces caused by rough roadways and minor collisions that tend to "unseat" a person.
- FP✓ **Workstation Integration** - The seat should not hinder the operator's ability to control the machine or hinder ingress or egress from the workstation.
- FP✓ **Maintainability** - The seat should be easy for maintenance personnel to repair or replace. It should use modular components when possible.

A seat designed according to the principles listed above would provide adequate support, would not impose any undue stress on the body, and would allow optimum posture. It would be comfortable, not contribute to fatigue, and allow the worker to be productive. It would address such factors as the alignment of the spine to reduce pressure between the discs, how much work the muscles have to do to maintain required work postures, and the compression of the blood vessels and nerves at the back of the thigh and behind the knee. Due to the differences in size and shape of workers, adjustability would be incorporated into the seat, i.e., operators could move it up and down and forwards and backwards. Padding would prevent discomfort and decrease the effects of whole-body vibration and shock. Its design would reduce interference to trunk, head, and limb movement and visibility. An adjustable backrest and armrests would give additional postural support and be an aid to standing up and sitting down.

Seating Design Guidelines

The following sections expand on the first principles of seating design for mobile machinery.

Seat Dimensions

A good fitting seat depends on many anthropometric and biomechanical factors, which we discuss generally in the following paragraphs. Be aware that the different shapes and sizes of workers suggest that a seat be adjustable by moving it in the up-down and fore-aft directions. Any seat you purchase should have this ability.

Seat Height

As the height of the seat increases beyond the popliteal height of the user, pressure will be felt on the underside of the thighs. The resulting reduction of circulation to the lower extremities may lead to a "pins and needles" feeling, swollen feet, and considerable discomfort. As the height decreases, the user will flex the spine more (due to the need to achieve an acute angle between the thigh and trunk), experience greater problems in standing up and sitting down, due to the distance through which his or her center of gravity must move, and require greater leg room. Usually, the optimal seat height for many purposes is close to the popliteal height. If this is not possible, a seat that is too low is preferable to one that is too high. For many purposes, the 5th-percentile female popliteal height represents the best compromise. If the seat is higher than this (e.g., to increase the eye height for better visibility), the ill effects may be mitigated by shortening the seat and rounding off its front edge to reduce the under-thigh pressure.

Seat Pan Depth

If the seat pan depth is beyond the buttock-popliteal length, the user cannot engage the backrest effectively without putting pressure on the backs of the knees. Furthermore, the deeper the seat pan, the greater the problems of standing up and sitting down.

Backrest

The higher the backrest, the more effective it will be in supporting the weight of the trunk. This is always desirable, but in some circumstances other requirements, such as the mobility of the shoulders needed to look to the rear, may be more important.

Seat Width

Most people require a width between 18 in (45.7 cm) and 20 in (50.8 cm) for support. This distance should provide adequate clearance between the armrests for the largest user.

Seat Pan to Seat Back Angle

This angle should be between 100 and 165 degrees as the seat back approaches the vertical position and will approach 180 degrees in cabs designed for low height workstations. As the backrest angle increases, a person supports more of the weight of the trunk; therefore, they diminish the compressive force between the trunk and pelvis. However, the horizontal component of the compressive force increases. This will drive the buttocks forward out of the seat unless counteracted by an adequate seat tilt, high-friction upholstery, or muscular effort from the subject. An increased seat back angle also leads to increased difficulty in getting in to and out of the seat.

Seat Back to Headrest Angle

In partially or fully reclined seats, a headrest is needed to allow operators to effectively view their primary visual areas over extended periods.

Seat Pan Angle

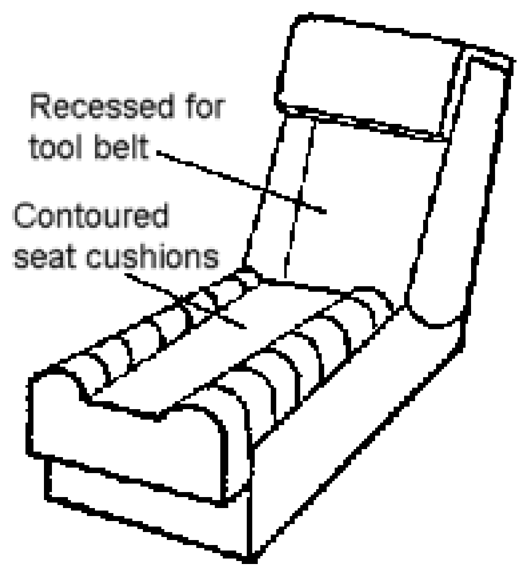
The angle of the seat pan relative to the workstation floor is important for comfort and body support during rapid decelerations or collisions. Excessive tilt reduces the hip-trunk angle and makes getting in to and out of the seat more difficult.

Armrests

Armrests may give additional postural support and be an aid to standing up and sitting down. Armrests should support the fleshly part of the forearm, but unless very well padded they should not engage the bony parts of the elbow where the highly sensitive ulnar nerve is near the surface. Arm rests should tilt up and out of the way when not in use and be adjustable in both height and angle.

Seat Surface

The seat surface should be mostly flat rather than shaped, although a rounded front edge is desirable to reduce under-thigh pressure. Sometimes, the sides of the seat pan are raised up slightly to aid in postural stability during lateral accelerations. The covering materials should be waterproof and rough to aid stability.



Personal Protective Equipment

The design should make accommodations for the operator's personal protective equipment. The seat pan and backrest should make allowances for tool belts or other equipment. Also, the headrest and backrest should accommodate a person wearing a hard hat.

Click HERE to view recommended seat design specifications for three workstation heights: over 36 in (91.4 cm), 24 in to 36 in (61.0 cm to 91.4 cm), and under 24 in (61.0 cm). For those applications where including adjustable headrest-back-seat pan configuration is not practical, a curved transition from the headrest to back support with a radius of 24 in to 32 in (61.0 cm to 81.3 cm) may be used. Make sure that the seat configuration never locks the operator's head into a position of more than 45 degrees relative to the back.

Vibration Isolation

The seat should have designed in vibration isolation whenever possible to reduce operator exposure to bumps, jolts, and other mechanical shocks. When space permits, this isolation is generally achieved by a spring and shock absorber or damper. Although cushions are used primarily for static comfort, they are also effective in decreasing the transmission of vibration above the resonance range of the human body. They are ineffective in the resonance range and may even amplify the vibration in the sub-resonance range. The seat should also offer lateral support (as in a concave seat back) against jerks, heavy swaying, or shocks. The shock-absorbing qualities of the seat should be suitable for fitting operators ranging in weight from the 5th-percentile female to the 95th-percentile male. A passive (molded seat pan) or active (seat belt) occupant restraint system should also be incorporated into the seat-workstation to prevent the operator from being thrown out of the seat during a turn, hard bump, or collision.

Workstation Integration

All seat adjustment levers, knobs, or buttons should be within hand's reach by 5th-percentile female and 95th-percentile male operators, should not block ingress or egress, and should not pose impact hazards in the event that unexpected machine motions throw the operator from the seat. All adjustment operations should be quick and should not require great force or the use of tools. The seat adjustment controls and moving parts should be able to be operated without risk of trapping fingers and should be designed so that they cannot be inadvertently removed. The adjustments should lock in all positions and should be spring loaded, where necessary, to help the operator in moving forward to a more upright position. All operating instructions should be clear and permanently displayed near the seat. The seat should not interfere with trunk, head, or limb movements needed to operate the machine.

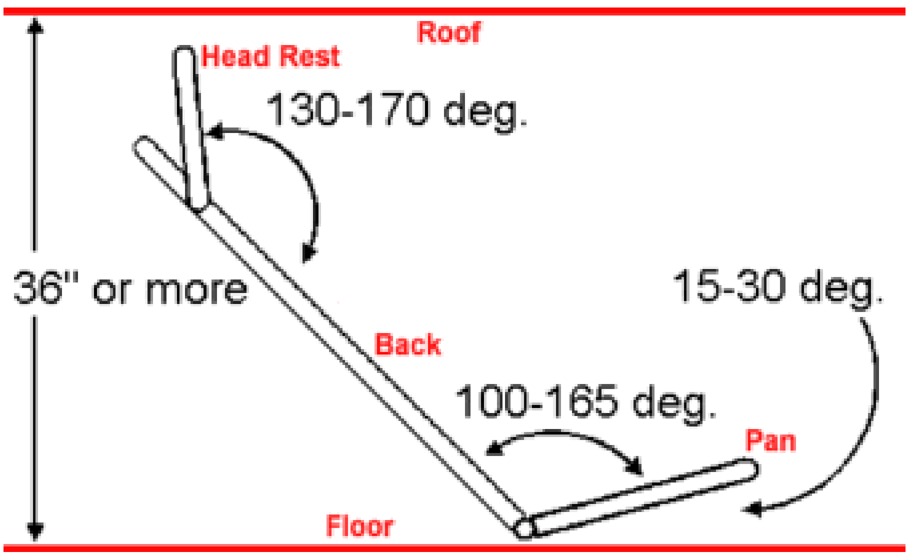
Maintainability

The seat pan and backrest covers should be easily changed or repaired and should be washable so that they can be maintained in good condition. The edges of the seat assembly should be smoothed or rounded so as not to catch clothing or equipment.

The seat adjustment mechanisms should be self-cleaning and able to withstand excessive water, dirt, and debris. The seat assembly components should be corrosion-resistant. The seat assembly construction should be robust, and the seat should feel solid and safe to the user. The seat should be easily removed from the workstation to effect repairs or to be replaced.

Seating Specifications

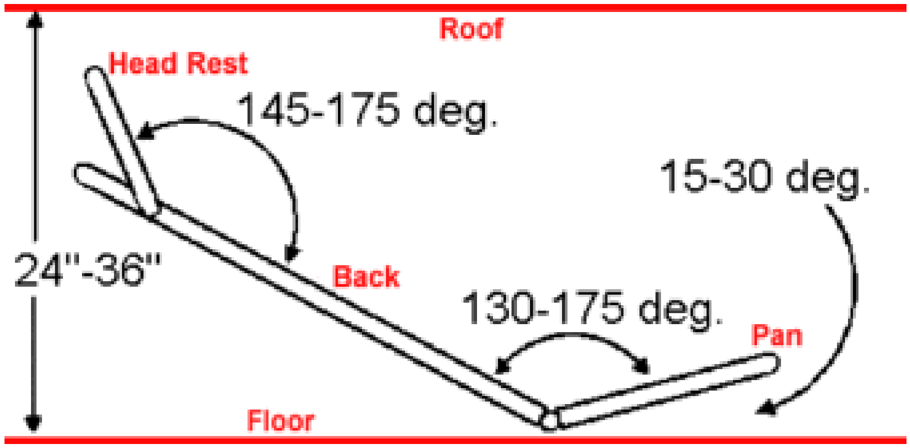
Working Height 36" or more



Working Height in (cm)	Pan Angle from Floor degrees	Back to Pan Angle degrees	Head Rest to Back Angle degrees
36 or more (91.4 or more)	15-30	100-165	130-170

Head Rest Travel along Back in (cm)	Seat & Head Rest Width in (cm)	Pan Length in (cm)	Height of Back in (cm)
7 (17.8)	18-20 (45.7-50.8)	12-24 (30.5-61.0)	16-24 (40.6-61.0) Adjustable

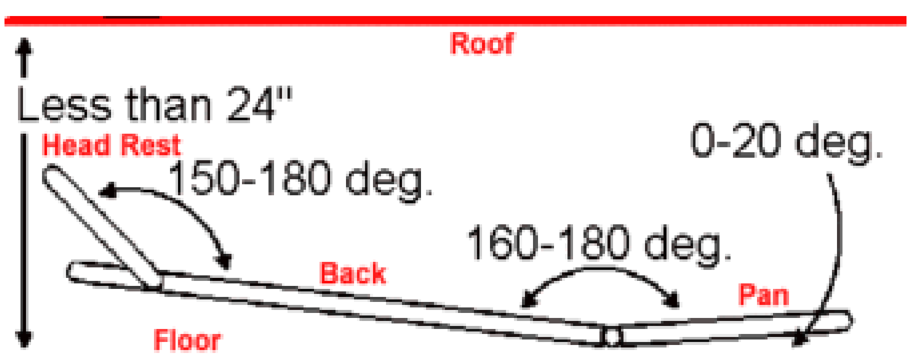
Working Height 24"-36"



Working Height in (cm)	Pan Angle from Floor degrees	Back to Pan Angle degrees	Head Rest to Back Angle degrees
24-36 (61.0-91.4)	15-30	130-175	145-175

Head Rest Travel along Back in (cm)	Seat & Head Rest Width in (cm)	Pan Length in (cm)	Height of Back in (cm)
7 (17.8)	18-20 (45.7-50.8)	12-14 (30.5-35.6) Adjustable	16-24 (40.6-61.0)

Working Height Less than 24"



Working Height in (cm)	Pan Angle from Floor degrees	Back to Pan Angle degrees	Head Rest to Back Angle degrees
Less than 24 (Less than 61.0)	0-20	160-180	150-180

Head Rest Travel along Back in (cm)	Seat & Head Rest Width in (cm)	Pan Length in (cm)	Height of Back in (cm)
7-12 (17.8-30.5)	20-22 (50.8-55.9)	12-14 (30.5-35.6)	16-24 (40.6-61.0) Adjustable

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Contact Information

You can contact the following NIOSH employees with questions or for more information about any items in this report.

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Glossary

acute - injuries that result from a single incident.

anthropometry - defining the physical measurements of a person's size and form. This information is used to design equipment and workplaces to accommodate the majority of users by designing for the extreme individuals (smallest, 5th percentile or largest, 95 percentile) or for an adjustable range. *adj*. - anthropometric

asymmetry (A) - position of the body that involves twisting at the legs, torso, or shoulders. When twisting is involved, measure angle that object is displaced from the front of the worker's body.

biomechanics - that field of study involving classical mechanical principles and their relationships as used by or applied to living organisms.

buttock-popliteal length - the horizontal distance from the rearmost surface of the buttock to the back of the lower leg.

cardiovascular - of, relating to, or involving the heart and the blood vessels: cardiovascular disease.

cumulative - injuries that develop gradually over periods of weeks, months, or years as a result of repeated stress.

distance (D) - vertical travel distance of the hands from the origin to the destination of the lift (measured as an absolute value).

egress - exit from a region or space.

frequency (F) - average number of lifts per minute over a 15 minute period.

gastrointestinal - of or relating to the stomach and intestines: the gastrointestinal tract.

hand coupling (C) - quality of the hand-to-object coupling classified as good, fair, or poor.

horizontal (H) - location of the hands measured as the horizontal distance from the midpoint between the ankles.

ingress - enter a region or space.

length of time - duration of the lifting task classified as short (1 hour), moderate (1-2 hours) or long (2-8 hours).

lifting index (LI) - term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. It is the ratio of the actual weight of the load and the recommended weight limit. It is desirable to design the job to have a lifting index ≤ 1. A lifting index > 3 identifies a job which should receive immediate attention.

lumbar region - the region of the spine comprised of the 5 lumbar vertebrate, L1-L5.

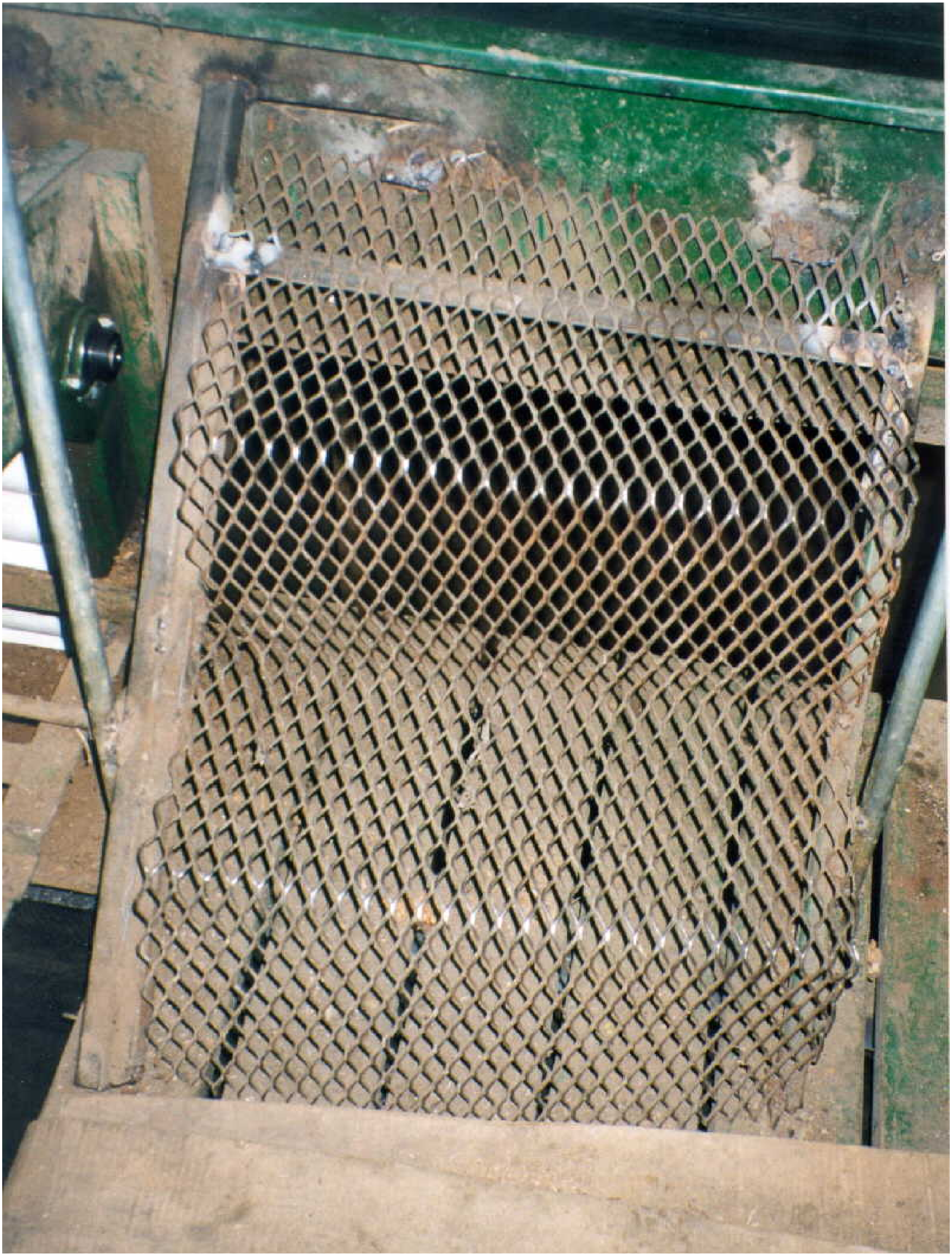
musculoskeletal system - the integrated system of muscles, bones and joints in the body.

popliteal height - the vertical distance from the footrest to the underside of the thigh.

Recommended Weight Limit (RWL) - the principal product of the revised NIOSH lifting equation. It is defined for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time (e.g. up to 8 hours) without an increased risk of developing lifting- related low back pain.

ulnar nerve - a spinal nerve innervating generally the medial part of the forearm and hand.

vertical (V) - location of the hands measured as the vertical distance above the floor.

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