



Ergonomics Standard

Specification Number CORP-09-10-03-01
Revision 1

Ergonomics Standard

1. Purpose / Abstract:

The purpose of this standard is to provide ergonomic guidelines for the design and renovation of manufacturing and logistics facilities work areas. These ergonomic recommendations focus on work area design in order to fit the job to the worker to prevent injuries and disorders. The goal of ergonomics is to make the work area fit the operator instead of making the operator fit the work area.

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3. Scope:

This document applies to all Cummins Inc. organizations including subsidiaries, joint ventures, other alliances or partnerships, and company owned distributors in which Cummins has a controlling interest or management responsibility.

This document is targeted specifically at Manufacturing and Industrial Engineers and all individuals responsible for designing the workplace; hereafter referred to as 'engineers', who design work areas. The principles mentioned in this document apply to all types of work.

Certain values given in this standard are based on recommendations from various sources; however, all anthropometric values are from the United States. It is strongly suggested that engineers along with their Safety Leaders, in plants outside of the United States, using this standard refer to their local anthropometric data to more accurately design work areas and task to fit the demographic of their plant's operators. Where they exist, legal regulations and requirements shall be followed. Engineers and plant Safety Leaders shall be responsible for ensuring that all relevant standards and regulations are adhered to.

4. Applicable Documents:

CME-08-0077-3, the previous Ergonomic Standard, is obsolete; however, the information has been included in this Corporate standard.

CORP-09-04-03-00, Hand Injury and Illness Prevention

CORP-13-00-00-01, Global Building Policy

CORP-09-04-36-00, Work at Heights and Ladder Safety Procedure

5. Definitions:

Anthropometry – The study of human body measurements used to understand physical variations among a population.

Neutral Reach Zone – In this zone, the operator, standing with their back straight, can comfortably reach objects by pivoting forearms at the elbow, using minimal body movement to perform the work.

Extended Reach Zone – In this zone, the operator may use full arm extension, from shoulder, without any back bending to grasp or touch an object.

Power Zone – The Power Zone is the neutral reach zone combined with neutral posture. Working in the Power Zone is more efficient and less stressful on the body.

NIOSH – National Institute for Occupational Safety and Health



6. Content:

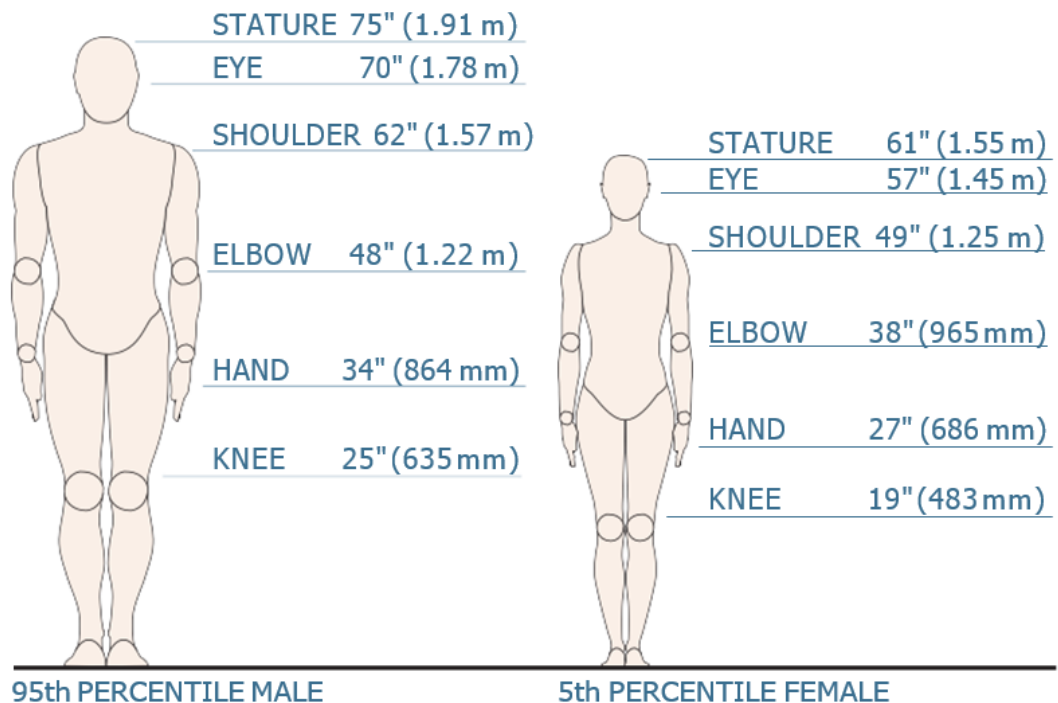
6.1 Workstations

6.1.1 Human Performance Design

Human performance design guidelines are based on functional anthropometry, which considers human capabilities to perform a function based on the following:

- Static anthropometric dimensions of the human body (e.g., length of a person's forearm)
- Body motion (e.g., joint range of motion)
- Body Posture (e.g., joint angles that minimize risk)
- Strength principles (e.g., force-length relationship)
- Static and dynamic capacities (e.g., speed and accuracy)
- Frequency and duration of work

Figure 6.1: Functional Anthropometry (North America) (Dimensions include 1" shoe height.)

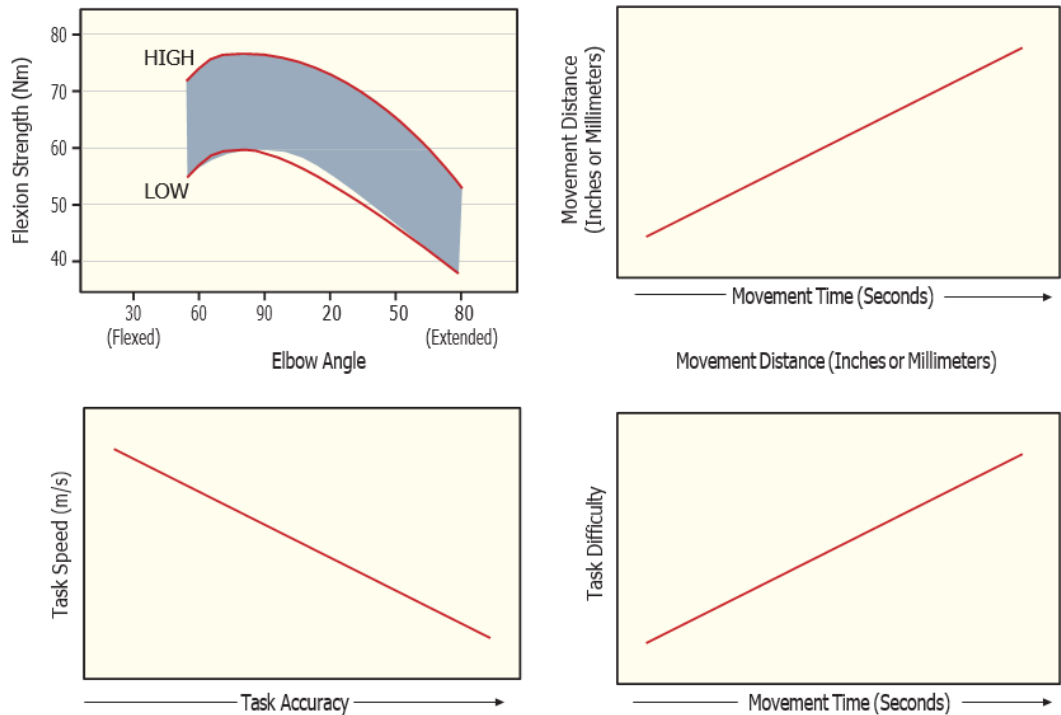




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Figure 6.2: Influences on Strength and Movement Time



6.1.2 Design Principles

Do not design for the average

- When you design for the average person, you limit the most (excluding approximately 67% of the working population)

Whenever feasible, design for adjustability

- Vertical work surface heights shall provide adjustability to accommodate hand working heights of most of the working population
- Visual displays shall provide adjustability to accommodate eye heights of most in the working population.

Design for extremes



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- Clearances shall be designed for largest or tallest people in the working population (accommodate the 95th percentile male)
- Reaches shall be designed for smallest or shortest people in the working population (accommodate the 5th percentile female)

Design based on functional anthropometry

- Design reaches shall be based on postures that minimize risk, rather than static anthropometry (e.g., 5th percentile female reach capability with the back upright, arm raised 45°, elbow at 135°)
- Work shall be designed based on strength data to accommodate most in the working population (e.g., design to accommodate strength capability of 75% of female working population)

6.1.3 Seated Versus Standing

The appropriate workstation design, seated or standing, is determined based on the nature of the job tasks.

Figure 6.3: Seated versus standing



Standing workstations shall be designed if the job demands include:

- Heavy lifting (≥ 10 lb or 4.5 kg)
- High force exertions (≥ 10 lb or 4.5 kg)
- Long horizontal reach distances (≥ 16 " or 406 mm)
- Overhead reach distances (≥ 62 " or 1.58 m above standing surface)



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- Frequent walking (e.g., walking to storage bins)

Seated workstations shall only be designed if the job demands include

- Precision or visually demanding tasks.
- Continuous foot pedal activation.
- All items are within horizontal and vertical reach zones.
- No large forces, more than 4.5 kg (10 lbs), are required
- Precise assembly/writing is done the majority of the time

If seated workstation is chosen, sitting should be limited to 55 minutes, followed by a change in posture to standing and/or walking. If the work area is designed for the operator to sit, proper leg clearance shall be provided. See Figure 6.11 for further information concerning clearances for workers in a seated position. The dimensions given are based on the 5th – 95th percentile male height. (Refer to section 6.1.4.1 to apply horizontal work distance guidelines) While seated, an operator's feet shall be supported either by the floor or by a foot rest.

6.1.3.1. Line of Sight

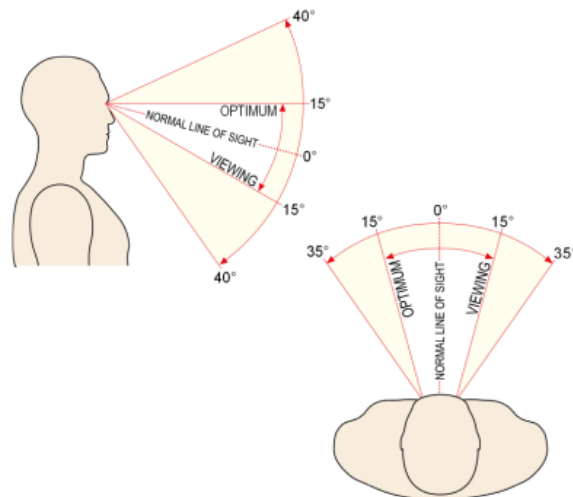
Maximum viewing

35° to either side, or 40° above or below the normal line of sight.

Optimum viewing

15° to either side, or 15° above or below the normal line of sight.

Figure 6.4: Line of Sight





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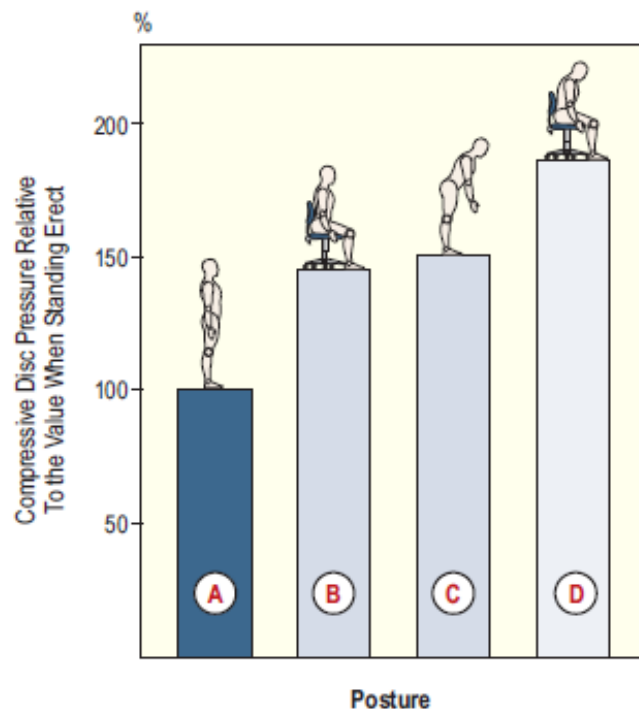
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6.1.3.2. Other Considerations

Standing workstations should be preferred to seated workstations because of the known mechanical changes in the lower back while seated:

- Back slouching postures (kyphosis), which increase compressive and shear forces on the discs in the spine
- Intradiscal pressure
- Posterior annulus strain
- Creep in posterior passive tissues, which reduce anterior/posterior stiffness and increase shearing movement
- Posterior migration of mechanical movement/lifting fulcrum, which reduces mechanical advantage of extensor muscles

Figure 6.5: Compressive Disk Pressure versus Posture



6.1.4 Horizontal Work Distance



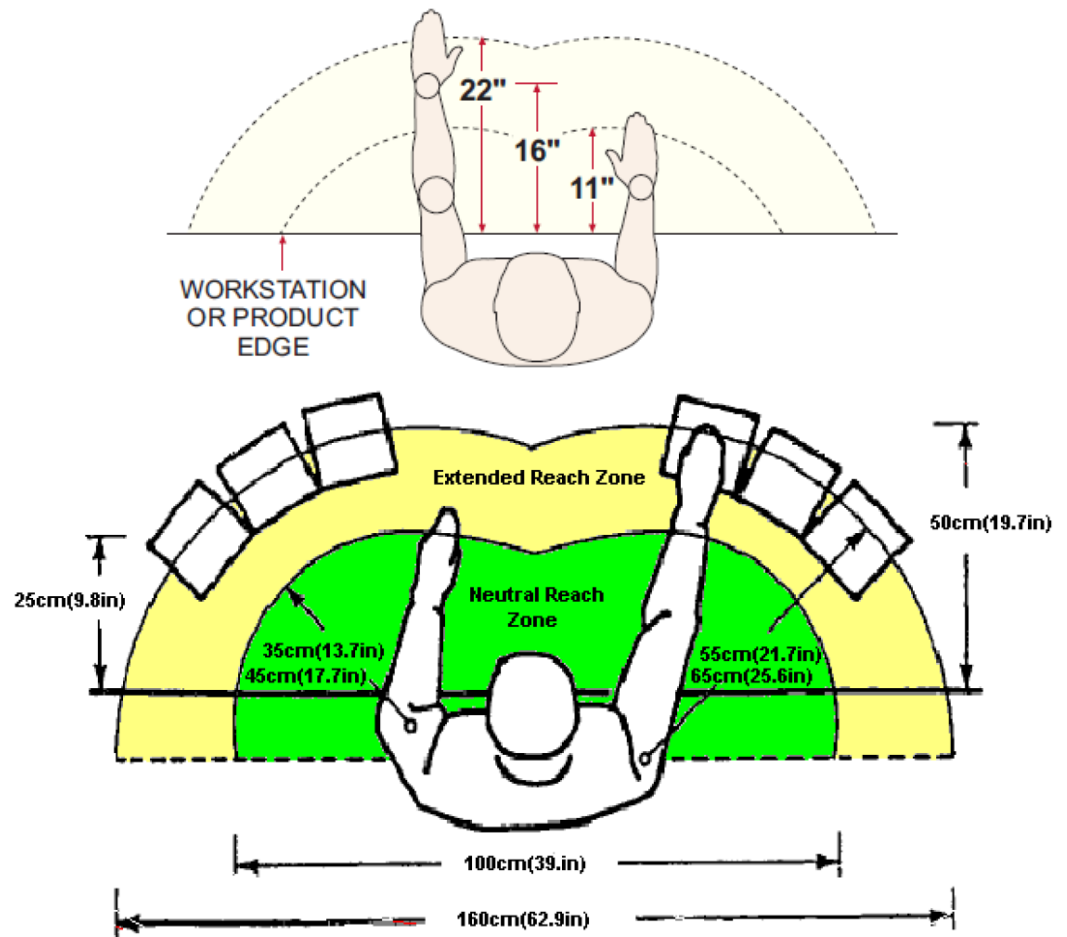
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6.1.4.1. Guidelines

- From edge of workstation or product (for seated and standing operations):
- Precision Tasks shall be: $\leq 11''$ (279mm)
- High-frequency ($\geq 2/\text{minute}$), high-force ($\geq 10 \text{ lb}$ or 4.5 kg), or long-duration ($\geq 10 \text{ seconds}$) tasks: $\leq 16''$ (406 mm)
- Large product assembly tasks: $\leq 22''$ (559 mm)
- Horizontal reach distance shall not exceed: 22'' (559 mm)

Figure 6.6: (Top) Horizontal Work Distance Guidelines; (Bottom) Horizontal grasp and normal working area at tabletop height.





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6.1.4.2. Countermeasures

- Move task or work piece closer
- Improve hand/tool access to task area
- Reduce task frequency
- Improve fixture design

6.1.4.3. Work Examples

- Tightening a fastener
- Assembling an electrical connector

6.1.4.4. Other Considerations

- Time or productivity penalties for longer horizontal reach distances: every 6" (152 mm) of horizontal reach distance is equal to approximately 0.2 seconds of wasted time
- Product quality penalties: quality decreases as tasks are performed farther away from the body

6.1.5 Layout of Work

6.1.5.1. Work Envelope

The area wherein manual tasks can be performed easily (or at all) is defined by the workspace (or reach) envelope. The Work Envelope is measured by the Horizontal and Vertical Reach Zones (H&VRZ) boundaries. These reach zone boundaries move with the operator wherever work should be performed and are referenced to the operator's body. To ensure optimal work performance and protect an operator from risk of harm, the engineer shall design work areas and tasks consistent with an operators Work Envelope as described. For jobs that require an operator to lift/lower, push/pull or carry objects to perform their task, also refer to section 6.2 Manual Material Handling.

6.1.5.2. Horizontal & Vertical Reach Zones

The horizontal and vertical reach zones are comprised of the neutral and extended reach zones, which are defined as follows:



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Neutral Reach Zone – In this zone, the operator, standing with back straight, can comfortably reach objects by pivoting forearms at the elbow, using minimal body movement to perform the work.

Extended Reach Zone – In this zone, the operator may use full arm extension, from shoulder, without any back bending to grasp or touch an object.

The Horizontal Reach Zone, shown in Figure 6.6, suggests the preferred distance and orientation of objects so that they are easily accessible to the operator without causing unnecessary bending or stretching while performing a job task. The boundaries on the work surface define the area wherein all tools, controls and visual displays shall be located to ensure an operator is capable of performing their work task without repetitive exertion on the body (e.g. back pain, neck strain, wrist inflammation, etc.). These tasks can include operating tools, reaching for controls, viewing workstation displays, etc. The boundaries are constructed separately for each arm and overlap in the middle where both hands can reach. This is the area where two-handed work can be done. The Horizontal Reach Zone applies even while an operator is in a seated position; refer to section 6.1.3 Sitting vs. Standing for guidance on clearances applicable to an operator in a sitting position.

6.1.6 Vertical Reach Distance for Large Product Assembly

6.1.6.1. Guidelines

From standing surface:

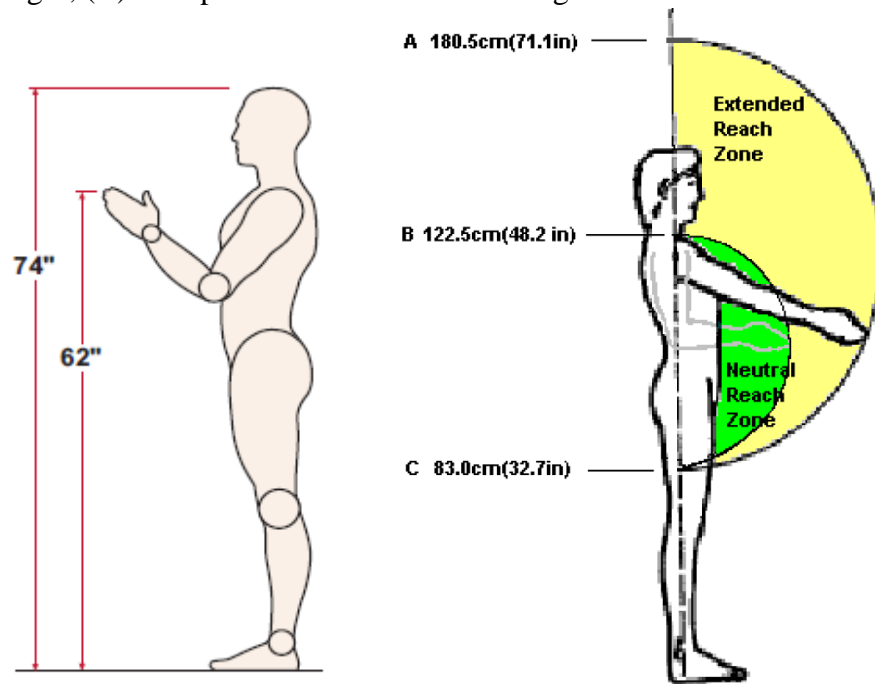
- High-frequency ($\geq 2/\text{minute}$), high-force ($\geq 10 \text{ lb}$ or 4.5 kg), or long-duration ($\geq 10 \text{ seconds}$) tasks: $\leq 62''$ (1.58 m)
- Infrequent or low-force tasks shall be: $\leq 74''$ (1.88 m)
- Vertical reach distance shall not exceed: $74''$ (1.88 m)



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Figure 6.7: (Left) Vertical Reach Distance Guidelines; (Right) vertical reach zones for an operator workstation or job task design: (A) 5th percentile female vertical grip reach; (B) 5th percentile female shoulder height; (C) 95th percentile male knuckle height.



Similarly there are designated vertical reach zones for standing positions, as shown in Figure 6.7 that should be used in the design of a work area or job to accommodate for an operator's occupational health while minimizing the risk of exertion and harm.

The vertical reach limits for an operator workstation or job task design:

- 5th percentile female vertical grip reach;
- 5th percentile female shoulder height;
- 95th percentile male knuckle height

6.1.6.2. Countermeasures

- Use mobile platform or stair ladders
- Install person lifts/booms
- Install pits with product on height adjustable tables
- Relocate parts



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- Reorient product with product rotators
- Reduce task frequency

6.1.6.3. Work Examples

- Tightening a fastener on top of generator
- Assembling hose connections at master rebuild center

6.1.6.4. Other Considerations

- Time or productivity penalties for longer vertical reach distances: every 6" (152 mm) of vertical reach distance is equal to approximately 0.2 seconds of wasted time
- Product quality penalties: quality decreases as tasks are performed farther away from the body

6.1.7 Standing Workstations

6.1.7.1. Guidelines

Hand working height from standing surface for assembly tasks:

- Optimal zone should be: adjustable 38"–47" (0.97–1.19 m)
- Acceptable zone shall be: adjustable 30"–57" (0.76–1.45 m)
- Fixed height: 42" (1.07 m)
- Precision or visually demanding tasks: adjustable 40"–51" (1.02–1.30 m), or fixed height 45" (1.14 m)

Standing Workstation Clearances

- Minimum overhead clearance: 80" (2.03 m)
- Work surface thickness: ≤ 2 " (51 mm)
- Knee space depth: ≥ 6 " (152 mm)
- Knee space width: ≥ 30 " (762 mm)

6.1.7.2. Countermeasures

- Use height adjustable work surface, platforms
- Improve fixture design
- Prioritize workstation layout based on task importance
- Remove equipment and parts beneath workstation
- Eliminate storage shelves beneath workstation



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6.1.7.3. Work Examples

- Engine Assembly on conveyor
- Wire harness assembly on table

6.1.7.4. Other Considerations

- The vertical height of the product will determine the hand working height relative to the work surface
- Know height or location at which employee's hand interacts with product (top, bottom, middle, front, side, or back)
- Prioritize the vertical height of the assembly tasks in the operation based on highest frequency tasks or most critical tasks
- Provide 10" (254 mm) of vertical height adjustability
- Part bins that support the assembly process:
 - Place in front of employee, not to the side
 - Horizontal reach distance: $\leq 16"$ (406 mm)
 - Vertical height: 24"–70" (0.61–1.78 m)
- Tool location that supports the assembly process:
 - Balanced overhead at $\leq 74"$ (1.88 m) above standing surface, or Tool holster at 42" (1.07 m) above standing surface
 - Add 15% or more to the appropriate dimensions for employees wearing heavy or protective clothing.

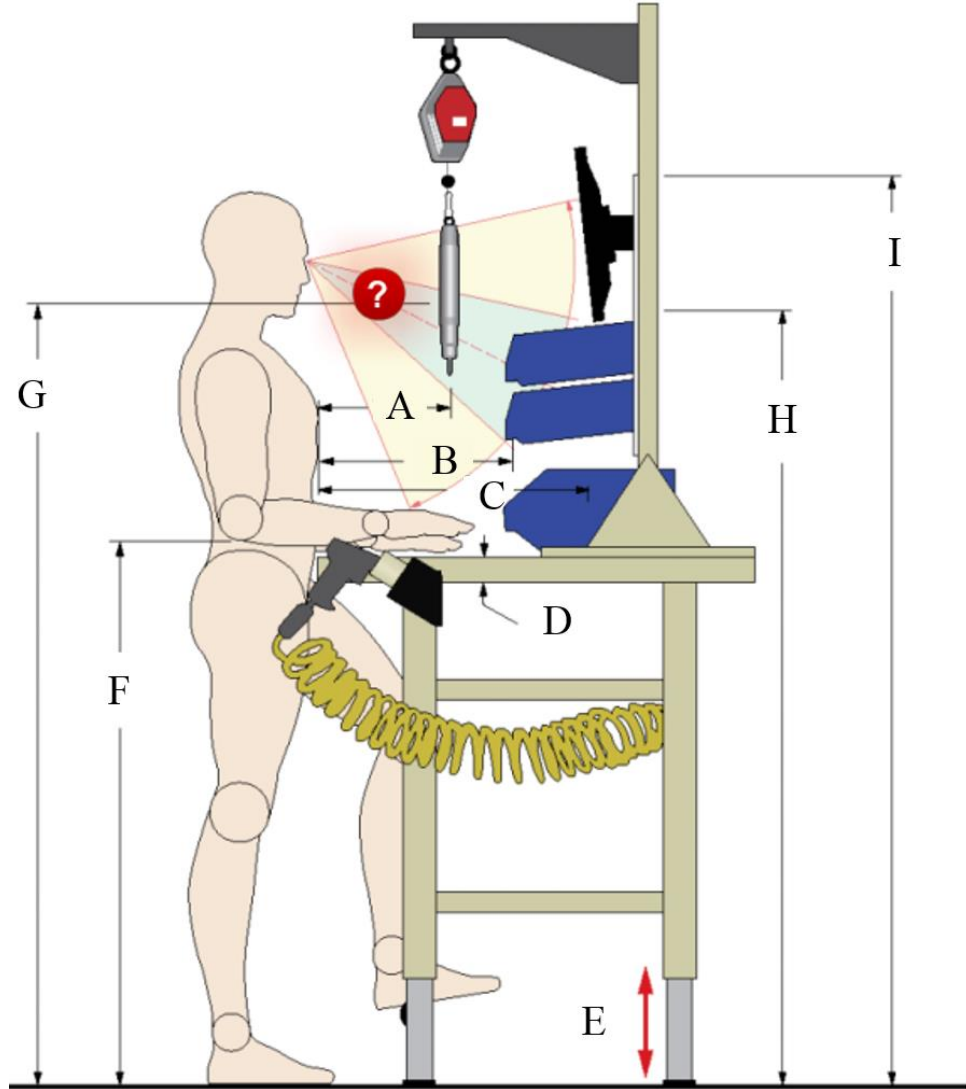
6.1.7.5. Standing Workstation Dimensions



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Figure 6.9: Standing Workstation Diagram





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Table 6.1: Standing Workstation Clearances by Country. See Figure 6.9 for measure references

	USA/Canada (in)	Mexico (mm)	Asia (mm)	Europe (mm)	South America (mm)
A	10	246	246	264	257
B	15	369	357	380	383
C	21	516	500	532	536
D	2	51	51	51	51
E	10	254	254	254	254
F	42-44	1029-1079	1016-1066	1077-1127	1067-1117
G	62-75	1484-1805	1485-1806	1576-1915	1542-1874
H	61	1529	1495	1561	1569
I	56-70	1394-1679	1356-1680	1430-1781	1439-1743

Table 6.2: Standing Hand Working Clearances by Country. Table refers to Measure F in Figure 6.9

	Optimal Zone		Precision or Visually Demanding Tasks	
	Fixed	Adjustable	Fixed	Adjustable
US/Canada (in)	42-44	39-48	45-47	41-52
Mexico (mm)	1029-1079	958-1150	1105-1155	1009-1252
Asia (mm)	1016-1066	931-1151	1092-1142	982-1253
Europe (mm)	1077-1127	983-1221	1153-1203	1034-1323
South America (mm)	1067-1117	989-1195	1143-1193	1040-1297

6.1.8 Display Height and Position for Standing Operations

6.1.8.1. Visual display:

- Optimal height (top of screen) adjustable 58"– 71" (1.47–1.80 m) above standing surface, or fixed height 66" (1.68 m) above standing surface
- Optimal viewing distance adjustable 18"–30" (457–762 mm), or fixed viewing distance 23" (584 mm)
- Position in front of employee (not beside or behind) when information is viewed

6.1.8.2. Touch Screen

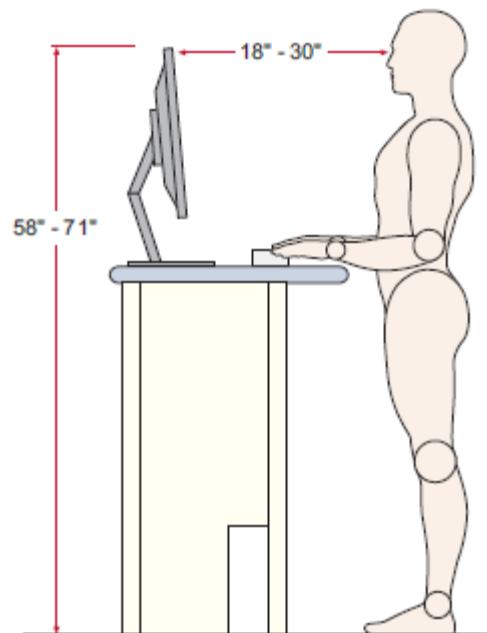


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- Optimal height (top of screen) adjustable 47"–71" (1.19– 1.80 m) above standing surface, or fixed height 59" (1.50 m) above standing surface
- Optimal touch distance: $\leq 22"$ (559 mm)
- Position displays perpendicular to standing surface or tilt slightly downward to avoid glare

Figure 6.10: Display Height and Position for Standing Operations



6.1.8.3. Countermeasures

- Height adjustable display arms
- Larger font and display screen for displays more than 30" (762 mm) away

6.1.8.4. Work Examples

- CNC control panel
- Work instruction display screen

6.1.8.5. Other Considerations



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- Limit neck bending and twisting to $\leq 20^\circ$, eliminate neck extension while viewing
- Comfortable line of sight is directly ahead and 15° below horizon
- Comfortable eye deviations are 15° above or below and right or left of the comfortable line of sight

6.1.9 Seated Workstations

6.1.9.1. Guidelines

Hand working height for assembly tasks from floor surface, for precision or visually demanding tasks:

- Adjustable height: 27"–36" (686–914 mm)
- Fixed height shall be: 36" (914 mm)
- Not-to-exceed hand working height: 36" (914 mm)
- Work surface thickness: ≤ 2 " (51 mm)
- Knee space depth: ≥ 18 " (457 mm)
- Knee space width: ≥ 30 " (762 mm)
- Thigh clearance between seat pan and underside of work surface ≥ 8 " (203 mm)

6.1.9.2. Countermeasures

- Use height adjustable work surface
- Use height adjustable chair with footrest (if necessary)
- Optimize/prioritize workstation layout
- Remove equipment and parts beneath workstation
- Eliminate storage shelves beneath workstation

6.1.9.3. Work Examples

- Assembly of circuit boards on worktable
- Inspection of medical devices

6.1.9.4. Other Considerations

- The vertical height of the product will determine the hand working height relative to the work surface
- Know height or location at which employee's hand interacts with product (top, bottom, middle, front, side, or back)



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- Prioritize the vertical height of the assembly tasks in the operation based on highest frequency tasks or most critical tasks
- Provide 9" (229 mm) of vertical height adjustability
- Add 15% or more to the appropriate dimensions for employees wearing heavy or protective clothing
- Part bins that support the assembly process:
 - Place in front of employee, not to the side
 - Horizontal reach distance: $\leq 16"$ (406 mm)
 - Vertical height: $\leq 46"$ (1.17 m)
- Tool location that supports the assembly process:
 - Balanced overhead at $\leq 46"$ (1.17 m) above floor surface, or
 - Tool holster at 36" (914 mm) above floor surface
- Displays that support the assembly process:
 - Optimal display height (top of screen) adjustable between 35"–46" (0.89–1.17 m) above floor surface
 - Fixed display height of 46" (1.17 m)
 - Optimal viewing distance adjustable 18"–30" (457–762 mm), or fixed viewing distance 23" (584 mm)
 - Position in front of employee (not beside or behind) when information is viewed

6.1.9.5. Seated Workstation Dimensions



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Figure 6.11: Seated Workstation Dimensions

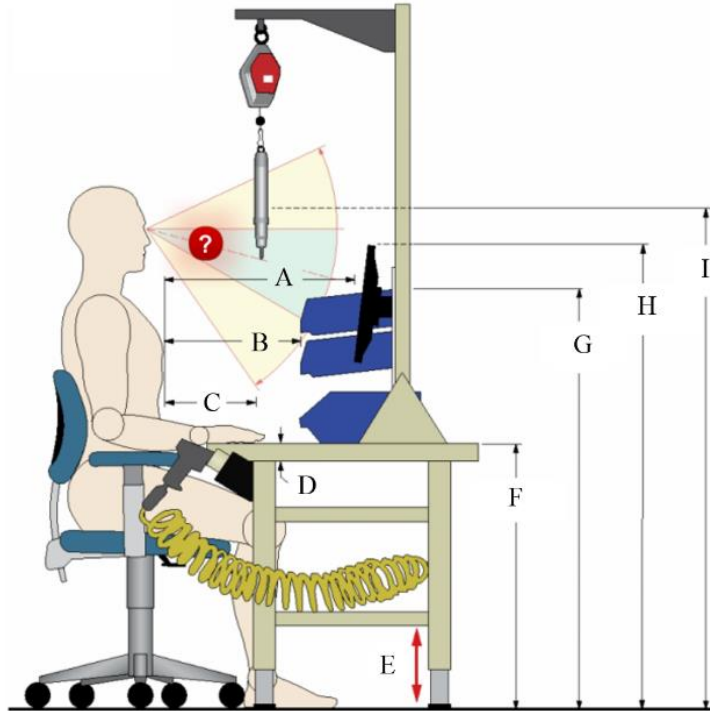


Table 6.3: Seated Workstation Dimensions by Country. See Figure 6.11 for measure references.

	USA/Canada (in)	Mexico (mm)	Asia (mm)	Europe (mm)	South America (mm)
A	21	516	500	532	536
B	15	369	357	380	383
C	10	246	246	264	257
D	2	51	51	51	51
E	10	254	254	254	254
F	27-29	642-692	642-692	684-735	669-719
G	46	1155	1131	1177	1183
H	41-51"	1019-1219	992-1220	1045-1293	1052-1266
I	55"	1320	1321	1402	1372



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Table 6.4: Seated Hand Working Heights by Country. Table refers to Measure F in Figure 6.11.

	Optimal Zone		Precision or Visually Demanding Tasks	
	Fixed	Adjustable	Fixed	Adjustable
US/Canada (in)	27-29	24-29	30-32	26-33
Mexico (mm)	642-692	584-692	718-768	635-794
Asia (mm)	642-692	567-692	718-768	618-794
Europe (mm)	684-735	599-735	760-810	650-837
South America (mm)	669-719	603-719	745-790	654-821

6.1.10 Anti-Fatigue Floor Matting

6.1.10.1. Guidelines

Provide industrial mats for employees who stand for 90% or more of their working hours.

- Thickness: ≥ 0.5 " (13 mm)
- Interlocking edges to securely join adjacent pieces
- Beveled edges to minimize trip hazards
- Place industrial mats at least 8" (203 mm) under a workstation or conveyor to prevent uneven standing surfaces

If operators are required to stand, anti-fatigue mats shall be provided as long as they do not create a trip hazard. Anti-fatigue insoles should also be considered as a substitute for anti-fatigue mats. In addition, footrests shall be added, where possible, to allow the worker to be in various positions.

6.1.10.2. Other Considerations

- During prolonged standing on hard surfaces, there is a lack of venous return and arterial circulation in the lower extremities that can cause the feet to swell and can lower skin temperatures, increasing leg discomfort and fatigue.
- The elastic surface of anti-fatigue matting works by creating a slightly unstable standing surface. Small amounts of muscle activity are required to maintain balance while standing on the matting. The muscle activity promotes blood flow, and prevents leg discomfort and fatigue.



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- Industrial mats significantly reduce discomfort compared to standing on concrete.
- Order mats to meet specific drainage, burn resistance, and hygiene requirements.

6.1.11 Automation and Fixture Criteria

6.1.11.1. Guidelines

6.1.11.2. For inserting raw parts into automated machines:

- Fixtures should be designed so parts are guided into place (flanged openings, beveled edges)
- Use laser pointers to indicate part location, orientation, alignment
- Provide poka-yoke (error proofing) mechanisms in machines and fastening devices to prevent human error

For retrieving parts:

- Automatically move parts to position of use (screw feeder or powered conveyors)
- Dispense parts using magazines to standard pick location and part orientation, to eliminate part separation and retrieval time
- Locate parts in standard locations (heights and distances) to reduce search times

For removing finished parts from automated machines:

- Automatically eject parts after processing to eliminate manual part removal and allow immediate insertion of next part (fixture ejectors)
- Parts should automatically move to next processing station without manual effort (powered or gravity conveyors)
- Tools and machines should automatically return to initial or start position to eliminate searching (tool balancers or CNC lathe)

6.1.12 Flow

6.1.12.1. Guidelines

- Standardize work procedures to ensure right tool is used for right task and also improves process stability and product quality
- Design for one-piece flow to reduce repetitive and/or static work postures and promote efficient work procedures and to reduce multiple part handling



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- Promote movement through the U-shaped work cell (e.g., one employee walks the part through the series of workstations) to support adequate blood flow
- The work flow should be designed to avoid static working conditions to minimize muscle fatigue and reduced blood flow
- Design for U-shaped work cells to optimize space utilization and resource allocation
- Arrange part storage bins in sequence of tasks whenever possible
- Order assembly tasks to minimize distance between tasks
- Minimize multiple handling of parts and tools to reduce wasted motion time
- Present parts in storage bins in same orientation as assembled to eliminate part reorientation
- Present tools in same orientation as used during assembly to eliminate tool reorientation
- Maintain consistent hand working heights throughout part retrieval and assembly tasks to reduce wasted motions



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6.2 Manual Material Handling

6.2.1 Manual Material Handling Introduction

Material Handling, for the purpose of this standard, is defined as the movement of material or the performance of work that is within the operators Work Envelope as defined in section 6.1.5.1 Work Envelope; even if the worker is working away from the designated work area. Ideally, all moving of material is to be performed in the Neutral Reach Zone.

Material Handling is comprised of three key components:

- Lifting and Lowering
- Pushing and Pulling
- Carrying

There are several tools that can be used to quantify reasonable limits with respect to material handling. It is recommended to utilize the NIOSH lifting equation for evaluation of material lifting and lowering tasks. If you have any questions on how to apply the equation, consult your plant Safety Leader for more detail.

6.2.2 Recommended Weight for Lifting and Lowering

6.2.2.1. Guideline

The recommended weight lifted should not exceed 35 lbs. (16 kg.). If there is an existing guideline, legal or site requirements, lower than 35 lbs. (16 kg), adhere to that. This value constitutes the weight lifting guideline for two-handed lifting under ideal lifting circumstances. If any of the following are present, consult the NIOSH lifting equation for recommended weight limit (RWL) and work to achieve Lifting Index less than or equal to 1.0:

- Frequency of lift is greater than 1/minute → NIOSH
- Part or all of the lift is outside the Power Zone → NIOSH

Furthermore, it is recommended to complete the NIOSH lifting equation for all lifts over 18 lbs. (8 kg.) with the goal of improving conditions to achieve 1.0 or lower Lifting Index.



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6.2.2.2. Countermeasures

- Improve height using
 - Height adjustable lift table
 - Load leveler
 - Raised platform
 - General hand working height for manual material handling (from standing surface):
 - Optimal zone: adjustable 38"-49" (0.97-1.25 m)
 - Acceptable zone shall: adjustable 24"-62" (0.61-1.58 m)
- Reduce load weight
- Use mechanical assist
- Provide handles or clamps, if possible, to improve hand coupling of load
- Redesign object to allow two-handed lifting, see section 6.2.4
- Reorient object to allow neutral wrist posture, see section 6.2.6
- Consider reach distances when designing and implementing packaging/line-side presentation

6.2.2.3. Work Examples

- Grasping part from machine
- Preventive maintenance or set-up tasks
- Lifting bag from pallet
- Retrieving box of parts from shelf
- Retrieving parts from bins/containers

6.2.2.4. Other Considerations

- Wrist angle affects grip strength (non-neutral postures reduce grip strength further)
- Repetition of lift affects grip strength (tasks done more frequently than one lift every 5 minutes reduce grip strength)
- Hand coupling affects ease of lift (consider adding proper handles or clamps for power-grip postures)
- Measurement tools for conducting analyses
 - Tape measure; scale
- Use appropriate analysis tool(s):

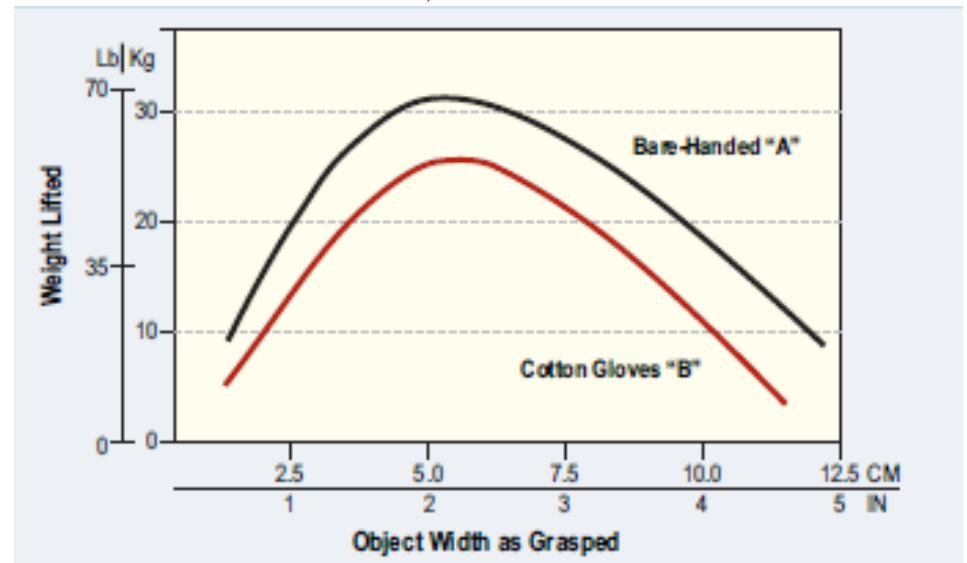


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- NIOSH Lifting Equation
- Snook & Ciriello Lift Guidelines
- For one-handed, infrequent lifting (<2/minute) from hand working heights 25”-50” (0.64-1.27 m), see Figure 6.14.

Figure 6.14: Acceptable Weights for Various Object Widths (Bare-Handed and with Cotton Gloves)



6.2.3 Pushing, Pulling, and Carrying

6.2.3.1. Pushing and Pulling

Pushing is to apply force so as to cause or tend to cause motion away from the source of the force. Pulling is to apply force so as to cause or tend to cause motion toward the source of the force.

Using Tables 6.5 and 6.6, these steps shall be followed to determine push/pull weights:

1. Select the push vertical distance – The height of the push or pull
2. Select the frequency of the push/pull
3. Select the push distance – The distance of the push or pull from beginning to end



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4. Select the type of push/pull – Initial force is only needed to get the object moving. Sustained force is constantly applied to keep the object moving.
5. Choose the acceptable pushing force

Table 6.5: Recommended Pushing Force in Metric Units

		Push Distance (cm)					
		210		760		1520	
		Forces		Forces		Forces	
		Initial	Sustained	Initial	Sustained	Initial	Sustained
Hand Height (cm)	Frequency of Lift	Maximum Acceptable Pushing Force (kg)					
at 135	1 per 8h	22	14	20	11	17	9
at 135	1 per 30min	21	12	19	9	16	7
at 135	1 per 5min	20	11	18	8	15	7
at 135	1 per 2min	18	10	16	7	14	6
at 135	1 per 1min	17	10	16	7	13	6
at 135	1 per 12s	15	8	14	7	12	6
at 135	1 per 6s	13	6	13	6	10	5
at 89	1 per 8h	22	13	21	11	17	10
at 89	1 per 30min	21	11	19	9	16	8
at 89	1 per 5min	20	10	19	9	16	7
at 89	1 per 2min	18	9	17	8	14	7
at 89	1 per 1min	17	9	16	8	14	6
at 89	1 per 12s	15	7	15	7	12	6
at 89	1 per 6s	14	6	14	6	10	5

		Push Distance (cm)					
		3050		4570		6100	
		Forces		Forces		Forces	
		Initial	Sustained	Initial	Sustained	Initial	Sustained
Hand Height (cm)	Frequency of Lift	Maximum Acceptable Pushing Force (kg)					
at 135	1 per 8h	17	8	17	8	15	6
at 135	1 per 30min	15	6	15	6	14	4
at 135	1 per 5min	14	6	14	5	12	4
at 135	1 per 2min	13	6	13	5	12	4
at 135	1 per 1min	12	5	12	5	N/A	N/A
at 135	1 per 12s	N/A	N/A	N/A	N/A	N/A	N/A
at 135	1 per 6s	N/A	N/A	N/A	N/A	N/A	N/A
at 89	1 per 8h	18	9	18	8	16	6
at 89	1 per 30min	16	7	16	6	14	5
at 89	1 per 5min	15	6	15	6	13	4
at 89	1 per 2min	14	6	14	6	12	4
at 89	1 per 1min	12	5	12	5	N/A	N/A
at 89	1 per 12s	N/A	N/A	N/A	N/A	N/A	N/A
at 89	1 per 6s	N/A	N/A	N/A	N/A	N/A	N/A



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Table 6.6: Recommended Pushing Force in Imperial Units

		Push Distance (in)					
		82		299		598	
		Forces		Forces		Forces	
		Initial	Sustained	Initial	Sustained	Initial	Sustained
Hand Height (in)	Frequency of Lift	Maximum Acceptable Pushing Force (lb)					
at 53	1 per 8h	48	31	44	24	37	20
at 53	1 per 30min	46	26	42	20	35	15
at 53	1 per 5min	44	24	40	18	33	15
at 53	1 per 2min	40	22	35	15	31	13
at 53	1 per 1min	37	22	35	15	29	13
at 53	1 per 12s	33	18	31	15	26	13
at 53	1 per 6s	29	13	29	13	22	11
at 35	1 per 8h	48	29	46	24	37	22
at 35	1 per 30min	46	24	42	20	35	18
at 35	1 per 5min	44	22	42	20	35	15
at 35	1 per 2min	40	20	37	18	31	15
at 35	1 per 1min	37	20	35	18	31	13
at 35	1 per 12s	33	15	33	15	26	13
at 35	1 per 6s	31	13	31	13	22	11

		Push Distance (in)					
		1200		1799		2401	
		Forces		Forces		Forces	
		Initial	Sustained	Initial	Sustained	Initial	Sustained
Hand Height (in)	Frequency of Lift	Maximum Acceptable Pushing Force (lb)					
at 53	1 per 8h	37	18	37	18	33	13
at 53	1 per 30min	33	13	33	13	31	9
at 53	1 per 5min	31	13	31	11	26	9
at 53	1 per 2min	29	13	29	11	26	9
at 53	1 per 1min	26	11	26	11	N/A	N/A
at 53	1 per 12s	N/A	N/A	N/A	N/A	N/A	N/A
at 53	1 per 6s	N/A	N/A	N/A	N/A	N/A	N/A
at 35	1 per 8h	40	20	40	18	35	13
at 35	1 per 30min	35	15	35	13	31	11
at 35	1 per 5min	33	13	33	13	29	9
at 35	1 per 2min	31	13	31	13	26	9
at 35	1 per 1min	26	11	26	11	N/A	N/A
at 35	1 per 12s	N/A	N/A	N/A	N/A	N/A	N/A
at 35	1 per 6s	N/A	N/A	N/A	N/A	N/A	N/A

6.2.3.2. Carrying

Carrying is defined as the actual transport of an object. Carrying will often be preceded or succeeded by a lift or lower, therefore take the lowest weight recommendation between the carry and lift/lower.

Using Tables 6.7 and 6.8, these steps shall be followed to determine carrying weights:



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1. Select the carrying height - If you are not sure how the object will be carried select the more conservative weight figure.
2. Select the frequency of the carry
3. Select the distance of the carry
4. Choose the acceptable weight of carry

Table 6.7: Recommended Weight of Carry in Metric Units

	Distance of Carry (cm)		
	210	430	850
Frequency of Carry	Maximum Acceptable Weight of Carry (kg)		
1 per 8h	16	16	16
1 per 30min	13	13	12
1 per 5min	13	13	12
1 per 2min	13	13	12
1 per 1min	13	13	12
1 per 20s	12	10	11
1 per 10s	11	9	10

Table 6.8: Recommended Weight of Carry in Imperial Units

	Distance of Carry (in)		
	83	169	335
Frequency of Carry	Maximum Acceptable Weight of Carry (lb)		
1 per 8h	35	35	35
1 per 30min	29	29	26
1 per 5min	29	29	26
1 per 2min	29	29	26
1 per 1min	29	29	26
1 per 20s	26	22	24
1 per 10s	24	20	22

6.2.4 Two-Person Lift

6.2.4.1. Guidelines

- Two-person lifting shall only be a temporary solution while engineering changes are investigated (e.g., lift assist)
- For sheet handling (metal, plywood, glass, paneling), limit weight to 44 lb (20 kg) (due to difficulty in grasping load)
- Prior to a two-person lift, both individuals should discuss lift path and plan to avoid surprise movements (synchronize movements)



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- Limit lift length to 1 minute to reduce potential muscle fatigue accumulation and disproportionate loading between lifters
- Provide engineering solutions to slide objects weighing more than 60 lb (27 kg) rather than lifting with a two-person team

6.2.4.2. Countermeasures

- Use lift assist to move material
- Use conveyance method to eliminate need to lift materials (carts, conveyors)
- Reduce material size or weight to allow a single-person lift

6.2.4.3. Work Examples

- Handling long metal sheets, plywood, or pipes at construction sites
- Carrying a large roll of material
- Transporting large panels to a worktable

6.2.4.4. Other Considerations

- Stairs, slopes, and platforms reduce lifting capability of two-person teams (one person may have to support the bulk of the load at times)
- Utilize individuals of similar size and strength; if heights vary drastically, the cumulative effects of spinal loading will be greater for taller individuals

6.2.5 Horizontal Reach

6.2.5.1. Guidelines

- Frequent reach zone (> 2/minute): ≤ 16" (406 mm) from edge of container
- Infrequent reach zone (< 2/minute): ≤ 22" (559 mm) from edge of container
- Minimize soft tissue compression from hard or sharp edges
- Toe clearance to minimize reach: 8" (203 mm) height and depth

6.2.5.2. Countermeasures

- Height and tilt adjustable table



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- Rotating load leveler
- Drop-down sides on large containers (in conjunction with proper hand working heights)
- Extension tool to retrieve product
- Padding along work area to minimize soft tissue compression

6.2.5.3. Work Examples

- Retrieving parts from container
- Palletizing material at various heights

6.2.5.4. Measurement Tools

- Tape measure
- If two-handed lift is required, the NIOSH Lifting Equation shall be used to determine if lift is within recommended guidelines

6.2.6 Part Presentation

6.2.6.1. Guidelines

- Present parts in same orientation as they are assembled to minimize part handling
- Design dunnage with spacers to improve access to parts
- Present parts individually to employee using dispensers, magazines, pre-formed dunnage, etc.
- Present more frequently used parts and heavy or bulk parts between 38"–49" (0.97–1.25 m) above standing surface

6.2.6.2. Countermeasures

- Mechanically reorient parts prior to employee handling
- Redesign dunnage to improve part presentation

6.2.6.3. Work Examples

- Reorienting part from vertical to horizontal orientation
- Rotating part to install into machine fixture

6.2.6.4. Other Considerations



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- Part stack-up may increase force exertions required to separate and obtain parts
- Design dunnage to optimize part count and delivery costs

6.2.6.5. Measurement Tools

- Tape measure

6.2.7 Conveyors

6.2.7.1. Guidelines

Figure 6.15: Work height and reach distances



- Working Height
 - Hand working height range: 38"–49" (0.97–1.25 m)
- Reach distance (from the front of the workstation or product):
 - Precision tasks: $\leq 11"$ (279 mm)
 - High frequency ($\geq 2/\text{min}$) or high force (≥ 10 lb) tasks: $\leq 16"$ (406 mm)
 - Large product assembly tasks: $\leq 22"$ (559 mm)
 - Not-to-exceed horizontal reach distance: 22" (559 mm)
- Clearances:
 - Work surface thickness: $\leq 2"$ (51 mm)
 - Knee space depth: $\geq 6"$ (152 mm)
 - Knee space width: $\geq 30"$ (762 mm)



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- Conveyor selection:
 - Powered, if parts movement exceeds strength guidelines
 - Multi-directional, if parts must be rotated or reoriented
 - Slides/chutes, if containers always move in one direction
 - Spiral, if space is limited and parts are small
 - Gravity, if loads are lightweight or containers are small
 - Curved skate wheel, if moving around corner or bend
 - Expandable skate wheel, if work layout must be flexible
 - Floor-mounted roller, if handling heavier pallet loads

6.2.7.2. Countermeasures

- Use height adjustable conveyor (at least 10" or 254 mm)
- Reduce conveyor width or use diverters
- Reposition conveyor for easier loading

6.2.7.3. Work Examples

- Retrieving parts from conveyor
- Transferring loads for packaging

6.2.7.4. Other Considerations

- Dimensions of material being transported
- Preventive maintenance of conveyor parts
- Load-carrying capacity
- Flow rate (units per hour) should be adjustable or automated (speed up, slow down)
- Conveyor support type (stand, wall-mounted, suspended, etc.)
- Environment:
 - Level or grade changes in the floor
 - Conditions of work area (moisture, dust, clean room, etc.)

6.2.7.5. Measurement Tools

- Tape measure
- Obtain part weights and production standards for other considerations (conveyor capacity and flow rates)



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6.2.8 Drums

6.2.8.1. Guidelines

- Use powered equipment (hoist or forklift) for drums whenever possible
 - If necessary, can use dolly/hand cart to handle drums weighing < 250 lb (113 kg)
- Use low-profile equipment when drums are used (scales, pallets, etc.)
- Manual drum handling techniques:
 - Tip on edge (to get hand cart or dolly underneath)
 - Lift and rotate (from vertical to horizontal or vice versa)
 - Roll on edge (chiming)
- Wheel design for the cart/dolly:
 - Recommended minimum wheel diameter of 8" (203 mm)
 - Front wheels swivel for pulled carts
 - Back wheels swivel for pushed carts

6.2.8.2. Countermeasures

- Use drum dolly/cart to transfer drums
- Use drum lifter or rotator to lift or empty containers
- Use siphons/pumps to remove material
- Use false-bottom or spring-loaded drum to raise working height toward bottom of drum
- Design drum with lightweight material

6.2.8.3. Work Examples

- Transferring drums to fill station
- Removing product from drums

6.2.8.4. Other Considerations

- Environment:
 - Floor material (low friction eases movement)
 - Avoid slopes, curbs, and stairs
 - Remove obstacles along path (ridges or cracks in floor)
 - Avoid congested areas to minimize maneuvering



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- When pouring drum contents, use a stand, fixture, or fixed object to support container weight
- Design workstation to allow simultaneous pouring and measuring
- Caster/tire composition (harder material reduces required force)
 - Polyurethane: durable, chemically inert, non-sparking, non-conductive, non-marking
 - Forged steel: heavy-duty, high capacity (up to 20,000 lb or 9072 kg)
 - Plastic: oil and water resistant, non-sparking, cost-effective
 - Pneumatic: cushioned ride for transfer of delicate items, can roll over lips and rough surfaces
- Tread of wheel (crowned tread is easier to move than flat, wide tread)

6.2.8.5. Measurement Tools

- Scale
- Push/pull gauge; measure both initial force (to overcome inertia) and sustained force (to maintain momentum)

6.2.9 Flow Racks

6.2.9.1. Guidelines

- Retrieval height (frequent): 38"–49" (0.97–1.25 m)
- Replenish height (infrequent): 38"–62" (0.97 –1.58 m)
- Rack angle: 0°–30°
- Bin dimension recommendations:
 - Width < 14" (356 mm); maximum 20" (508 mm)
 - Length < 20" (508 mm); maximum 24" (610 mm)
 - Depth < 6" (152 mm); if depth > 6" (152 mm), provide front cutout
- Minimum clearance between levels: 5" (127 mm) (from top of the bin front to the bottom of the next shelf height)
- Minimum horizontal hand clearance between the edge of the box and the closest structure of the flow rack should be 4" on each side.

6.2.9.2. Countermeasures

- Use gravity flow racks to minimize material handling



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- Minimize weight in container if it is to be manually handled

6.2.9.3. Other Considerations

- For storage rack design:
 - Hand clearance between rows of bins depends on size of parts/objects
 - Use middle shelves for heavier or more frequently used containers
 - Use low and high shelves for lighter-weight containers or empties
- Part bins:
 - Place in front of employee, not to the side
 - Horizontal reach distance: $\leq 16"$ (406 mm)
 - Vertical height: 24"–70" (0.61–1.78 m)

6.2.9.4. Measurement Tools

- Tape measure
- Protractor to measure angle

6.2.10 Small Containers (Trays, Totes, Cases, Boxes)

6.2.10.1. Guidelines

Dimensions for trays/totes/cases/boxes:

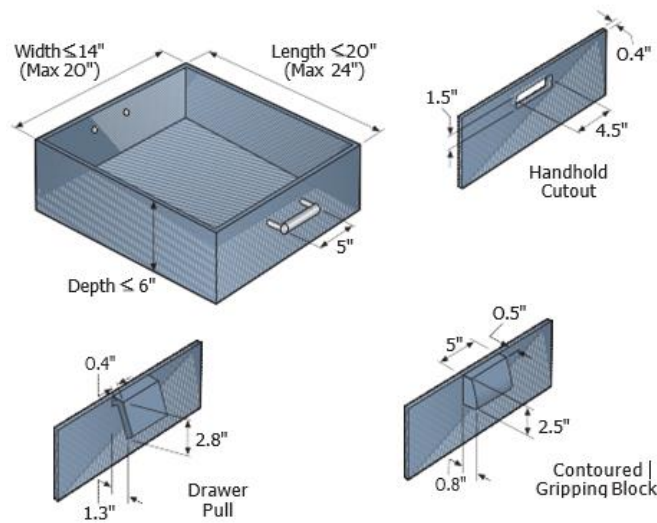
- Width $\leq 14"$ (356 mm); maximum 20" (508 mm)
- Length $\leq 20"$ (508 mm); maximum 24" (610 mm)
- Depth $\leq 6"$ (152 mm); if depth $> 6"$, provide front cutout



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Figure 6.16: Container dimensions and handles/handholds



Container handles:

- Provide handles/handholds at both ends
- Minimum handle length 4.5" (114 mm) (5" or 127 mm ideal)
- For low storage heights (< 40" or 1.02 m) see handhold cutout and drawer pull in Figure 6.16:
 - Handhold cutout length 4.5" (114 mm), height 1.5" (38 mm), thickness 0.4" (10 mm), or drawer pull height 2.8" (71 mm), width 1.3" (33 mm), thickness 0.4" (10 mm)
- For high storage heights (> 40" or 1.02 m) see contoured gripping block in Figure 6.16:
 - Use contoured gripping block, height 2.5" (64 mm), narrow width 0.5" (13 mm), wide width 0.8" (20 mm)

6.2.10.2. Countermeasures

- Redesign container with grips/handholds
- Reduce weight or use smaller containers
- Provide front cutouts on bins to reduce pressure points
- Tilt container to reduce reach distance

6.2.10.3. Work Examples

- Carrying parts container to work area



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- Retrieving screws from parts bin

6.2.10.4. Other Considerations

- Hook or oblique grasps are preferred over lateral pinch grasps or grasps that put pressure on a localized area
- Select and use proper container for material
- Avoid load shifting by using dividers or baffles
- Keep load uniform in container
- Keep center of load below handles
- Minimize weight in container if it is to be manually handled
- Consider lifting frequency in container design (increasing the rate of lifting reduces maximum acceptable weight). Use NIOSH Lifting Equation or Snook and Ciriello tables to determine acceptable weights for specific lifting tasks.

6.2.10.5. Measurement Tools

- Tape measure
- Scale

6.2.11 Lift Tables/Load Levelers

6.2.11.1. Guidelines

- Minimum 36" (914 mm) of height adjustability
- Powered adjustments preferred over manual
 - Hand controls preferred over foot pedal activation
 - Controls should be easy to reach (within 16" or 406 mm)
- Use rotating top to reduce reach
- Use low-profile table if forklift use is limited (use hand truck to deliver pallets of material)
- Use load levelers if load changes constantly (layers of product being loaded or unloaded)
- Provide tilt adjustability to reduce reach (ensure product/load is stable)

6.2.11.2. Countermeasures

- Modify lift table surface to improve handling (roller or skate wheel conveyor surface, ball roller surface, low-friction slip sheet)

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- Retrofit table with tilt adjustability to reduce reach distances

6.2.11.3. Work Examples

- Palletizing material at end of line (finished goods)
- Retrieving parts for assembly

6.2.11.4. Other Considerations

- Preventive maintenance of lift table or load leveler mechanisms
- Floor space should accommodate required workstation and equipment footprint
- Use adequate guarding and accordion cover when necessary
- Select table based on load capacity and size; use smallest table possible to reduce reach distance and footprint
- Label and color-code controls (up/down) to minimize error

6.2.11.5. Measurement Tools

- Tape measure
- Scale

6.2.12 Lift Assists

6.2.12.1. Guidelines

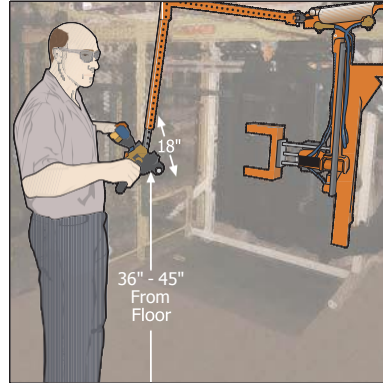
- Handle criteria:
 - Positioned ≤ 18 " apart (457 mm)
 - Height 36"– 45" (0.91–1.14 m) from floor; adjustable preferred over fixed
- Maneuvering forces (two hands at elbow height):
 - Frequent > 2 /min: 11.8 lb (5.4 kg)
 - Infrequent < 2 /min: 29.5 lb (13.4 kg)
- Visual access to end effector
- Convey proper grasp of object to employee
- Use Intelligent Assist Devices (IAD) when possible to reduce initiating forces



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Figure 6.17: Lift assist



6.2.12.2. Countermeasures

- Design flexibility and adjustability into lift assist (adjustable handle angles/widths)
- Use customized end effectors (for ease of use)
- Use universal end effectors that can be used for several parts
- Use multiple-part end effectors to handle more than one part at a time

6.2.12.3. Work Examples

- Transferring parts from conveyor to pallet
- Removing parts from auto assembly fixture
- Maneuvering or reorienting objects

6.2.12.4. Other Considerations

- Place tension or balance control of height adjustment within easy reach
- Use floating handles to maintain consistent hand height
- Involve employees during prototype and testing; work with vendors to trial lift assists
- Design product packaging to allow access for lift assist
- Lift assist material should be lightweight
- Hinged arms provide more flexibility and maneuverability than fixed arms
- Preventive maintenance of lift assist device



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- Label and color-code controls (up/down) to minimize error
- Environment:
 - Remove obstacles (structural columns, pallets, etc.) along lift assist path
 - Avoid congested areas to minimize maneuvering time

6.2.12.5. Measurement Tools

- Tape measure

6.2.13 Hand Carts, Hand Trucks, and Trolleys

Refer to section 6.2.3.1 for force guidelines for pushing and pulling.

6.2.13.1. Guidelines

Cart handles:

- Continuous vertical handles preferred
- Position separated handles maximum 18" (457 mm) apart
- Height: 36"–45" (0.91–1.14 m) from floor
- Diameter: 1.5" (38 mm)
- Length: minimum 5" (127 mm) for bare hand, 5.5" (140 mm) for gloved

Pushing/pulling:

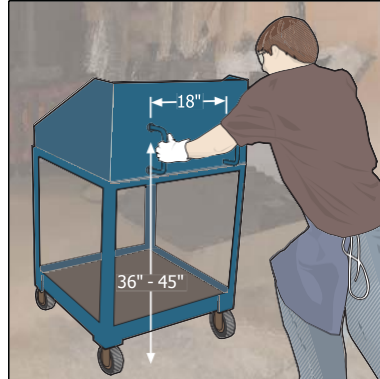
- Replace with powered vehicles when distances are
 - > 52 feet (16 m) for 2-wheeled carts
 - > 108 feet (33 m) for 4-wheeled carts
- Pushing preferred over pulling
- General push/pull guidelines are provided for various distances and frequencies; see section 6.2.3 for additional detail
- Avoid stacking products, which may obstruct the field of vision



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Figure 6.18: Hand Cart



6.2.13.2. Countermeasures

- Use recommended diameter wheels/casters, see section 6.2.14
- Change composition of wheels
- Use powered pusher
- Reduce load on cart
- Use lightweight cart material

6.2.13.3. Work Examples

- Pushing cart of parts to machine
- Transferring parts to next workstation
- Maneuvering manual pallet jacks

6.2.13.4. Measurement Tools

- Tape measure
- Push/pull gauge; measure both initial force (to overcome inertia) and sustained force (to maintain momentum)

6.2.14 Wheels/Casters

6.2.14.1. Guidelines

- Recommended minimum wheel diameter of 8" (203 mm)
- Front wheels should swivel for pulled carts, back wheels should swivel for pushed carts
- Tread of wheel (crowned tread is easier to move than flat, wide tread)



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- Select wheel material, hardness, and caster configuration according to application, load requirements, floor conditions, and environment
- Caster/tire composition (harder material reduces required force)
 - Polyurethane: durable, chemically inert, non-sparking, non-conductive, non-marking
 - Forged steel: heavy-duty, high capacity (up to 20,000 lb or 9,072 kg)
 - Plastic: oil and water resistant, non-sparking, cost-effective
 - Pneumatic: cushioned ride for transfer of delicate items, can roll over lips and rough surfaces
- Environment:
 - Hard, dry floor is best
 - Avoid slopes, curbs, and stairs
 - Remove obstacles (ridges or cracks in floor)
 - Avoid congested areas to minimize maneuvering



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Table 6.9: Caster Configurations

Configuration	Features	
4-Wheel Non-Tilt (all swivel)	<ul style="list-style-type: none"> Multi-directional Ideal for confined areas Difficult straight line travel Not towable 	
4-Wheel Caster Steer (2 swivel, 2 rigid)	<ul style="list-style-type: none"> Most common Easy turning, straight line travel Trails well 	
4-Wheel Diamond Pattern (all rigid)	<ul style="list-style-type: none"> Center point pivot Suitable for light loads No lateral translation 	
4-Wheel Diamond Pattern (2 swivel, 2 rigid)	<ul style="list-style-type: none"> Turns, maneuvers well No center point pivot No lateral translation Difficult to tow in a train 	
6-Wheel Tilt (4 swivel, corners; 2 rigid, middle)	<ul style="list-style-type: none"> Recommended for heavy loads, longer platforms Middle wheels slightly above rolling surface 4-wheel contact Noisier due to rocking (tilt) 	
4-Wheel Wagon (2 swivel, 2 rigid)	<ul style="list-style-type: none"> Good maneuverability for pulling Recommended for light loads No lateral translation Trails well 	

6.2.14.2. Countermeasures

- Use larger wheels and wheel/caster shocks, especially when rolling over uneven surfaces
- Conduct routine preventive maintenance on all wheels/casters
- Select appropriate wheel/caster configuration



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6.2.14.3. Work Examples

- Pushing/pulling a parts cart or rack to a workstation
- Maneuvering a dolly in a work area
- Transporting large products on a flatbed

6.2.14.4. Other Considerations

- A larger diameter requires less force to push/pull when the rolling surface is uneven. On a flat surface, diameter has little influence on push/pull force.
- Harder material is more susceptible to flat spotting if left under a load for a period of time and creates more noise. Debris embeds more easily in a harder wheel, potentially impeding rolling. Softer material is more elastic, which results in smoother rolling.
- Implement shock absorption functionality to reduce exposure to vibration and noise and provide smoother travel.
- Use worst-case scenario to measure push/pull forces; position swivel wheels perpendicular to direction of movement before measuring and conduct measurement on least favorable rolling surface (incline, rough terrain), taking multiple measurements for initial and sustained push/pull forces.
- Wheel brakes or wheel locks shall be implemented for loading/unloading material on cart.

6.2.14.5. Measurement Tools

- Tape measure
- Push/pull force gauge; measure both initial and sustained force

6.3 Hand and Arm Strength

6.3.1.1. Force Guidelines

Force guidelines are provided to accommodate a full range of healthy, working-age adults. Guidelines include both frequent (≥ 2 force applications per minute) and infrequent (< 2 force applications per minute) situations.

Two types of guidelines are provided:

- Recommended: to optimize human performance



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- Acceptable: not-to-exceed

6.3.2 Machine/Part Assembly/Tool:

6.3.2.1. Finger Push

Figure 6.19: 1 Index finger push

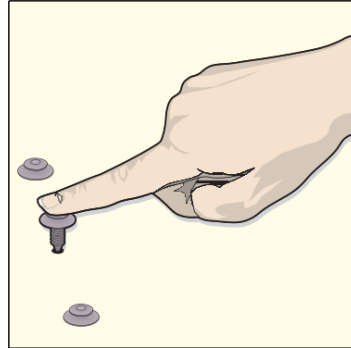


Table 6.10: Finger Push Force Guidelines

Force Exertions: Finger Push	Frequent ($\geq 2/\text{min}$)		Infrequent ($< 2/\text{min}$)	
	Recommended	Acceptable	Recommended	Acceptable
1 index finger	3.4 lb (1.5 kg)	5 lb (2.3 kg)	8.6 lb (3.9 kg)	11.2 lb (5.1 kg)
2 fingers on same hand	5.0 lb (2.3 kg)	7.5 lb (3.4 kg)	12.5 lb (5.7 kg)	16.3 lb (7.4 kg)
2 fingers on different hands	11.0 lb (5.0 kg)	16.5 lb (7.5 kg)	27.5 lb (12.5 kg)	35.8 lb (16.3 kg)

Countermeasures

- Optimize fasteners
- Use alternative fasteners
- Provide external assistance (powered tool)
- Allow for two-handed operation

Work Examples

- Push nuts, push pins, Christmas-tree fasteners
- Part connection
- Assembly tasks

Other Considerations



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- Design application to allow power grip
- Design application for whole hand or multiple fingers

Measurement Tools

- Force gauge/transducers

6.3.2.2. Finger Pull

Figure 6.20: 1 Finger pull

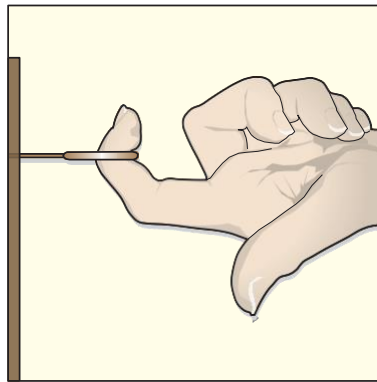


Table 6.11: Finger Pull Force Guidelines

Force Exertions: Finger Pull	Frequent ($\geq 2/\text{min}$)		Infrequent ($< 2/\text{min}$)	
	Recommended	Acceptable	Recommended	Acceptable
1 finger	3.9 lb (1.8 kg)	6.0 lb (2.7 kg)	9.6 lb (4.3 kg)	12.5 lb (5.7 kg)
2 fingers on same hand	8.4 lb (3.8 kg)	12.5 lb (5.7 kg)	20.9 lb (9.5 kg)	27.1 lb (12.3 kg)

Countermeasures

- Use optimal release mechanisms

Work Examples

- Breaking down collapsible bins
- Assembly/disassembly

Other Considerations

- Design application to allow power grip
- Design application to allow multiple fingers



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Measurement Tools

- Force gauge/transducers

6.3.2.3. Thumb Push

Figure 6.21: 1 Thumb push

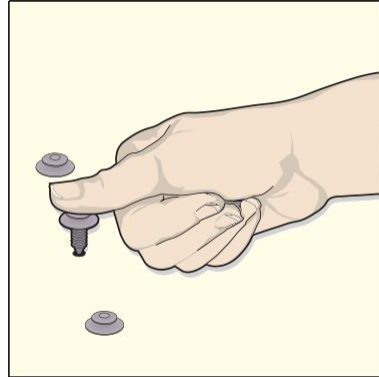


Table 6.12: Thumb Push Force Guidelines

Force Exertions: Thumb Push	Frequent ($\geq 2/\text{min}$)		Infrequent ($< 2/\text{min}$)	
	Recommended	Acceptable	Recommended	Acceptable
1 thumb	5.3 lb (2.4 kg)	8.0 lb (3.6 kg)	13.3 lb (6.0 kg)	17.3 lb (7.8 kg)
2 thumbs	10.0 lb (4.5 kg)	15.0 lb (6.8 kg)	25.0 lb (11.3 kg)	32.5 lb (14.7 kg)

Countermeasures

- Optimize fasteners
- Use alternative fasteners
- Provide external assistance (powered tool)
- Allow for two-handed operation

Work Examples

- Part installation
- Push nuts, push pins, Christmas-tree fasteners
- Part connection
- Push wire harness

Other Considerations

- Design application to allow power grip



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- Design application for two hands

Measurement Tools

- Force gauge/transducers

6.3.2.4. One-Handed Pinch-Grip

Figure 6.22: Chuck pinch grip with no wrist deviation

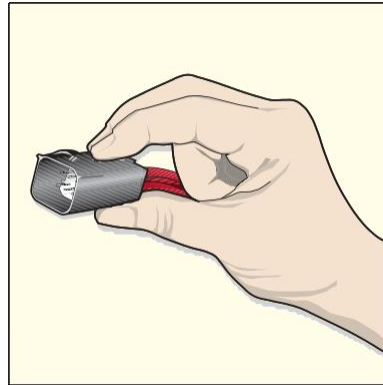


Table 6.13: One-Handed Pinch-Grip Force Guidelines

Force Exertions: Pinch Grip	Frequent ($\geq 2/\text{min}$)		Infrequent ($< 2/\text{min}$)	
	Recommended	Acceptable	Recommended	Acceptable
Chuck pinch grip* (with wrist deviation†)	2.0 lb (0.9 kg)	2.4 lb (1.1 kg)	4.0 lb (1.8 kg)	5.1 lb (2.3 kg)
Chuck pinch grip (no wrist deviation)	3.2 lb (1.4 kg)	4.7 lb (2.1 kg)	7.9 lb (3.6 kg)	10.3 lb (4.7 kg)
Key pinch grip‡ (with wrist deviation)	2.0 lb (0.9 kg)	2.9 lb (1.3 kg)	4.8 lb (2.2 kg)	6.3 lb (2.9 kg)
Key pinch grip (no wrist deviation)	3.9 lb (1.8 kg)	6.0 lb (2.6 kg)	9.7 lb (4.4 kg)	12.6 lb (5.7 kg)

*Chuck pinch grip: thumb opposing the pads of the index and middle fingers

† Wrist deviation: noticeable flexion, extension, ulnar, radial

‡ Key pinch grip: thumb opposing the side of the index finger

Countermeasures

- Use power/air tools
- Use fixtures/jigs



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Work Examples

- Installing parts
- Joining electrical connectors
- Manually holding parts during assembly tasks

Other Considerations

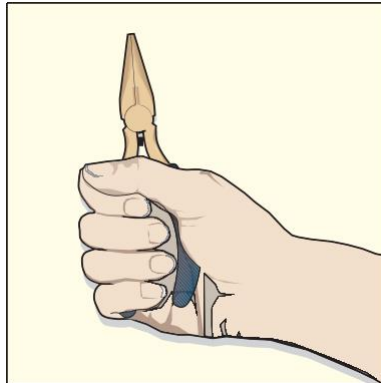
- Design application to allow power grip
- Design for assembly to allow neutral hand/wrist postures
- Optimal grip span is 1.1" (28mm)

Measurement Tools

- Force gauge/transducers
- Psychophysical comparison using grip meter

6.3.2.5. Power-Grip

Figure 6.23: 1 Hand power grip with no wrist deviation





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Table 6.14: Power-Grip Force Guidelines

Force Exertions: Power Grip	Frequent ($\geq 2/\text{min}$)		Infrequent ($< 2/\text{min}$)	
	Recommended	Acceptable	Recommended	Acceptable
1 hand (with wrist deviation*)	6.4 lb (2.9 kg)	9.5 lb (4.3 kg)	15.9 lb (7.2 kg)	20.7 lb (9.4 kg)
1 hand (no wrist deviation)	12.7 lb (5.8 kg)	19.1 lb (8.7 kg)	31.8 lb (14.4 kg)	41.3 lb (18.7 kg)
2 hands (with wrist deviation)	9.0 lb (4.1 kg)	13.5 lb (6.1 kg)	22.6 lb (10.2 kg)	29.3 lb (13.2 kg)
2 hands (no wrist deviation)	18.0 lb (8.2 kg)	27.1 lb (12.3 kg)	45.1 lb (20.5 kg)	58.6 lb (26.7 kg)

* Wrist deviation: noticeable flexion, extension, ulnar, radial

Countermeasures

- Use power/air tools
- Use fixtures/jigs

Work Examples

- Using hand tools (clippers, etc.)
- Manually holding parts during assembly tasks

Other Considerations

- Design for assembly to allow neutral hand/wrist postures
- Optimal grip span is 2" (51 mm)

Measurement Tools

- Force gauge/transducers
- Psychophysical comparison using grip meter

6.3.2.6. Push/Pull with Grip Force



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Figure 6.24: Push/Pull with 1 handed grip

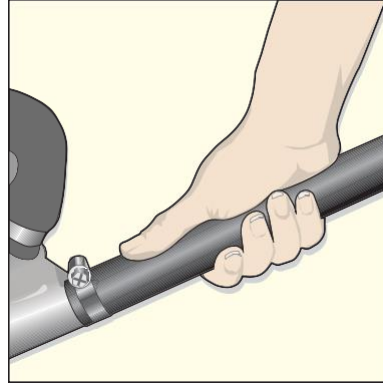


Table 6.15: Push/Pull with Grip Force Guidelines

Force Exertions: Push/Pull	Frequent ($\geq 2/\text{min}$)		Infrequent ($< 2/\text{min}$)	
	Recommended	Acceptable	Recommended	Acceptable
With 1-handed grip on plastic surface	6.7 lb (3.1 kg)	10.1 lb (4.6 kg)	16.9 lb (7.7 kg)	21.9 lb (10.0 kg)
With 1-handed grip on rubber surface	8.0 lb (3.6 kg)	12.0 lb (5.4 kg)	20.0 lb (9.1 kg)	25.9 lb (11.8 kg)

Countermeasures

- Optimize inside diameter (ID) of hose to match connection point
- Optimize clamp
- Provide appropriate lubricant

Work Examples

- Installing a hose
- Removing hoses from a mandrel
- Connecting parts

Other Considerations

- Is grip action or shoulder exertion the limiting factor? Complete an assessment to determine acceptability at the shoulder joint.
- Employees should wear thin, high-friction gloves.

Measurement Tools



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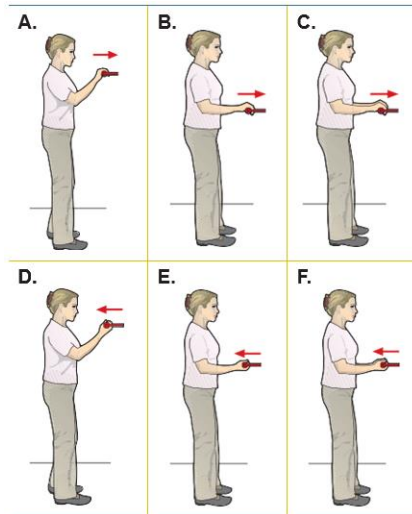
- Force gauge/transducers

6.3.2.7. Standing Arm Strength

These guidelines should be applied in a stationary standing position when only the arms are in use, according to table below. Examples include manual use of torque wrench, pushing to rotate engine on carrier, or pressing a housing into place on a generator set.

Table 6.16 / Figure 6.25: Standing Arm Strength Guidelines

Force Exertions		Frequent ($\geq 2/\text{min}$)		Infrequent ($< 2/\text{min}$)	
		Recommended	Acceptable	Recommended	Acceptable
A.	Push out at shoulder height – 1 hand	6.8 lb (3.1 kg)	10.2 lb (4.6 kg)	17.0 lb (7.7 kg)	22.1 lb (10.1 kg)
B.	Push out at elbow height – 1 hand	7.4 lb (3.4 kg)	11.1 lb (5.1 kg)	18.5 lb (8.4 kg)	24.1 lb (11.0 kg)
C.	Push out at elbow height – 2 hands	11.8 lb (5.4 kg)	17.7 lb (8.0 kg)	29.5 lb (13.4 kg)	38.3 lb (17.4 kg)
D.	Pull in at shoulder height – 1 hand	7.0 lb (3.2 kg)	10.5 lb (4.8 kg)	17.6 lb (8.0 kg)	22.8 lb (10.3 kg)
E.	Pull in at elbow height – 1 hand	7.5 lb (3.4 kg)	11.2 lb (5.1 kg)	18.7 lb (8.5 kg)	24.3 lb (11.1 kg)
F.	Pull in at elbow height – 2 hands	13.1 lb (5.9 kg)	19.6 lb (8.9 kg)	32.7 lb (14.8 kg)	42.4 lb (19.2 kg)



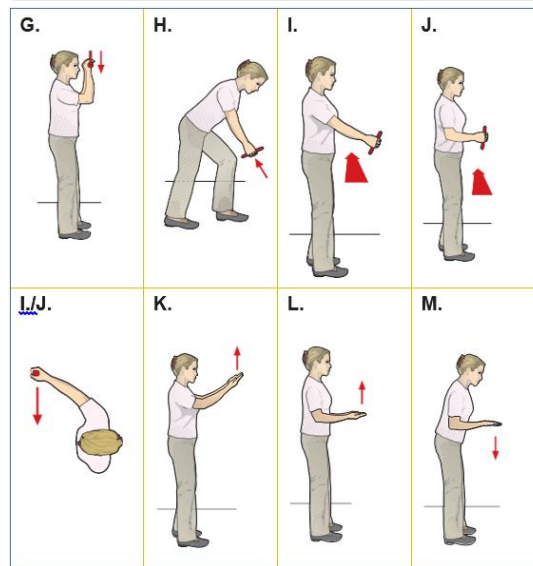


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Table 6.17 / Figure 6.26: Standing Arm Strength Guidelines (Cont.)

Force Exertions		Frequent ($\geq 2/\text{min}$)		Infrequent ($< 2/\text{min}$)	
		Recommended	Acceptable	Recommended	Acceptable
G.	Pull down from overhead – 2 hands	17.9 lb (8.1 kg)	26.8 lb (12.2 kg)	44.7 lb (20.3 kg)	58.1 lb (26.4 kg)
H.	Pull up from knee height – 1 hand	6.3 lb (2.9 kg)	9.5 lb (4.3 kg)	15.8 lb (7.2 kg)	20.5 lb (9.3 kg)
I.	Pull across body (lateral) at waist height – 1 hand, elbow fully extended	2.5 lb (1.1 kg)	3.8 lb (1.7 kg)	6.3 lb (2.9 kg)	8.2 lb (3.7 kg)
J.	Pull across body (lateral) at waist height – 1 hand, elbow at 90°	3.3 lb (1.5 kg)	5.0 lb (2.3 kg)	8.4 lb (3.8 kg)	10.9 lb (4.9 kg)
K.	Lift up at shoulder height – 2 hands	4.7 lb (2.1 kg)	7.0 lb (3.2 kg)	11.7 lb (5.3 kg)	15.3 lb (6.9 kg)
L.	Lift up at elbow height – 2 hands	7.7 lb (3.5 kg)	11.5 lb (5.2 kg)	19.1 lb (8.7 kg)	24.9 lb (11.3 kg)
M.	Press down at elbow height – 1 hand	12.8 lb (5.8 kg)	19.2 lb (8.7 kg)	30.0 lb (13.6 kg)	41.6 lb (18.9 kg)



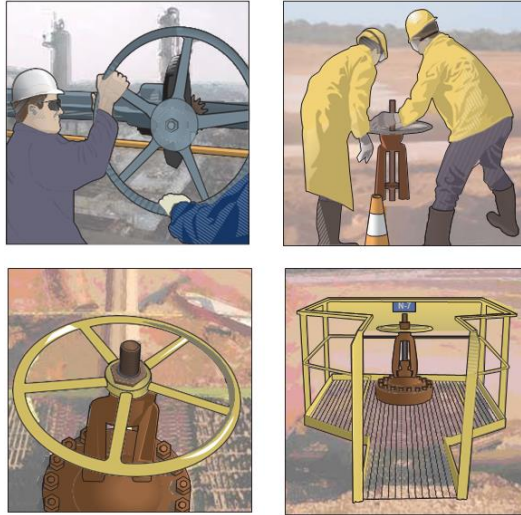


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6.3.3 Upper-body Strength for Hand Wheels

Figure 6.27: Hand wheel example tasks



6.3.3.1. Guidelines

Preferred:

- Mechanized hand wheels that are activated multiple times per day or daily

Acceptable for manual breaking or seating forces:

- Recommended: ≤ 70 lb (31.8 kg)
- Not-to-exceed: 110 lb (49.9 kg)

Acceptable for manual turning forces:

- Recommended: ≤ 35 lb (15.9 kg)
- Not-to-exceed: 75 lb (34 kg)

6.3.3.2. Hand Wheel Placement

Hand wheel orientation

- Recommended: vertical
- Acceptable: horizontal

Horizontal reach distance

- Recommended: ≤ 11 " (279 mm)
- Acceptable: ≤ 16 " (406 mm)



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Vertical hand wheel height (middle of wheel)

- Recommended: 49"–62" (1.25–1.58 m)
- Acceptable: 38"–74" (0.97–1.88 m)

Horizontal hand wheel height

- Recommended: 38"–47" (0.97–1.19 m)
- Acceptable: 30"–57" (0.76–1.45 m)

6.3.3.3. Hand Wheel Size

Handle diameter

- Recommended: 1.8" (46 mm)
- Acceptable: 1.5" (38 mm)

Large hand wheel diameter

- Recommended: ≥ 30 " (762 mm)
- Acceptable: 24" (610 mm)

6.3.3.4. Accessibility

- Minimum overhead clearance: 80" (2.03 m)
- Minimum access around hand wheel: 46" (1.17 m)
- Minimum hand access: 6" (152 mm)

6.3.3.5. Standing Surface

- Flat
- Stable
- High friction
- Minimum 24" x 24" (610 x 610 mm)

6.3.4 Glove Effects

6.3.4.1. Guidelines

- Glove types: Nitrile, cotton, nylon, latex, rubber, leather
- Gloves decrease maximum power grip by 7%–26%
- Gloves decrease sensory discrimination
- Gloves increase ability for manual torque application

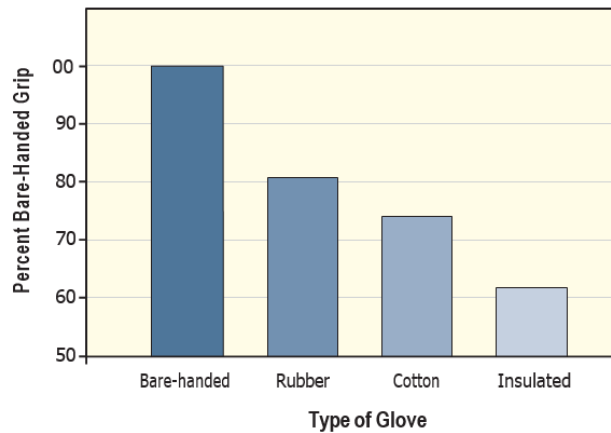


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- Gloves that are too small require the employee to exert force to perform a task and to move the hand within the glove, leading to increased fatigue.
- Gloves that are too large cause the employee to lose dexterity and, as a result, exert more force than necessary to hold objects and tools.
- Please reference Hand Injury and Illness Prevention CORP-09-04-03-00 for other requirements.

Figure 6.28: Effects of Glove Type on Grip Strength



6.3.4.2. Other Considerations

Table 6.17: Comparison of Bare-Hand and Glove-Hand Strength

Indices	Bare Hand	Gloved Hand
Thermal Tolerance	Poor	Good
Tactile Perception	Excellent	Poor
Grip Strength	Good	Reduced
Range of Motion	Excellent	Poor
Manipulative Ability	Excellent	Reduced
Torque Capability	Poor	Improved
Dexterity	Excellent	Reduced
Chemical Resistance	Poor	Excellent
Electrical Energy	Poor	Excellent
Radiation	Poor	Excellent
Biohazard Risk	Poor	Excellent
Abrasive Trauma	Poor	Excellent



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6.3.4.3. Countermeasures

- Determine optimal glove design for operation based on friction, protection, and sensory factors
- Ensure gloves are sized properly

6.3.4.4. Measurement Tools

- Force gauge/transducers
- Psychophysical comparison using grip meter

6.4 Hand Tools

6.4.1 Introduction to Hand Tools

The content in this section applies to all hand tools including power and manual tools. In many operations, the time of exposure to hand tools is significant. Consequently, these tools should be carefully chosen to accommodate a large range of operators. Consider both right-handed and left-handed operators. Whenever possible, buy tools that can be used by both types of operator. If this is not possible, ensure that a right handed user does not use a left handed tool and vice versa. This may force the operator to complete his or her job in awkward positions and cause unnecessary strain.

Hand tools often cause contact stress, or concentrated pressure on some part of the body by a sharp, hard, or pointed object. It is important to note that while gripping a tool handle or squeezing a trigger the operator should be informed (during training) not to use excessive force while operating the tool. This too could cause unnecessary strain and discomfort on the wrist or finger of an operator.

6.4.2 Hand Tools Overview

6.4.2.1. Handle Types

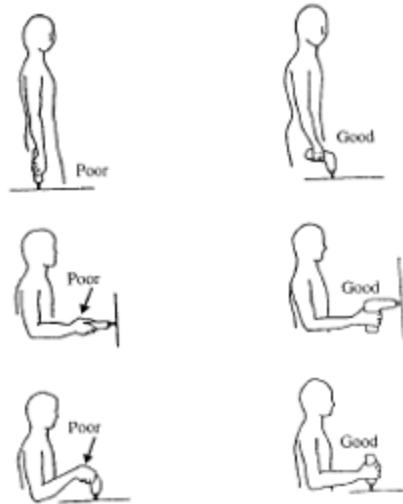
Select a tool with an angle that allows the operator to work with a straight wrist. Tools with bent handles are better than those with straight handles when the force is applied horizontally. Tools with straight handles are better than those with bent handles when the force is applied vertically. Refer to Figure 6.29 for further clarification.



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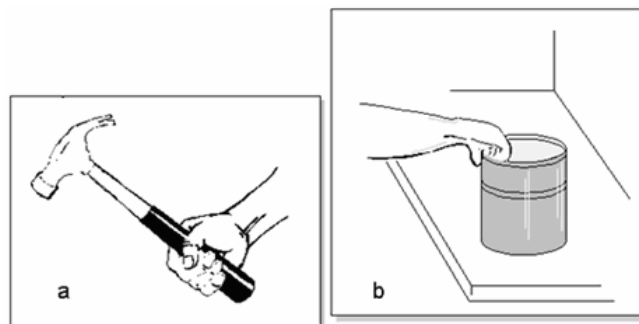
Figure 6.29: Proper orientation of power tools in the workplace



6.4.2.2. Handle Shape

For operations that require a power grip, as shown in Figure 6.30a, the shape of a handle should be round or cylindrical. An operator uses a power grip when his or her fingers bunch firmly around an object and overlap by the thumb. The recommended range for a tool diameter is 1.2 inches (3 cm) to 1.8 inches (4.6 cm). Other tools require a pinch grip, as shown in Figure 6.30b, where the fingers are on one side of the object and the thumb is on the other. Generally, the object does not touch the palm. The recommended diameter or grip span needed for tools used with a pinch grip, such as tweezers, has a range of 0.3 inches (0.8 cm) to 0.5 inches (1.3 cm).

Figure 6.30: (a) Left – Power Grip and (b) Right – Pinch grip





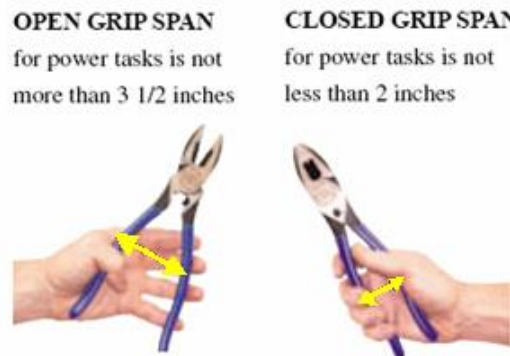
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6.4.2.3. Double-Handled Tool

The span between the handles should be considered when using tools such as pliers and tongs. For double-handled tools that require one hand for operation such as pliers, snips, and cutters, the maximum recommended span is 2 inches (5.1 cm) when closed and 3.5 inches (8.9 cm) when open see Figure 6.31. Using a tool with a span which is either greater or lower than the recommended range could reduce the operators' maximum grip strength. When continuous force is required, consider using a clamp, grip, or locking pliers. In addition, select a tool with spring-loaded handles to return the handles to the open position.

Figure 6.31: Double Handle Tool Span



6.4.2.4. Handle Lengths

Design all handle lengths to be greater than or equal to 3.9 inches (10 cm) (based on the Hand Breadth size of the 95th Percentile male). If an operator wears gloves while working, add a minimum of 0.5 inches (1.3 cm) for a total tool length of 4.4 inches (11.3 cm). If the handle is too short, the end will press against the palm of the operator's hand causing a contact stress and potentially lead to an injury.

6.4.2.5. Handle Surfaces

When possible, use tools with padded grips to minimize tissue damage. However, avoid tools with finger grooves as these are generally designed for the 95th percentile male and may not be appropriate for a wide range of workers.



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Select a tool with a non-slip surface for better grip. Adding a sleeve to the tool, as shown in Figure 6.32, may improve the surface texture of the handle but a sleeve will also increase the tool handle diameter. If a sleeve is added to a tool, ensure that the altered diameter remains in the recommended range. In addition, ensure the sleeve fits snugly during use to prevent slippage within the sleeve. Use Table 6.18 as a reference for preferred hand tool dimensions.

Figure 6.32: Example of Hand Tools and Sleeves



Table 6.18: Hand Tool Dimension Summary

Dimension Description	Centimeters	Inches
Handle length without using gloves	≥ 10	≥ 3.9
Handle length using gloves	≥ 11.3	≥ 4.4
Handle diameter (power grip)	3-4.6	1.2-1.8
Handle diameter (pinch grip)	0.8-1.3	0.3-0.5
Double Handled Tool Span (Closed)	≤ 5.1	≤ 2
Double Handled Tool Span (Open)	≤ 8.9	≤ 3.5

6.4.2.6. Hanging Tools

Hanging tools refer to tools suspended in the air that are attached by a cord from some stationary position or mounted on trolley and/or articulated arms. The tools are at a height above the workstation not to interfere with an operators work when the suspended tool is not needed. However the hung tools are easily accessible provided they are within the workers maximum recommended standing reach height; see section 6.1.6.

Use a tool balancer to support the weight of the tool when possible. Tool balancers hold a hand-operated tool in a pre-set position to minimize



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operator effort during the use of the tool. Two critical specifications include the load capacity and the reach of the tool balancer. The load capacity is the tool weight that the balancer can bear. The tool balancer reach is the maximum displacement that the tool can be pulled from its coiled position at the base of the tool balancer (ideally used perpendicular above the work area). Check with the balancer manufacturer to ensure that the device meets the requirements applicable to a given task.

Described in Table 6.19, are recommended target resistance values in kilograms (kg) and Table 6.20 show target values in pounds (lbs) for a given tool balancer’s retractable cord resistance for all tools needing either one-handed or two-handed operations. Balancers are to be purchased with adjustable tension options to comply with the target values. A force meter can be used to measure the tension or resistance of the tool balancer hose in relation to the tool attached to it.

Table 6.19: Recommended Values of Tool Balancer Resistance in Metric Units

Balancer Values for One & Two Handed Suspended Tools	
One Handed	Two Handed
Values: 1 kg	Values: 1.81 kg
Values: 1 kg – 1.81 kg: Consult with Safety Leader	Values: 1 kg – 3 kg: Consult with Safety Leader
Anything beyond 1.81 kg is unacceptable	Anything beyond the 3 kg is unacceptable

Table 6.20: Recommended Values of Tool Balancer Resistance in Imperial Units

Balancer Values for One & Two Handed Suspended Tools	
One Handed	Two Handed
Values: 2.2 lbs	Values: 4 lbs
Values: 2.2 lbs - 4 lbs: Consult with Safety Leader	Values: 4 lbs - 6.6 lbs: Consult with Safety Leader
Anything beyond 4 lbs is unacceptable	Anything beyond the 6.6 lbs is unacceptable

To select a balancer, consider the weight of the total load (tool plus cable or hose plus other attachments). When the total weight has been determined, the balancer model with the proper tension (weight range) should be chosen.



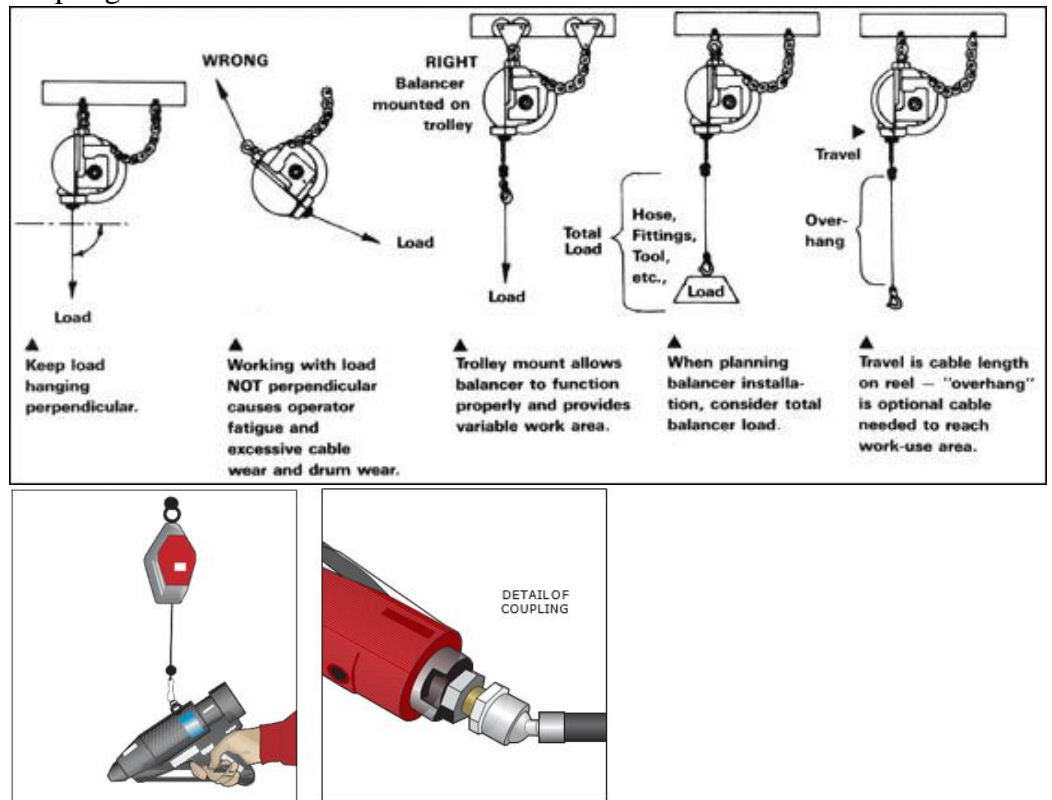
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For situations where a tool exceeds the recommended weight limit recorded consider installing a manipulator. Manipulators give the operator precise control when lifting offset loads, fragile or delicate loads, high temperature or hazardous loads. Low noise levels and low maintenance make manipulators acceptable in a wide range of handling environments. Consult your plant Safety Leader for analysis on a manipulator for a specific application.

Incorrect use of a tool balancer such as pulling the hose at an angle, see Figure 6.33 (a), can negatively affect the performance of the task and increase the risk of harm to the user: due to awkward stress and forces on parts of the body caused by the tension forces being exerted at an angle.

Figure 6.33: (a) Top – Proper positioning of Tool Balancers and cord types, (b) Lower Left – Tool balancer and (c) Lower Right – Swivel coupling





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For example, in Figure 6.34, the tool balancer distance is causing the operator to pull and sustain the tension of the tool at an angle, thus causing serious torsion on his left wrist, which over time could result in wrist fatigue. However Figure 6.35 illustrates the tool balancer perpendicular to the work task enabling a more efficient force distribution on the operators' arm and wrist. This can be achieved by mounting the tool balancer on trolleys and articulated arm.

Figure 6.34: An improperly positioned Tool Balancer that exceeds the operator's work envelope.

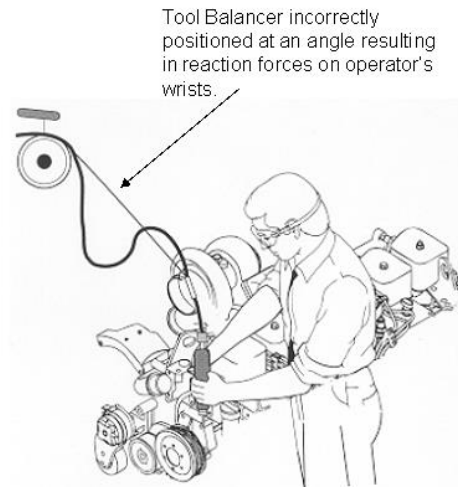
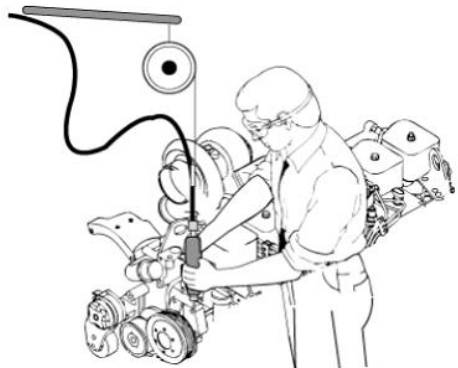


Figure 6.35: A properly positioned Tool Balancer that is perpendicularly above the area of its designated use within the operator's work envelope.





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Engineers should consider the following before purchasing a tool balancer:

- Provide balancers with cord tensions that are adjustable
- Minimize the resistance as much as possible
- Provide a tool balancer with an articulating arm (freedom of motion)
- Position tool balancers perpendicularly above the designated work area

Tools that are hung at a work area without a tool balancer should still be positioned as perpendicular to the area of use as possible; and should be placed at the proper height as not to interfere with other work stations' operations and accordance to Section 6.1.6 for consideration of appropriate hanging tool height.

Additional Considerations

- When to implement balancers:
 - Repetitive tasks: use when tool weight > 6 lb (2.7 kg)
 - Infrequent tasks: use when tool weight > 10 lb (4.5 kg)
 - Precision tasks: use when tool weight > 1 lb (0.5 kg)
 - Ideal when tool is used in only one orientation
- Swivel couplings reduce resistance created by hose-to-gun interface during gun positioning, see Figure 6.33 (c)
- Direct exhaust away from user's hand to reduce exposure to cold temperatures
- Provide secondary handle when feed force is high or tool weight is excessive
- Provide flange at end of tool handle to prevent hand from slipping and to provide support

6.4.2.7. Torque reaction

With the exception of pulse or impact tools, torque limiting devices should be added when torque values reach the maximum recommended levels in Table 6.19. Pulse tools are specially designed so that almost no reaction forces occur in the handle. Examples of various types of power tools, in Figure 6.35, which may need torque limiting devices to protect the operator from harm.



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Table 6.19: Maximum Recommended Torque Values Without a Torque Limiting Device

Tool Type	Maximum Torque (N*m)	Maximum Torque (ft*lbs)
In-line power tools	3	2.5
Pistol grip not including pulse tools	6.78	5
Right angle	50	36.8

Figure 6.36: Power tool examples - Pistol Grip (Left), In-Line (Center), and Right Angle (Right)



6.4.2.8. Torque-Limiting Methods:

- Operating modes:
 - Recommended: Hydraulic pulse systems or automatic shut-off mechanism to reduce torque reaction peak and duration. Faster speed shut-off mechanisms reduce peak torques.
 - Acceptable: Mechanical clutch (slip, friction, or cushion clutch, etc.) limits reaction torque exposure but may expose employees to significant levels of vibration.
 - Not recommended: Stall or direct-drive mechanisms; maximum torque reaction time is under employee control by releasing the throttle, exposing the employee to long durations of reaction torque.
- Torque-absorbing devices:
 - Lightweight torque reaction bars mounted to tool
 - Torque-absorbing suspension balancers (torque reaction tubes)



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- Tool-mounted nut-holding devices
- Mounted tool support reaction arms
- Complete tasks with higher dynamic force reactions on horizontal surfaces (versus vertical), especially for right-angle tools.

6.4.3 Choosing a Powered Fastening Tool

Use Table 6.20 to determine the appropriate powered fastening tool based on:

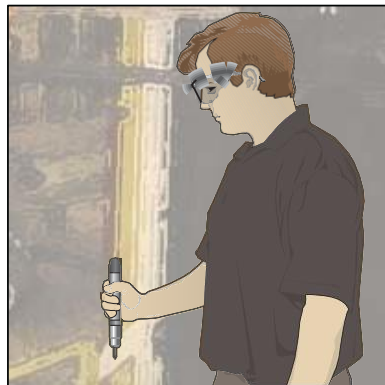
- Surface orientation
- Hand working height
- Standing or seated position

Table 6.20 Recommended Powered Fastening Tool

Surface Orientation	Hand Working Height	Position	Recommended Powered Fastening Tool
Vertical	38"–47" (0.97–1.19 m)	Standing	Pistol-grip
	> 47" (1.19 m)		Right-angled grip
	< 38" (965 mm)	Seated	Pistol-grip
Horizontal	38"–47" (0.97–1.19 m)	Standing	In-line grip
	> 47" (1.19 m)		Right-angled grip
	< 38" (965 mm)		Pistol-grip
	Underneath unit with limited access < 60" (1.52 m)	Seated	Pistol-grip

6.4.4 In-Line Powered Fastening Tools

Figure 6.37: In-line powered fastening tool





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6.4.4.1. Handle (Grip) Cross-Sectional Shape:

- Recommended: oval or egg-shaped
- Acceptable: cylindrical

6.4.4.2. Handle (Grip) Shape:

- Recommended: double frustum (largest diameter at middle finger)
- Acceptable: cylindrical (symmetrical diameter)
- Shape handle to maximize hand contact surface area

6.4.4.3. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (30–51 mm)
- Provide larger diameter flange at bottom of handle

6.4.4.4. Handle Angle:

- Recommended: in line with tool-aiming axis

6.4.4.5. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or slightly etched surfaces
 - Slightly soft composite or rubber surface
- Avoid:
 - Finger grooves or recesses
 - Sharp edges or hard surfaces
 - Cold temperatures or metal surfaces that retain heat

6.4.4.6. Dynamic Reaction Force (Torque):

- Recommended: ≤ 2.36 lb-ft (3.2 Nm)
- See Table 6.19 for maximum torque values without a torque limiting device

6.4.4.7. Application:

- Horizontal surface (vertical fastener)

6.4.4.8. Weight:



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- Recommended: ≤ 4.0 lb (1.8 kg)
- Acceptable: ≤ 6.0 lb (2.7 kg)
- Not-to-exceed: 6.0 lb (2.7 kg), unless a counterbalance system is provided
- Includes weight of all attachments
- Suggested power-to-weight ratio: ≥ 70 W/lb

6.4.4.9. Grip Force:

- or 2-handed operation: ≤ 6.4 lb (2.9 kg) recommended
- 1-handed precision operation: ≤ 2.0 lb (0.9 kg) recommended

6.4.4.10. Feed Force:

- Horizontal surface: ≤ 12.8 lb (5.8 kg)

6.4.4.11. Center of Gravity (Balance of Tool During Use):

- In vertical plane, aligned directly through middle of shaft
- In horizontal plane, aligned with middle finger where hand grasps handle

6.4.4.12. Finger(s) Trigger Design:

- Recommended: push to start
- Acceptable: 2-finger trigger (index, middle fingers) with recommended length 1.5"–2.5" (38–64 mm)

6.4.4.13. Finger(s) Trigger Force:

- 2-finger force: ≤ 5.0 lb (2.3 kg)

6.4.4.14. Vibration:

Where they exist, legal requirements shall be followed, e.g. UK, The Control of Vibration at Work Regulations 2005.

- Based on total daily exposure:
 - 4 to less than 8 hours: 4 m/s^2
 - 2 to less than 4 hours: 6 m/s^2
 - 1 to less than 2 hours: 8 m/s^2
 - Less than 1 hour: 12 m/s^2
- Minimize length of socket extensions



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6.4.4.15. Exhaust:

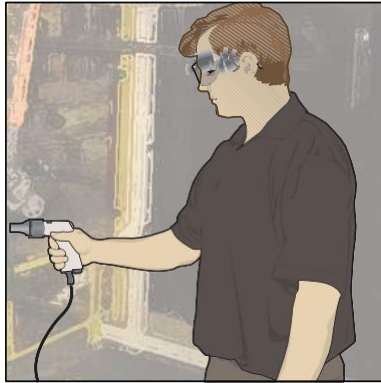
- Direct cool air below 66°F (19°C) or hot air above 95°F (35°C) away from exposed skin

6.4.4.16. Balancers or Supports:

- Attach tool balancer at center of gravity using single attachment

6.4.5 Pistol-Grip Powered Fastening Tools

Figure 6.38: Pistol-grip powered fastening tool



6.4.5.1. Handle (Grip) Cross-Sectional Shape:

- Recommended: oval or egg-shaped
- Acceptable: cylindrical

6.4.5.2. Handle (Grip) Shape:

- Recommended: trapezoid (largest diameter at index finger)
- Acceptable: cylindrical (symmetrical diameter)
- Shape handle to maximize hand contact surface area

6.4.5.3. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (30–51 mm)
- Provide larger diameter flange at bottom of handle

6.4.5.4. Handle (Grip) Length:

- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)



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- Add 0.5" (13 mm) for tools requiring gloves
- 6.4.5.5. Handle Angle:
- Recommended: 102° angle from handle to aiming axis
 - Acceptable: 90° angle from handle to aiming axis
- 6.4.5.6. Handle (Grip) Surface, Texture, Material:
- Recommended:
 - High-friction or slightly etched surfaces
 - Slightly soft composite or rubber surface
 - Avoid:
 - Finger grooves or recesses
 - Sharp edges or hard surfaces
 - Cold temperatures or metal surfaces that retain heat
- 6.4.5.7. Dynamic Reaction Force (Torque):
- Recommended: ≤ 5 lb-ft (6.78 Nm)
 - See Table 6.19 for maximum torque values without a torque limiting device
- 6.4.5.8. Application:
- Vertical surface (horizontal fastener)
- 6.4.5.9. Weight:
- Recommended: ≤ 4.0 lb (1.8 kg)
 - Acceptable: ≤ 6.0 lb (2.7 kg)
 - Not-to-exceed: 6.0 lb (2.7 kg), unless a counterbalance system is provided
 - Includes weight of all attachments
 - Suggested power-to-weight ratio: ≥ 70 W/lb
- 6.4.5.10. Grip Force:
- 1- or 2-handed operation: ≤ 6.4 lb (2.9 kg) recommended
 - 1-handed precision operation: ≤ 2.0 lb (0.9 kg) recommended
- 6.4.5.11. Feed Force:
- Vertical surface: ≤ 6.8 lb (3.1 kg)



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6.4.5.12. Center of Gravity (Balance of Tool During Use):

- In vertical plane, aligned directly over center of grasping handle
- In horizontal plane, aligned closer to handle to minimize top-heavy tool

6.4.5.13. Finger(s) Trigger Design:

- Recommended: 2-finger trigger (index, middle fingers) with recommended length 1.5"–2.5" (38–64 mm)
- Acceptable: 1-finger trigger (index finger) with recommended length 1" (25.4 mm)

6.4.5.14. Finger(s) Trigger Force:

- 2-finger force: ≤ 5.0 lb (2.3 kg)
- 1-finger force: ≤ 2.5 lb (1.1 kg)

6.4.5.15. Vibration:

- Based on total daily exposure:
 - 4 to less than 8 hours: 4 m/s^2
 - 2 to less than 4 hours: 6 m/s^2
 - 1 to less than 2 hours: 8 m/s^2
 - Less than 1 hour: 12 m/s^2
- Minimize length of socket extensions

6.4.5.16. Exhaust:

- Direct cool air below 66°F (19°C) or hot air above 95°F (35°C) away from exposed skin

6.4.5.17. Balancers or Supports:

- Attach tool balancer through center of gravity using single or dual attachments
- Position and angle tool in orientation of use

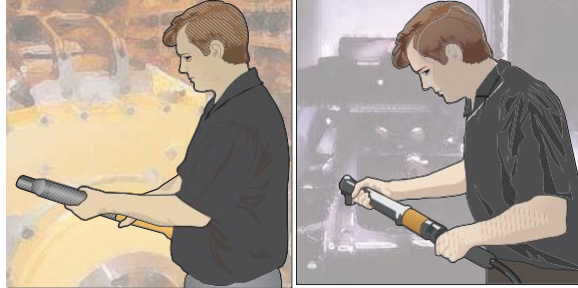
6.4.6 Right-Angle Powered Fastening Tools



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Figure 6.39: Right-angle powered fastening tool



6.4.6.1. Handle (Grip) Cross-Sectional Shape:

- Recommended: cylindrical

6.4.6.2. Handle (Grip) Shape:

- Recommended: cylindrical (symmetrical diameter)
- Shape handle to maximize hand contact surface area

6.4.6.3. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (30–51 mm)

6.4.6.4. Handle (Grip) Length:

- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)
- Add 0.5" (13 mm) for tools requiring gloves

6.4.6.5. Handle Angle:

- Recommended: handle perpendicular to aiming or fastening axis

6.4.6.6. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or slightly etched surfaces
 - Slightly soft composite or rubber surface
- Avoid:
 - Finger grooves or recesses
 - Sharp edges or hard surfaces
 - Cold temperatures or metal surfaces that retain heat



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6.4.6.7. Dynamic Reaction Force (Torque):

- Recommended: ≤ 37 lb-ft (50 Nm)
- See Table 6.19 for maximum torque values without a torque limiting device

6.4.6.8. Application:

- Horizontal surface (vertical fastener)
- Vertical surface (horizontal fastener)

6.4.6.9. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)
- Acceptable: ≤ 6.0 lb (2.7 kg)
- Not-to-exceed: 6.0 lb (2.7 kg), unless a counterbalance system is provided
- Includes weight of all attachments
- Suggested power-to-weight ratio: ≥ 70 W/lb

6.4.6.10. Grip Force:

- or 2-handed operation: ≤ 6.4 lb (2.9 kg) recommended

6.4.6.11. Feed Force:

- Horizontal surface: ≤ 12.8 lb (5.8 kg)
- Vertical surface: ≤ 6.8 lb (3.1 kg)

6.4.6.12. Center of Gravity (Balance of Tool during Use):

- Located between hand-grasping locations

6.4.6.13. Finger(s) Trigger Design:

- Recommended: lever with recommended length ≤ 3 " (76 mm)
- Not-to-exceed: lever with length 3.0" (76 mm)
- Provide spring-loaded lever hand trigger to return trigger to start position

6.4.6.14. Finger(s) Trigger Force:

- Lever force ≤ 6.8 lb (3.1 kg)



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6.4.6.15. Vibration:

- Based on total daily exposure:
 - 4 to less than 8 hours: 4 m/s²
 - 2 to less than 4 hours: 6 m/s²
 - 1 to less than 2 hours: 8 m/s²
 - Less than 1 hour: 12 m/s²
- Minimize length of socket extensions

6.4.6.16. Exhaust:

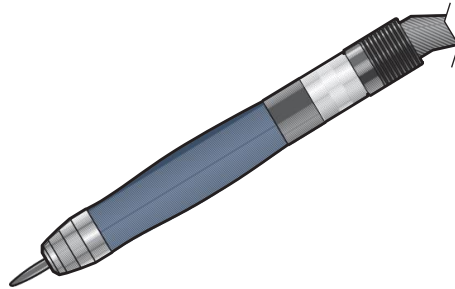
- Direct cool air below 66°F (19°C) or hot air above 95°F (35°C) away from exposed skin

6.4.6.17. Balancers or Supports:

- Attach tool balancer through center of gravity using multiple attachments
- Position and angle tool in orientation of use

6.4.7 Precision (Pinch-Grip) Abrasive/Grinding Tools

Figure 6.40: Precision, pinch-grip, abrasive tool



6.4.7.1. Vibration:

- Based on total daily exposures:
 - 4 to less than 8 hours: 4 m/s²
 - 2 to less than 4 hours: 6 m/s²
 - 1 to less than 2 hours: 8 m/s²
 - less than 1 hour: 12 m/s²
- Use vibration-dampened spindle

6.4.7.2. Handle (Grip) Cross-Sectional Shape:

- Recommended: tapered (widest at grip location)



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- Acceptable: cylindrical
- 6.4.7.3. Handle (Grip) Shape:
- Recommended: cylindrical
 - Shape handle to maximize hand contact surface area
- 6.4.7.4. Handle (Grip) Diameter:
- Recommended: 0.3"–0.6" (8–15 mm)
 - Acceptable: 0.3"–0.9" (8–22 mm)
 - Provide larger diameter flange at bottom of handle
- 6.4.7.5. Handle (Grip) Length:
- Recommended: 3.9" (99 mm)
 - Acceptable: 2.8"–4.6" (71–117 mm)
 - Handle should be long enough to allow base of first finger or thumb to support it, and short enough so it does not come in contact with forearm or wrist.
- 6.4.7.6. Handle Angle:
- Recommended: in line with the tool-grinding axis
- 6.4.7.7. Handle (Grip) Surface, Texture, Material:
- Recommended:
 - High-friction or slightly etched surface
 - Slightly soft composite or rubber surface
 - Covered with vibration-dampening material
 - Avoid:
 - Sharp edges or hard surfaces
 - Cold temperatures or metal surfaces that retain heat
- 6.4.7.8. Application:
- Recommended: Orient part to provide visual access to grinding surface
 - Acceptable: Grinding on horizontal surface
- 6.4.7.9. Weight:
- Recommended: ≤ 1.0 lb (0.5 kg)



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- Not-to-exceed: 1.0 lb (0.5 kg), unless a counterbalance system is provided
- Includes weight of all attachments
- Recommended: air-governed control speed

6.4.7.10. Grip Force:

- Recommended: ≤ 2.0 lb (0.9 kg)

6.4.7.11. Center of Gravity (Balance of Tool During Use):

- In vertical plane, aligned directly through middle of shaft
- In horizontal plane, aligned with natural pinch grip location during use

6.4.7.12. Trigger Design:

- Recommended: knob
- Acceptable: lever ≤ 2.5 " (64 mm) long

6.4.7.13. Lever Force:

- Recommended: ≤ 2.5 lb (1.1 kg)

6.4.7.14. Exhaust:

- Direct cool air below 66°F (19°C) or hot air above 95°F (35°C) away from exposed skin

6.4.8 In-Line (Power-Grip) Abrasive/Grinding Tools

Figure 6.41: In-line abrasive tool



6.4.8.1. Vibration:



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- Based on total daily exposures:
 - 4 to less than 8 hours: 4 m/s²
 - 2 to less than 4 hours: 6 m/s²
 - 1 to less than 2 hours: 8 m/s²
 - less than 1 hour: 12 m/s²
- Use vibration-dampened spindle
- Minimize length of extended housing

6.4.8.2. Handle (Grip) Cross-Sectional Shape:

- Recommended: oval or egg-shaped
- Acceptable: cylindrical

6.4.8.3. Handle (Grip) Shape:

- Recommended: double frustum (largest diameter at middle finger)
- Acceptable: cylindrical (symmetrical diameter)
- Shape handle to maximize hand contact surface area

6.4.8.4. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (30–51 mm)
- Provide larger diameter flange at bottom of handle

6.4.8.5. Handle (Grip) Length:

- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)
- Add 0.5" (13 mm) for tools requiring gloves

6.4.8.6. Handle Angle:

- Recommended: in line with the tool-grinding axis

6.4.8.7. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or slightly etched surface
 - Slightly soft composite or rubber surface
 - Covered with vibration-dampening material
- Avoid:



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- Sharp edges or hard surfaces
- Cold temperatures or metal surfaces that retain heat

6.4.8.8. Application:

- Recommended: Orient part to provide visual access to grinding surface
- Acceptable: Grinding on horizontal surface

6.4.8.9. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)
- Acceptable: ≤ 6.0 lb (2.7 kg)
- Not-to-exceed: 6.0 lb (2.7 kg), unless a counterbalance system is provided
- Includes weight of all attachments
- Recommended: air-governed control speed

6.4.8.10. Grip Force:

- 2-handed operation: ≤ 6.4 lb (2.9 kg)
- 1-handed operation: ≤ 2.0 lb (0.9 kg)

6.4.8.11. Center of Gravity (Balance of Tool During Use):

- In vertical plane, aligned directly through middle of shaft
- In horizontal plane, aligned with natural pinch grip location during use

6.4.8.12. Trigger Design:

- Recommended: lever with recommended length ≤ 3.0 " (76 mm)
- Not-to-exceed: lever with length 3.0" (76 mm)
- Provide spring-loaded lever hand trigger to return trigger to start position

6.4.8.13. Trigger Force:

- Lever force ≤ 6.8 lb (3.1 kg)

6.4.8.14. Exhaust:

- Direct cool air below 66°F (19°C) or hot air above 95°F (35°C) away from exposed skin



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6.4.9 Right-Angle or Vertical Abrasive/Grinding Tools

Figure 6.42: Right-angle abrasive tool



6.4.9.1. Vibration:

- Based on total daily exposures:
 - 4 to less than 8 hours: 4 m/s²
 - 2 to less than 4 hours: 6 m/s²
 - 1 to less than 2 hours: 8 m/s²
 - less than 1 hour: 12 m/s²
- Use vibration-dampened spindle
- Minimize length of extended housing

6.4.9.2. Handle (Grip) Cross-Sectional Shape:

- Recommended: cylindrical

6.4.9.3. Handle (Grip) Shape:

- Recommended: cylindrical (symmetrical diameter)
- Shape handle to maximize hand contact surface area

6.4.9.4. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (30–51 mm)
- Provide larger diameter flange at bottom of handle

6.4.9.5. Handle (Grip) Length:

- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)
- Add 0.5" (13 mm) for tools requiring gloves



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6.4.9.6. Handle Angle:

- Recommended: perpendicular with the tool-grinding axis

6.4.9.7. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or slightly etched surface
 - Slightly soft composite or rubber surface
 - Covered with vibration-dampening material
- Avoid:
 - Sharp edges or hard surfaces
 - Cold temperatures or metal surfaces that retain heat

6.4.9.8. Application:

- Recommended: Orient part to provide visual access to grinding surface
- Acceptable: Grinding on horizontal surface

6.4.9.9. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)
- Acceptable: ≤ 6.0 lb (2.7 kg)
- Not-to-exceed: 6.0 lb (2.7 kg), unless a counterbalance system is provided
- Includes weight of all attachments
- Provide a second support handle perpendicular to the primary handle

6.4.9.10. Grip Force:

- 2-handed operation: ≤ 6.4 lb (2.9 kg)
- 1-handed operation: ≤ 2.0 lb (0.9 kg)

6.4.9.11. Center of Gravity (Balance of Tool During Use):

- In vertical plane, aligned directly through grinding wheel, point, or cone
- In horizontal plane, aligned directly through middle of handle shaft

6.4.9.12. Trigger Design:

- Recommended: 2-finger trigger (index, middle finger) with recommended length 1.5"–2.5" (38–64 mm)



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- Acceptable: lever with recommended length ≤ 3.0 " (76 mm)
- Provide spring-loaded lever hand trigger to return trigger to start position

6.4.9.13. Trigger Force:

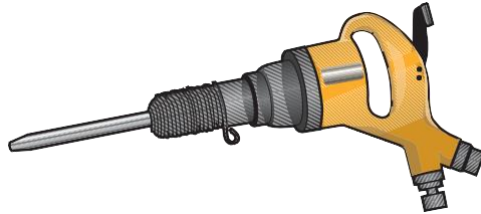
- 2-finger trigger: ≤ 5.0 lb (2.3 kg)
- Lever force: ≤ 6.8 lb (3.1 kg)

6.4.9.14. Exhaust:

- Direct cool air below 66°F (19°C) or hot air above 95°F (35°C) away from exposed skin

6.4.10 Percussive Tools

Figure 6.43: Percussive tool



6.4.10.1. Vibration:

- Based on total daily exposures:
 - 4 to less than 8 hours: 4 m/s²
 - 2 to less than 4 hours: 6 m/s²
 - 1 to less than 2 hours: 8 m/s²
 - less than 1 hour: 12 m/s²
- Use vibration-dampened spindle
- Minimize chisel length
- Provide chisel isolators

6.4.10.2. Handle (Grip) Cross-Sectional Shape:

- Recommended: oval or egg-shaped
- Acceptable: cylindrical

6.4.10.3. Handle (Grip) Shape:

- Recommended: cylindrical (symmetrical diameter)
- Shape handle to maximize hand contact surface area



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6.4.10.4. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (31–51 mm)
- Provide larger diameter flange at bottom of handle

6.4.10.5. Handle (Grip) Length:

- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)
- Add 0.5" (13 mm) for tools requiring gloves
- Avoid closed-loop handles

6.4.10.6. Hand Opening Access:

- Length \geq 5.5" (140 mm)
- Width \geq 2.5" (64 mm)

6.4.10.7. Handle Angle:

- Recommended: 102° angle from handle to aiming axis
- Acceptable: 90° angle from handle to aiming axis

6.4.10.8. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or slightly etched surface
 - Slightly soft composite or rubber surface
 - Covered with vibration-dampening material
- Avoid:
 - Sharp edges or hard surfaces
 - Cold temperatures or metal surfaces that retain heat

6.4.10.9. Application:

- Recommended: Vertical surfaces
- Acceptable: Horizontal surface at lower heights

6.4.10.10. Weight:

- Recommended: \leq 12.0 lb (5.4 kg)
- Acceptable: \leq 18.0 lb (8.2 kg)
- Always provide a counterbalance system
- Includes weight of all attachments



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6.4.10.11. Grip Force:

- 2-handed operation: ≤ 6.4 lb (2.9 kg)

6.4.10.12. Feed Force:

- Horizontal surface: ≤ 12.8 lb (5.8 kg)
- Vertical surface: ≤ 6.8 lb (3.1 kg)

6.4.10.13. Thumb Trigger Design:

- Trigger length 1.0"–1.4" (25–35 mm)
- Trigger width 0.7"–0.9" (19–22 mm)
- Trigger depression ≤ 1.0 " (25 mm)
- Provide spring-loaded lever palm trigger to return trigger to start position

6.4.10.14. Thumb Trigger Force:

- 2-finger trigger: ≤ 2.5 lb (1.1 kg)

6.4.10.15. Exhaust:

- Direct cool air below 66°F (19°C) or hot air above 95°F (35°C) away from exposed skin

6.4.11 Welding Guns

Figure 6.44: Welding gun



6.4.11.1. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)
- Acceptable: ≤ 6.0 lb (2.7 kg)
- Not-to-exceed: 6.0 lb (2.7 kg), unless a counterbalance system is provided



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- Includes weight of all attachments
- 6.4.11.2. Handle (Grip) Cross-Sectional Shape:
- Recommended: oval or egg-shaped
 - Acceptable: cylindrical
- 6.4.11.3. Handle (Grip) Shape:
- Recommended: trapezoid (largest diameter at index finger)
 - Acceptable: cylindrical (symmetrical diameter)
 - Shape handle to maximize hand contact surface area
- 6.4.11.4. Handle (Grip) Diameter:
- Recommended: 1.6" (41 mm)
 - Acceptable: 1.2"–2.0" (30–51 mm)
 - Provide larger diameter flange at bottom of handle
- 6.4.11.5. Handle (Grip) Length:
- Recommended: 5.5" (140 mm)
 - Acceptable: 4.0"–6.0" (102–152 mm)
 - Add 0.5" (13 mm) for tools requiring gloves
- 6.4.11.6. Handle Angle:
- Recommended: bent 30°–60° from welding tip
- 6.4.11.7. Handle (Grip) Surface, Texture, Material:
- Recommended:
 - High-friction or slightly etched surface
 - Slightly soft composite or rubber surface
 - Avoid:
 - Sharp edges or hard surfaces
 - Cold temperatures or metal surfaces that retain heat
- 6.4.11.8. Grip Force:
- 2-handed operation: ≤ 6.4 lb (2.9 kg)
 - 1-handed operation: ≤ 2.0 lb (0.9 kg)
- 6.4.11.9. Trigger Design:



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- Recommended: 2-finger trigger (index, middle finger) with recommended length 1.5"–2.5" (38–64 mm)
- Acceptable: 1-finger trigger (index finger) with recommended length 1.0" (25 mm)

6.4.11.10. Trigger Force:

- 2-finger trigger: ≤ 5.0 lb (2.3 kg)
- 1-finger trigger: ≤ 2.5 lb (1.1 kg)

6.4.11.11. Application:

- Recommended: Orient part to provide visual access to grinding surface
- Acceptable: Welding on vertical surface

6.4.12 Spray Guns

Figure 6.45: Spray gun



6.4.12.1. Trigger Design:

- Recommended: lever with recommended length ≤ 3.0 " (76 mm)
- Acceptable: 2-finger trigger (index, middle finger) with recommended length 1.5"–2.5" (38–64 mm)

6.4.12.2. Trigger Force:

- Lever: ≤ 6.8 lb (3.1 kg)
- 2-finger trigger: ≤ 5.0 lb (2.3 kg)

6.4.12.3. Handle (Grip) Cross-Sectional Shape:

- Recommended: oval or egg-shaped
- Acceptable: cylindrical



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6.4.12.4. Handle (Grip) Shape:

- Recommended: trapezoid (largest diameter at index finger)
- Acceptable: cylindrical (symmetrical diameter)
- Shape handle to maximize hand contact surface area

6.4.12.5. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (30–51 mm)
- Provide larger diameter flange at bottom of handle

6.4.12.6. Handle (Grip) Length:

- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)
- Add 0.5" (13 mm) for tools requiring gloves

6.4.12.7. Handle Angle:

- Recommended: 102° angle from handle to aiming axis
- Acceptable: 90° angle from handle to aiming axis

6.4.12.8. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or slightly etched surface
 - Slightly soft composite or rubber surface
 - Water resistant
- Avoid:
 - Sharp edges or hard surfaces
 - Cold temperatures or metal surfaces that retain heat

6.4.12.9. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)
- Acceptable: ≤ 6.0 lb (2.7 kg)
- Not-to-exceed: 6.0 lb (2.7 kg), unless a counterbalance system is provided
- Includes weight of all attachments



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6.4.12.10. Grip Force:

- 2-handed operation: ≤ 6.4 lb (2.9 kg)
- 1-handed operation: ≤ 2.0 lb (0.9 kg)

6.4.12.11. Exhaust:

- Direct cool air below 66°F (19°C) or hot air above 95°F (35°C) away from exposed skin

6.4.13 Pliers

Figure 6.46: Bent handle pliers



6.4.13.1. Handle Grip Span:

- Recommended: ≥ 2.0 " (51 mm) when fully closed
- Recommended: ≤ 3.5 " (89 mm) when fully open

6.4.13.2. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)

6.4.13.3. Manual Torque:

- Recommended: ≤ 1.50 lb-ft (2.03 Nm)
- Acceptable: ≤ 1.75 lb-ft (2.38 Nm)

6.4.13.4. Handle (Grip) Diameter:

- Recommended: 0.3"–0.6" (8–15 mm)
- Acceptable: 0.3"–0.9" (8–22 mm)
- Provide larger diameter thumb stop at top of handle

6.4.13.5. Handle (Grip) Shape:



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- Recommended: oval or flattened
- Acceptable: circular
- Contour shape of handle to match form of thumb and base of palm
- Round the ends of handles

6.4.13.6. Handle (Grip) Length:

- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)
- Handle should be long enough so that it does not press into palm at base of thumb

6.4.13.7. Handle Angle:

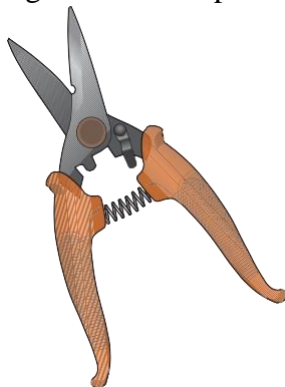
- Recommended: bent handles, with angle between jaw head and handle between 105° and 135°

6.4.13.8. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or non-slip surface
 - Slightly soft composite or rubber surface
- Avoid:
 - Sharp edges, hard surfaces, deep ribs, or finger grooves
 - Cold temperatures or metal surfaces that retain heat

6.4.14 Snips

Figure 6.47: Snips



6.4.14.1. Handle Grip Span:

- Recommended: ≥ 2.0 " (51 mm) when fully closed



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- Recommended: ≤ 3.5 " (89 mm) when fully open

6.4.14.2. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)

6.4.14.3. Grip Force:

- Recommended: ≤ 2.0 lb (0.9 kg)
- Acceptable: ≤ 3.5 lb (1.6 kg)
- Recommended: spring-loaded mechanism to return snips to open position

6.4.14.4. Handle (Grip) Diameter:

- Recommended: 0.3"–0.6" (8–15 mm)
- Acceptable: 0.3"–0.9" (8–22 mm)
- Provide larger diameter thumb stop at top of handle

6.4.14.5. Handle (Grip) Shape:

- Recommended: oval or flattened
- Acceptable: circular
- Contour shape of handle to match form of thumb and base of palm
- Round the ends of handles

6.4.14.6. Handle (Grip) Length:

- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)
- Handle should be long enough so that it does not press into palm at base of thumb

6.4.14.7. Handle Angle:

- Recommended: bent handles, with angle between jaw head and handle between 105° and 135°

6.4.14.8. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or non-slip surface
 - Slightly soft composite or rubber surface



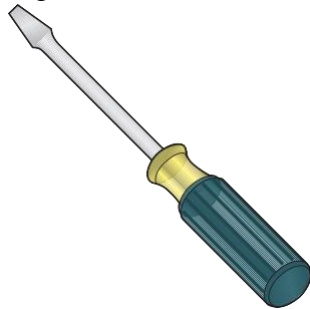
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- Avoid:
 - Sharp edges, hard surfaces, deep ribs, or finger grooves
 - Cold temperatures or metal surfaces that retain heat

6.4.15 Screwdrivers

Figure 6.48: Screwdriver



6.4.15.1. Manual Torque:

- Recommended: ≤ 2.34 lb-ft (3.18 Nm)
- Acceptable: ≤ 3.04 lb-ft (4.12 Nm)

6.4.15.2. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)

6.4.15.3. Grip Force:

- Recommended: ≤ 2.0 lb (0.9 kg)

6.4.15.4. Handle (Grip) Cross-Sectional Shape:

- Recommended: T-handle
- Acceptable: cylindrical

6.4.15.5. Handle (Grip) Shape:

- Recommended: oval
- Acceptable: cylindrical
- Round the top of the handle

6.4.15.6. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (30–51 mm)
- Provide larger diameter thumb stop at base of handle



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6.4.15.7. Handle (Grip) Length:

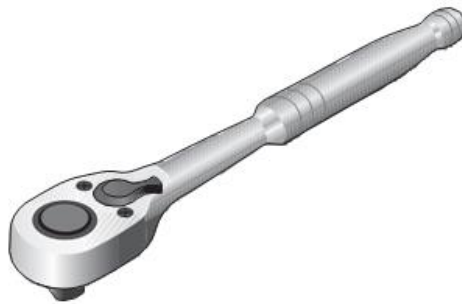
- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)
- Handle should be long enough so that it does not press into palm at base of thumb

6.4.15.8. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or non-slip surface
 - Slightly soft composite or rubber surface
- Avoid:
 - Sharp edges, hard surfaces, deep ribs, or finger grooves
 - Cold temperatures or metal surfaces that retain heat

6.4.16 Wrenches

Figure 6.49: Wrench



6.4.16.1. Manual Torque:

- Recommended: ≤ 36.88 lb-ft (50 Nm) (do not exceed the range for which the tool is designed)

6.4.16.2. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)

6.4.16.3. Grip Force:

- Recommended: ≤ 2.0 lb (0.9 kg)



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6.4.16.4. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (30–51 mm)

6.4.16.5. Handle (Grip) Shape:

- Recommended: circular
- Acceptable: oval
- Round the ends of the handles

6.4.16.6. Handle (Grip) Length:

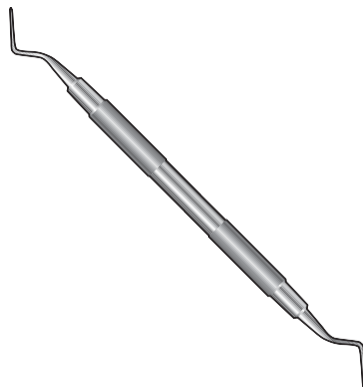
- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)

6.4.16.7. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction, non-slip, or slightly etched surface
 - Slightly soft composite or rubber surface
- Avoid:
 - Sharp edges, hard surfaces, deep ribs, or finger grooves
 - Cold temperatures or metal surfaces that retain heat

6.4.17 Precision (Pinch-Grip) Tools

Figure 6.50: Precision pinch-grip tool



6.4.17.1. Weight:

- Recommended: ≤ 1.0 lb (0.5 kg)



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6.4.17.2. Grip Force:

- Recommended: ≤ 2.0 lb (0.9 kg)

6.4.17.3. Handle (Grip) Diameter:

- Recommended: 0.3"–0.6" (8–15 mm)
- Acceptable: 0.3"–0.9" (8–22 mm)
- Provide larger diameter thumb stop at tip of tool

6.4.17.4. Handle (Grip) Shape:

- Recommended: oval
- Acceptable: circular
- Contour shape of handle to match form of thumb and base of palm
- Round the ends of tool

6.4.17.5. Handle (Grip) Length:

- Recommended: 3.9" (100 mm)
- Acceptable: 2.8"–4.6" (71–117 mm)
- Handle should be long enough so that it does not press into palm at base of thumb

6.4.17.6. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction, non-slip, or slightly etched surface
 - Slightly soft composite or rubber surface
- Avoid:
 - Sharp edges, hard surfaces, deep ribs, or finger grooves
 - Cold temperatures or metal surfaces that retain heat

6.4.18 Striking Tools

Whenever possible, find substitutes to avoid the usage of striking tools.

Figure 6.51: Hammer striking tool



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6.4.18.1. Vibration:

- Based on total daily exposures:
 - 4 to less than 8 hours: 4 m/s^2
 - 2 to less than 4 hours: 6 m/s^2
 - 1 to less than 2 hours: 8 m/s^2
 - less than 1 hour: 12 m/s^2
- Cover handle with vibration-dampening material

6.4.18.2. Weight:

- Recommended: $\leq 4.0 \text{ lb}$ (1.8 kg)

6.4.18.3. Grip Force:

- Recommended: $\leq 2.0 \text{ lb}$ (0.9 kg)

6.4.18.4. Handle (Grip) Cross-Sectional Shape:

- Recommended: oval
- Acceptable: cylindrical

6.4.18.5. Handle (Grip) Shape:

- Recommended: oval
- Acceptable: cylindrical

6.4.18.6. Handle (Grip) Diameter:

- Recommended: 1.6" (41 mm)
- Acceptable: 1.2"–2.0" (30–51 mm)

6.4.18.7. Handle Angle:

- Recommended: handle bent 5° to 19°

6.4.18.8. Handle (Grip) Length:



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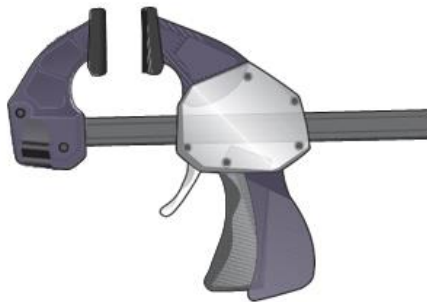
- Recommended: 5.5" (140 mm)
- Acceptable: 4.0"–6.0" (102–152 mm)

6.4.18.9. Handle (Grip) Surface, Texture, Material:

- Recommended:
 - High-friction or non-slip surface
 - Slightly soft composite or rubber surface
- Avoid:
 - Sharp edges, hard surfaces, deep ribs, or finger grooves
 - Cold temperatures or metal surfaces that retain heat

6.4.19 Clamps

Figure 6.52: Clamp



6.4.19.1. Handle Grip Span:

- Recommended: ≥ 2.0 " (51 mm) when fully closed
- Recommended: ≤ 3.5 " (89 mm) when fully open

6.4.19.2. Weight:

- Recommended: ≤ 4.0 lb (1.8 kg)

6.4.19.3. Grip Force:

- Recommended: ≤ 2.0 lb (0.9 kg)
- Recommended: spring-loaded mechanism to return the pliers to open position

6.4.19.4. Handle (Grip) Shape:

- Recommended: oval or flattened



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- Acceptable: circular
 - Round the ends of the handles
- 6.4.19.5. Handle (Grip) Diameter:
- Recommended: 1.6" (41 mm)
 - Acceptable: 1.2"–2.0" (30–51 mm)
- 6.4.19.6. Handle (Grip) Length:
- Recommended: 5.5" (140 mm)
 - Acceptable: 4.0"–6.0" (102–152 mm)
 - Handle should be long enough so that it does not press into palm at base of thumb
- 6.4.19.7. Handle (Grip) Surface, Texture, Material:
- Recommended:
 - High-friction or non-slip surface
 - Slightly soft composite or rubber surface
 - Avoid:
 - Sharp edges, hard surfaces, deep ribs, or finger grooves
 - Cold temperatures or metal surfaces that retain heat

6.5 Access

6.5.1 Machine/Equipment

6.5.1.1. Upper-Extremity Access

Figure 6.53: Upper-extremity arm access, shoulder to hand – 1 arm



Table 6.21: Upper-Extremity Access Guidelines

Access Type	Opening	Minimum (Width x Height)/Diameter
A. Push-button access – 1 finger	Circular	1.5" (38 mm) diameter

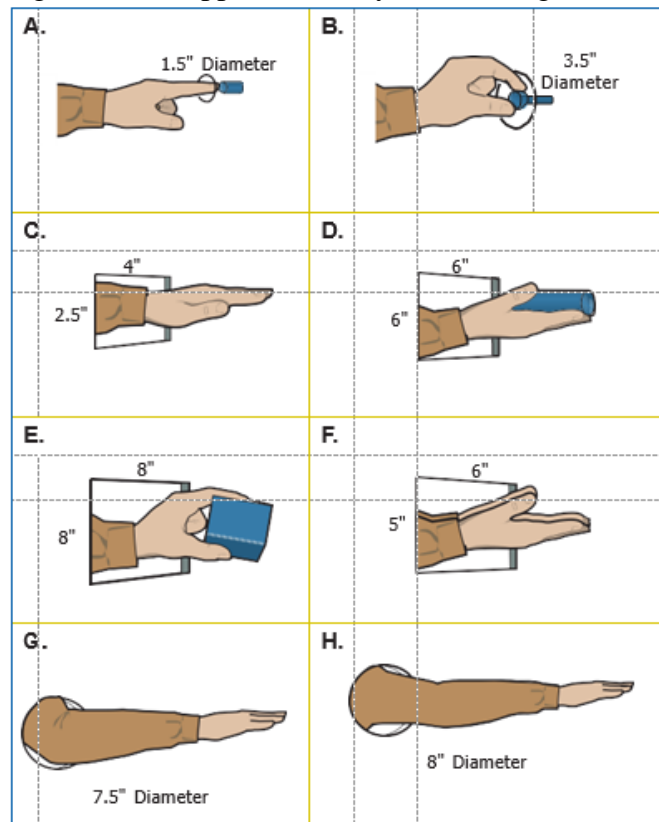


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B.	Knob access – 2 fingers	Circular	3.5" (89 mm) diameter
C.	Hand access (empty) – 1 hand	Rectangular	4" x 2.5" (102 x 64 mm)
D.	Hand access (small object) – 1 hand	Rectangular	6" x 6" (152 x 152 mm)
E.	Hand access (large object) – 1 hand	Rectangular	8" x 8" (203 x 203 mm)
F.	Hand access (empty) – 2 hands	Rectangular	6" x 5" (152 x 127 mm)
G.	Arm access (elbow to hand) – 1 arm	Circular	7.5" (191 mm) diameter
H.	Arm access (shoulder to hand) – 1 arm	Circular	8" (203 mm) diameter

Figure 6.54: Upper-extremity access images referenced in Table 6.21



Other Considerations

- Add 0.75" (19 mm) if wearing gloves
- Design to minimize sharp edges
- Design access openings to accommodate part size and hand clearance

6.5.1.2. Hand-Tool Use Access



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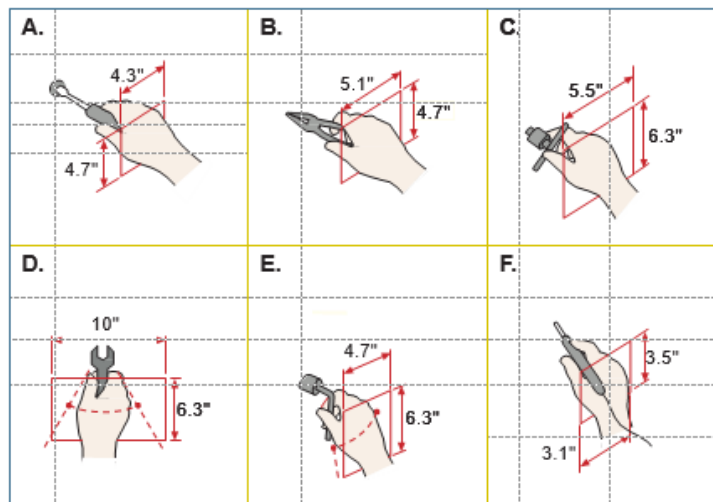
Figure 6.55: Hand-tool access



Table 6.22 Hand-Tool Access Guidelines

Hand Tool	Task	Minimum (Width x Height)
A. Screwdriver	Using common screwdriver, with freedom to turn hand through 180°	4.3" x 4.7" (109 x 119 mm)
B. Pliers	Using pliers and similar tools	5.1" x 4.7" (130 x 119 mm)
C. T-handle wrench	Using T-handle wrench, with freedom to turn hand through 180°	5.5" x 6.3" (140 x 160 mm)
D. Open-end wrench	Using open-end wrench, with freedom to turn wrench through 60°	10" x 6.3" (254 x 160 mm)
E. Allen-type wrench	Using Allen-type wrench, with freedom to turn wrench through 60°	4.7" x 6.3" (119 x 160 mm)
F. Test probe	Using test probe	3.1" x 3.5" (79 x 89 mm)

Figure 6.56: Hand-tool access images referenced in Table 6.22





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Other Considerations

- Add 0.75" (19 mm) if wearing gloves
- Provide socket extensions to improve tool access
- Use angled or flexible tool socket to improve tool access

6.5.1.3. Maintenance

Guidelines

- Horizontal clearance: minimum 46" (1.17 m) beside or around a piece of equipment
- Vertical clearance: minimum 80" (2.03 m) above any piece of equipment requiring overhead maintenance
- Hand clearance: minimum 2" (51 mm) between equipment to be removed and the surrounding equipment
- Hand access diameter: minimum 8" (203 mm) to promote one-handed force exertion

Other Considerations

- Provide sufficient clearance or access
 - to components requiring regular maintenance
 - for maintenance and diagnostic equipment
 - for fixed and mobile mechanical lifting devices
 - for person-lifts and mobile platforms for overhead work
- Provide clear and unobstructed path to equipment requiring maintenance (e.g., no pipes to step over or duck under)
- Locate access ports to provide visual access to displays when making adjustments

6.5.2 Building/Enclosures

Please reference CORP-13-00-00-01 Global Building Policy for any building construction or changes.

6.5.2.1. Whole-Body Access

Guidelines

- Minimum overhead clearance: 80" (2.03 m)
- Minimum horizontal width to accommodate



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- Body breadth 25" (635 mm)
- Body depth 15" (381 mm)
- Add a minimum 4" (102 mm) to improve access comfort

6.5.2.2. Whole-Body Hatch Access

Figure 6.57: Whole-body hatch access

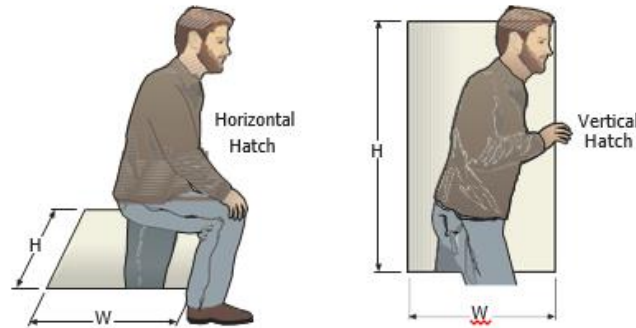


Table 6.23: Whole-Body Hatch Access Guidelines

	Horizontal Hatch (Floor or Ceiling)		Vertical Hatch (Wall)
	Rectangular	Circular	Rect., Circ., Elliptical
Wearing normal clothing	23" x 13" (584 mm x 330 mm)	23" (584 mm)	26" x 29" (660 mm x 737 mm)
Wearing heavy clothing	29" x 20" (737 mm x 508 mm)	30" (762 mm)	31" x 34" (787 mm x 864 mm)
Add (minimum) for access comfort	4" (102 mm)	4" (102 mm)	4" (102 mm)

6.5.2.3. Aisle Access

Figure 6.58: Aisle access





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Guidelines

- Minimum width to accommodate a single person transporting equipment or products: 48" (1.22 m)
 - Primary aisles: 72" wide (1.83 m)
 - Secondary aisles: 48" wide (1.22 m)
- Minimum height: 80" (2.03 m)
- Use floor markers to identify walkways/pathways
- Where possible, avoid locating aisle against walls, as access is limited to one side

6.5.2.4. Door Access

Figure 6.59: Door access



Guidelines

- High enough and wide enough to accommodate materials and transfer systems (carts, dollies, forklifts, etc.)
- Power-assist doors for high-traffic areas
- Low-force doors where manual material handling (carrying) occurs
- Adhere to the Americans with Disabilities Act (ADA) where appropriate
- Avoid having doors open into aisles

6.5.3 Access from Heights

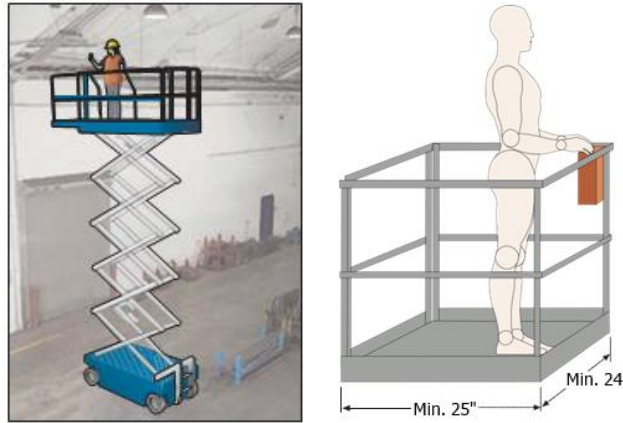
6.5.3.1. Platform Access



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Figure 6.60: Access platforms at height



Guidelines

- Minimum deck size 24" x 25" (610 x 635 mm)
- Adjustment mechanism:
 - Preferred: powered platform
 - Acceptable: hand crank of 3" (76 mm)
 - For maintenance and diagnostic equipment
- Install toe plates and handrails for platforms higher than
 - 48" (122 mm) above floor level in North America
 - 39.5" (100 mm) above floor level in Europe
- Deck material should be suitable for the work environment (stainless steel, aluminum, chemical resistant, etc.)
- For additional information, refer to OSHA standards
- 29 CFR 1910.66, 29 CFR 1910.67, and 29 CFR 1910.68

Other Considerations

- Platforms allow employees to work above floor level
- Comfortable platform height is where the part or work is between waist and chest level
- Operators shall use restraints while in vehicle.

6.5.3.2. Fixed-Ladder Access

If there is any regional legal requirement beyond these guidelines, those requirements shall be followed.

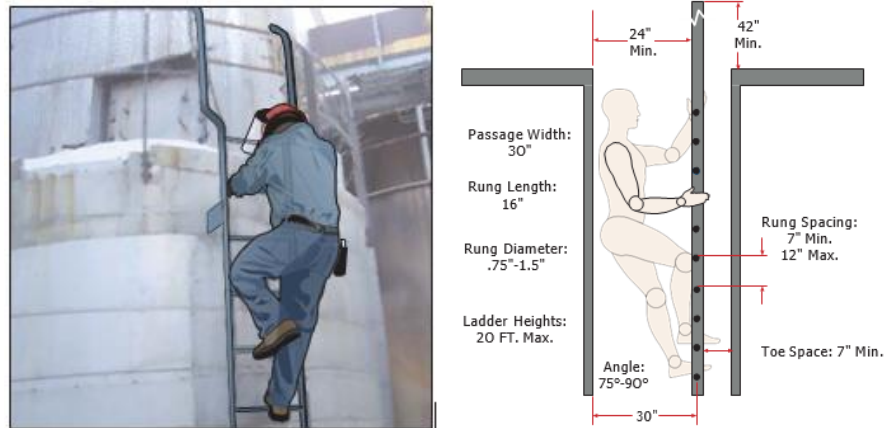


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Refer to Cummins Work at Heights and Ladder Safety Procedure, CORP-09-04-36-00.

Figure 6.61: Fixed-ladder access



Guidelines

- Angle: 75°–90° from floor
- Maximum height: 20 ft. (6.1 m) without landing platform
- Minimum height extended above surface: 42" (1.07 m)
- Minimum passage width: 30" (762 mm)
- Minimum passage depth (between ladder and obstruction behind person on ladder): 24" (610 mm)
- Rung spacing: uniform distance, 7"–12" (178–305 mm)
- Minimum rung length: 16" (406 mm)
- Rung diameter: uniform diameter, 0.75"–1.5" (19–38 mm)
- Minimum toe depth clearance: 7" (178 mm)
- For additional information, refer to OSHA standard 29 CFR 1910.27

Other Considerations

- Fixed ladders are used to move vertically up slopes more than 75° from the floor
- Fixed ladders are designed to ascend and descend while facing the ladder

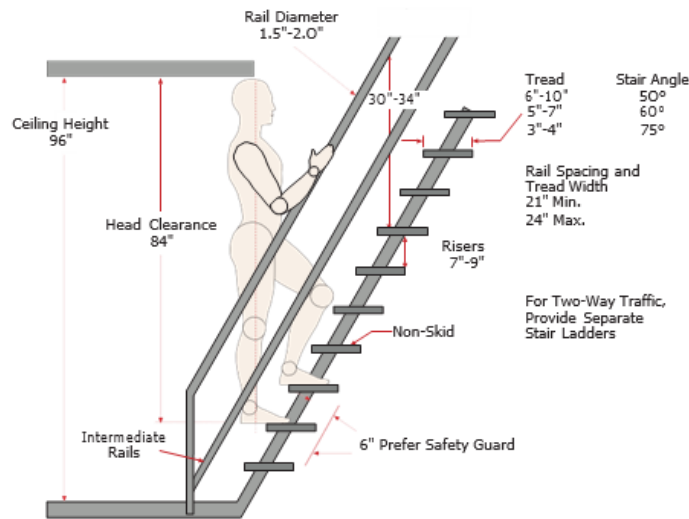
6.5.3.3. Stair-Ladder Access



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Figure 6.62: Stair-ladder access



Guidelines

- Angle: 50°–75° from floor
- Tread depth based on stair angle:
 - 6"–10" (152–254 mm) for 50° stair angle
 - 5"–7" (127–178 mm) for 60° stair angle
 - 3"–4" (76–102 mm) for 75° stair angle
- Vertical distance between (risers): 7"–9" (178–229 mm)
- Non-skid step surfaces
- Always provide handrails
- Handrail height: 30"–34" (762–864 mm) above the surface
- Minimum railing diameter:
 - Hardwood: 2" (51 mm)



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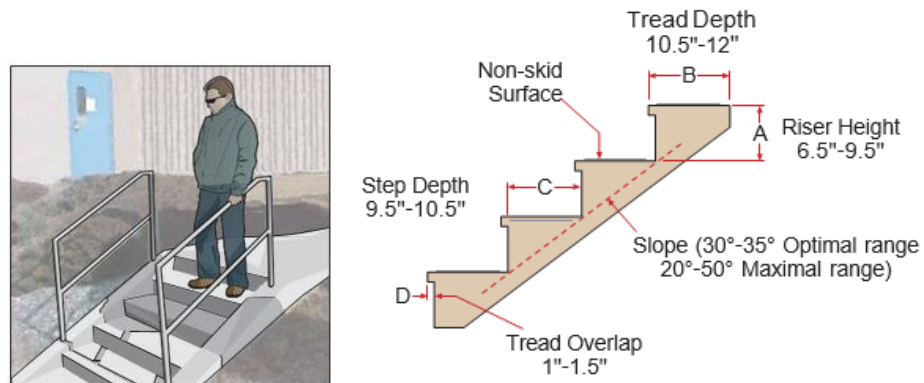
- Metal: 1.5" (38 mm)
- Maximum horizontal spacing between support brackets: 8 ft. (2.44 m)
- Locate intermediate rails halfway between the step and top rail
- Minimum wall clearance: 3" (76 mm)
- Minimum head clearance: 7 ft. (2.13 m)
- For additional information, refer to OSHA standards 29 CFR 1910.24 and 29 CFR 1910.26

Other Considerations

- Stair ladders are used to move vertically up slopes between 50° and 75° from floor
- Stair ladders are designed to ascend while facing the ladder and descend while facing away from it
- Mobile stairs/ladders shall have wheel brakes.

6.5.3.4. Stair Access

Figure 6.63: Stair access



Guidelines

- Slope: 30°–50° from the floor
- Non-skid surface on stair tread
- For additional information, refer to OSHA standard 29 CFR 1910.24



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Table 6.24: Riser Heights and Tread Depths Based on Stair Slopes

Slope	Riser Height	Tread Depth
30°	6.5" (165 mm)	11.0" (279 mm)
35°	7.2" (183 mm)	10.2" (259 mm)
40°	8.0" (203 mm)	9.5" (241 mm)
45°	8.8" (224 mm)	8.8" (224 mm)
50°	9.5" (241 mm)	8.0" (203 mm)

Other Considerations

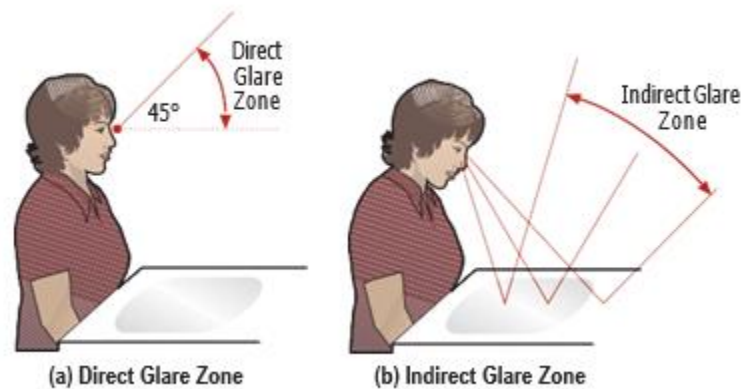
- Indicate tread edges using bright or contrasting color (especially first and last two steps)
- Use matte finish on steps to reduce glare from overhead lighting
- Avoid carpet patterns on stair tread
- Handrails should contrast with wall and stair colors

6.6 Environment

6.6.1 Visual

6.6.1.1. Glare

Figure 6.64: Direct and indirect glare zones



Controlling Direct Glare

- Position lighting units as far away from employee's line of sight as is practical
- Use several low-intensity lighting sources rather than one bright one



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- Use lighting sources that produce a batwing light distribution, and position employees so the highest light levels come from the sides, not front and back
- Use lighting with louvers and prismatic lenses
- Use indirect lighting
- Use light shields, hoods, and visors if other methods are impractical

Controlling Indirect Glare

- Avoid placing lighting units in the indirect glare zone (b, above)
- Use lighting with diffusing or polarizing lenses
- Use surfaces that diffuse light, such as flat paint, non-glossy paper, and textured finishes
- Change the orientation of the work space, task, viewing angle, or viewing direction until maximum visibility is achieved

6.6.1.2. Lighting

Table 6.25: Guidelines for Recommended Range of Illuminance

Type of Activity	Examples	Illuminance (lux)
Working in public spaces with dark surroundings	Exterior inactive storage, railroad switching, outdoor substations, parking areas	20–50
Simple orientation for short visits	Native interior storage area, exterior pedestrian entrances, truck maneuvering areas	50–100
Visual tasks performed only occasionally	Elevators, locker rooms, exterior active storage areas	100–200
Visual tasks of high contrast or large size	Reading printed material and typed originals, rough bench and machine work, ordinary inspection, rough assembly, loading docks, toilets and washrooms	200–500
Visual tasks of medium contrast or small size	Reading pencil handwriting and poorly printed or reproduced materials, medium bench and machine work, difficult inspection, medium assembly, welding, painting, active storage areas, control rooms	500–1,000
Visual tasks of low contrast or very small size	Reading handwriting in hard pencil on poor quality paper, very poorly reproduced material, very difficult inspection	1,000–2,000
Visual tasks of low contrast or very small size over a prolonged period	Fine assembly, very difficult inspection, fine bench and machine work	2,000–5,000
Prolonged and exacting visual tasks	The most difficult inspection, extra-fine bench and machine work, extra-fine assembly	5,000–10,000
Special visual tasks of extremely low contrast and small size	Some surgical procedures	10,000–20,000



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Measurement Criteria

1. Determine the visual requirements for the task.
2. Take reading at object, work surface, or display position (1 lux = 0.093 footcandle).
3. Compare illumination levels with recommended values in Table
4. 10.4 to determine the recommended illumination range.
5. Fine-tune the selection based on two parameters:
 - Age: If employees performing the visual task are
 - under 40, select an illumination level from lower third of given range.
 - 40 to 55, select an illumination level from middle third of range.
 - over 55, select an illumination level from upper third of range.
 - For more reflective work surfaces lower illumination levels can be used. If the work surface has a reflectivity
 - > 70%, select an illumination level from lower third of given range.
 - 30%–70%, select an illumination level from middle third of range.
 - < 30%, select an illumination level from upper third of range.

Note: Adequacy of light for a task can often be determined subjectively by questioning those routinely exposed to the environment.

Controls and Considerations

- Adjustable task lighting for levels > 1,000 lux
- Head-mounted lighting (e.g., safety glasses with LEDs)
- Equipment-mounted lighting (e.g., pneumatic drivers with LEDs)
- Full-spectrum lighting
- Clean and maintain light sources regularly



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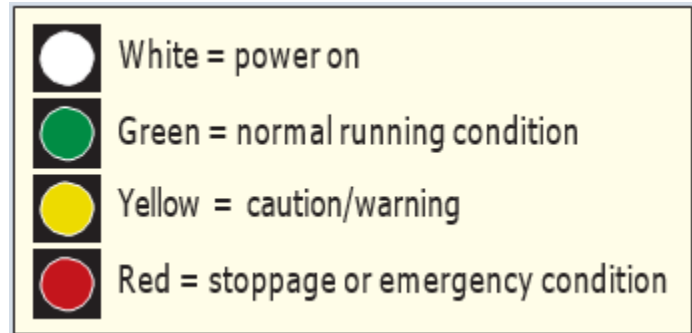
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Table 6.26: Reflectivity of Work Surface Colors

Color	Reflectivity
White	100%
Aluminum, white paper	80-85%
Ivory, deep lemon yellow	70-75%
Deep yellow, cream, light okra, light green, pastel blue, pale pink	60-65%
Lime green, pale gray, blue gray, pink, deep orange	50-55%
Powdered chalk, pale wood, sky blue	40-45%
Pale oakwood, dry cement	30-35%
Deep red, grass green, pale leaf, wood brown, green, olive green	20-25%
Dark blue, purple, reddish brown, slate gray, dark brown	10-15%
Black	0%

6.6.1.3. Color

- Indicator lights should follow standard color-coding in Figure 6.64.



- Color-coding should not be the only form of discrimination (use labels, texture, etc.).
- For large areas, choose colors with uniform reflectivity (similar colors).
- Avoid bright or highly saturated primary colors (red, blue, yellow).
- In areas where highly repetitive work is performed or that have a large amount of wall or floor space, use stimulating colors to highlight door features or partitions. Paint equipment in these areas a brighter shade than that of the room.
- Divide large areas with colors to give identity to various groups within them.
- Be cognizant of cultural stereotypes when choosing color.



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6.6.2 Temperature

There are extreme temperatures that could affect workers occupational health and subsequently affect the operator's ability to meet the level of quality performance expected of them. For design of work areas and their strategic location within the facility, an engineer should take into consideration, sustaining ambient temperatures in work areas which will help an individual maintain their natural body temperature (37°C or 98.6 °F) and will increase the comfort of the working environment for the operator.

There are other factors that may impact the choice of ambient temperature target for a given work environment. Product and/or process requirements may dictate a higher degree of temperature control than is strictly required for human comfort (especially in high precision machining or assembly). All of these factors should be considered when selecting the designed ambient temperature target and range.

For 8-hour exposures, external (outside the body) temperatures between 19 and 26 degrees Celsius (66 and 79 degrees Fahrenheit) are considered comfortable for 95% of the operator population, provided that the humidity at the upper limit and the air velocity at the lower limit are not extreme.² The Table 6.27 below presents recommended maximum workloads for 2-hour exposures at various heat and humidity levels.



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Table 6.27: Recommended work load for temperature and relative humidity conditions

Maximum Recommended Work Load					
Temperature		Relative Humidity			
°C	°F	20%	40%	60%	80%
27	80	Very Heavy	Very Heavy	Very Heavy	Heavy
32	80	Very Heavy	Heavy	Moderate	Light
38	100	Heavy	Moderate	Light	Not Recommended
43	110	Moderate	Light	Recommended	Recommended
49	120	Light	Recommended	Recommended	Recommended

Very Heavy	Shoveling or ditch digging, handling moderately heavy cases (> 15 pounds) to and from a pallet, lifting 45 pound cases 10 times per minute
Heavy	Cement making, industrial cleaning, large-sized packing, moving light cases to and from a pallet
Medium	Bench work, lathe or medium-sized press operation, machining, brick laying
Light	Small parts assembly, milling machine or drill press operation, small parts finishing

6.6.2.1. Heat

Standards

- Criteria for a recommended standard occupational exposure to hot environments: ISO/DIS 7933, ACGIH 1992, NIOSH 1986

Guideline

- Core body temperature should not exceed 100.4°F (38°C)

Measurement Criteria

- Determine workload:

Table 6.28: Workload Type by Kcal/hr

Workload	Kcal/Hour
Light	200
Medium	200 - 350
Heavy	350 - 500

Sum up kcal/minute for the various types of work performed during the shift (Table 6.28).

Example: Assembly line work using a heavy hand tool:



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- Walking 2.0 kcal/minute
- Intermediate value between heavy work with two arms and light body work 3.0 kcal/minute
- Add 1.0 kcal/minute for basal metabolism
- Total = 6.0 kcal/minute
- To convert from kcal/minute to kcal/hour, multiply by 60 (360 kcal/hour = heavy workload).
- Measure environmental heat using wet bulb globe thermometer (accounts for temperature and humidity).
- Using Table 10.8, select the work/rest regimen that best describes the work situation to determine the recommended threshold limit value (TLV®). Compare the measured value to the recommended TLV to determine if heat exposure is safe.
 - TLV's are based on two assumptions:
 - Nearly all acclimatized, fully clothed employees with adequate water and salt intake can function effectively under the given working conditions without exceeding a deep body temperature of 100.4°F (38°C).
 - The resting place wet bulb globe temperature (WBGT) is the same or very close to that of the workplace. Where the WBGT of the work area is different from that of the rest area, use a time-weighted average.
- If heavier clothing that impedes sweat or has a higher insulation value is required, reduce permissible heat exposure TLV's in Table 10.8 by the corrections in Table 10.9.



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Table 6.29: Assessment of Work

Body Position and Movement	Kcal/minute
Sit	0.3
Stand	0.6
Walk	2.0 - 3.0
Walk uphill	add 0.8 per meter (yard) rise
Type of Work	Kcal/minute
Hand work, light (e.g., writing)	0.4
Hand work, heavy (e.g., typewriting)	0.9
One arm, light	1.0
One arm, heavy (e.g., hammering)	1.7
Both arms, light (e.g., filing metal, planing wood, raking garden)	1.5
Both arms, heavy	2.5
Whole body, light	3.5
Whole body, moderate (e.g., cleaning floor, beating carpet)	5.0
Whole body, heavy (e.g., railroad-track laying, digging, barking trees)	7.0
Whole body, very heavy	9.0

Table 6.30: Permissible Heat Exposure Threshold Limit Values

Work/Rest Regimen (Each Hour)	Workload		
	Light	Medium	Heavy
Continuous work	86°F (30.0°C)	80°F (26.7°C)	77°F (25.0°C)
75% work, 25% rest	87°F (30.6°C)	82°F (28.0°C)	78°F (25.9°C)
50% work, 50% rest	89°F (31.4°C)	85°F (29.4°C)	82°F (27.9°C)
25% work, 75% rest	90°F (32.2°C)	88°F (31.1°C)	86°F (30.0°C)

Table 6.31: WBGT (wet bulb globe temperature) Correction Factors

Clothing Type	WBGT Correction	
	°F	°C
Summer lightweight work clothing	0	0
Cotton coveralls	-4	-2
Winter work clothing	-8	-4
Water barrier, permeable	-11	-6



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Countermeasures and Controls

- Individual response to heat stress varies widely, and factors like health conditions and medications can have a significant impact.
- Reduce air temperature to at least 77°F (25°C) and reduce humidity to at least 55% (air conditioning and dilution ventilation).
- Increase air flow across the employee (has little effect if temperatures exceed 99°F, or 37°C). Generally, air velocity changes have a lesser impact than temperature or humidity changes.
- Install heat shields or other form of insulation between employee and heat source.
- Direct heat flow away from employee.
- Provide cooling vests with ice pockets. Discourage ice vest use when bending/lifting is required.
- Provide cool-off areas with large quantities of drinking water.
- For material handling tasks, multiply recommended load weight by
- 0.88 if working in a thermal environment of 90°F (32°C) to estimate heat-adjusted recommended lift weight.
- Wear as little clothing as is practical. Clothing should be absorbent (cotton), open weave to allow air to move across skin, loose fitting, and should reflect heat where appropriate (aluminum covered suits).
- Acclimatization of employees to hot work environments is an effective administrative control strategy; provide five successive days of heat exposures lasting at least one hour each.
- If changes to clothing are required, clothing shall comply with personal protective equipment requirements.

6.6.2.2. Cold

Standards:

- Criteria for a recommended standard occupational exposure to cold environments: ACGIH TLV, ANSI Z-365.



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Guidelines

- Exposure to air temperatures below 45°F (7°C) warrants ergonomic intervention.
- For exposures to air temperatures below 40°F (4°C), provide dry, insulated clothing to maintain employee's core body temperature above 96.8°F (36°C).
- The environmental air, tool exhaust, and materials that come in contact with the hands or forearms should not be colder than 66°F (18°C) for prolonged (> 10 minutes) or repeated (> 2 times/minute) contact.

Measurement Tools

- Thermometer for environmental temperature
- Temperature gauge for measuring tools or product

Countermeasures and Controls

Clothing

- All clothing shall comply with local personal protective equipment requirements.
- Provide three layers of warm clothing:
 - Inner layer to trap warm air next to skin, transfer moisture from skin to outer layers (wool, polypropylene, silk)
 - Intermediate layer to insulate, hold still air around the body (wool, down, synthetic batting, polyester pile)
 - Outer layer to resist wind and moisture, protect underlying layers, transfer moisture to external environment (hard-finished, tightly woven fabrics, breathable coatings)
- Provide semi-permeable clothing (rather than impermeable clothing) to enable higher body heat storage and faster re-warming of extremities during work
- Remove layers if activity/temperature increases, before the wearer begins to sweat (moisture lowers insulation value of clothing)

Footwear



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- Provide waterproof layers to keep feet dry
- Shoes and boots should be oversized to allow sock layering, to provide the benefit of air as an insulator

Gloves

- Gloves should cover hands and wrists
- Provide mittens when work involves primarily the hands rather than the fingers
- Provide partial gloves, which expose the tips and middle phalanges of the fingers only when dexterity is required
- In severe conditions, use gloves covered by mittens for additional protection (remove mittens when dexterity is required)
- Seams should not be located at the fingertips
- Gloves should be properly sized so they breathe and minimally interfere with task requirements
- Replacement gloves should be readily available in case gloves get torn, wet, etc.

Task / Tools

- Structure tasks performed in the cold for minimal downtime. Body heat loss in the cold is rapid and significant when a person is not active. Do not overwork people in cold weather.
- Avoid contact with metal (work tables, tools). Insulate using rubber, plastic, or other non-thermally conductive material.
- Limit contact with vibrating tools; the combination of both vibration and cold temperatures accelerates onset of injury.
- Minimize fine finger movement; dexterity is reduced in a cold environment.
- Avoid tool exhaust directed onto the body (especially the hands) in a cold environment.
- Provide a facility for warming the body and/or hands when exposure to cold exceeds reasonable tolerance levels.

6.7 Controls and Displays

6.7.1 Visual Displays in Manufacturing Environments



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Visual display's include paper documents, computer screens and other visual devices that workers may see but do not interact with. If visual displays are not designed and installed properly they can cause ergonomic injuries.

There are numerous types of displays that range from text to color coding. Labels with text should be consistent, with letters arranged in the horizontal plane and in the upright position. For optimal legibility, the ratio between letter height and the distance from the worker the object should be approximately 0.007:1, with a letter width to height ratio from 0.7:1 to 0.9:1.

Due to color blindness red and green may be difficult for some to distinguish between, if you cannot avoid the use of these colors incorporate a second method of identification for those with colorblindness. Due to the physiology of the eye, the color blue for text may be an issue as the general population's sensitivity to blue may decrease. For color and surface related glare, please refer to section 6.6.1.1 for more explanation.

The use of visual displays should be minimized as an operator may become overburdened and may not see each display. For visual display terminals (VDTs) an important factor to consider when designing is the amount of information that is presented within a screen.

6.7.2 Controls

Controls include push buttons, Human Machine Interface's (HMIs), and other devices that the operator will physically interact with. Characteristics of control operation include control forces, direction and type. During the design phase, these characteristics should match the range of ability for the general population in terms of strength, skill and training.

Minimize the use of controls when possible, however when controls are required use the following as a guide:

- Consolidate controls by function or sequence while remembering to distribute groups of controls so that no limb is over tasked (arms and legs)
- Fast or precise movements that require less energy should be performed by the hands



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- Use controls that can be easily identified by incorporating different control shapes, colors, or locations
- Design and locate controls so their motion and that of their associated displays are compatible (e.g. a rightward movement of the control should be associated with a rightward or upward movement of the associated display indicator)
- Position all controls to be operated by the hands within the operators work envelope
- Use zero force anti-tie-down controls when possible
- Use pushbutton controls with discrete settings (i.e. controls with preset operating settings) when tasks being controlled require a limited number of settings. Only use continuous controls (i.e. controls with user-adjusted operation values) where settings along a range are desirable. Use Tables 6.32 and 6.33 to evaluate the benefits of each type of control.

Table 6.32: Discrete Adjustment Controls

Control Characteristic	Rotary/Selector Switch	Thumbwheel	Pushbutton (Hand)	Pushbutton (Foot)	Toggle Switch
Time required to make settings	Medium	-	Very quick	Quick	Very quick
Maximum recommended control settings	3 to 24	3 to 24	2	2	2 to 3
Space required	Medium	Small	Small	Large	Small
Possibility for accidental activation	Low	Low	Medium	High	Medium
Preferred control movement limit	270 degrees	-	0.32cm x 2.75cm (1/8in x 1-1/12in)	1.27cm x 10.16cm (1/2in x 4in)	120 degrees
Effectiveness of visually identifying position of control	Fair to good	Good	Poor (unless backlit when on)	Poor	Fair

Table 6.33: Continuous Adjustment Controls

Control Characteristic	Knob	Thumbwheel	Handwheel	Crank	Pedal	Lever
Large forces can be developed	No	No	Yes	Yes	Yes	Yes
Space required	Small to medium	Small	Large	Medium to large	Large	Medium to large
Possibility for accidental activation	Medium	High	High	Medium	Medium	High
Preferred control movement limit	Unlimited	180 degrees	+/- 60 degrees	Unlimited	Small (unless rotary)	+/- 45 degrees
Identifiability of control settings	Good	Poor	Fair to good	Fair	Poor	Good
Effectiveness of visually identifying position of control	Fair to good	Poor	Poor to fair	Poor	Poor	Fair to good



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6.7.3 Control Selection

The following selection criteria help determine which control is most suitable for a specific application based on:

- Speed and accuracy of the response needed
- Space available
- Ease of use
- Readability in an array of similar controls

Use Table 6.34 to select the appropriate control for an application and Tables 6.32 and 6.33 for additional detail.

Table 6.34: Ratings of Common Controls

Control	Required Operation Speed	Required Operation Accuracy	Required Space to Mount Control	Ease of Operation in Array of Like Controls	Ease of Check Reading in Array of Like Controls
Push Button	Good	Unsuitable	Small	Good	Poor
Toggle Switch	Good	Poor	Small	Good	Good
Rotary Selector Switch	Good	Good	Medium	Poor	Good
Knob	Unsuitable	Fair	Small to Medium	Poor	Good
Crank	Fair	Poor	Medium to Large	Poor	Poor
Lever	Good	Horizontal=Poor Vertical=Fair	Medium to Large	Good	Good
Hand Wheel	Poor	Good	Large	Poor	Poor
Pedal	Good	Poor	Large	Poor	Poor

6.7.4 Display and Gauge Location

6.7.4.1 Guidelines

- Locate frequently used visual displays and gauges
 - 58"– 71" (1.47–1.80 m) from floor for standing workstations
 - 35"– 46" (0.89 –1.17 m) from floor for seated workstations
- Arrange displays and gauges in a horizontal row rather than a vertical row



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6.7.4.2. Countermeasures

- Group most frequently used gauges and displays and place them in the optimum viewing area
- Angle gauge surfaces 10° downward (toward employee) from the vertical plane to reduce glare on them

6.7.4.3. Work Examples

- Monitoring machine status
- Data entry into PC on shop floor

6.7.4.4. Other Considerations

- Limit neck bending and twisting to $\leq 20^\circ$, eliminate neck extension while viewing
- Comfortable line of sight is directly ahead and 15° below horizon
- Comfortable eye deviations are 15° above or below and right or left of the comfortable line of sight
- Appropriate location of power supply during new line installations
- Replace CRT monitors with flat screen LCDs to optimize workspace
- Optimal adjustable display height (top of screen) 58"–71" (1.47–1.80 m) from floor, or if fixed, 66" (1.68 m)
- Optimal adjustable viewing distance 18"–30" (457–762 mm) from floor, or if fixed, 23" (584 mm)

6.7.4.5. Measurement Tools

- Tape measure
- Protractor, to measure angle

6.7.5 Quantitative Versus Qualitative Displays

Select a quantitative display to read a precise numeric value, such as a fixed scale with moving pointer, moving scale with fixed pointer, or digital display.





Select a qualitative gauge to read approximate values or to discern a trend, rate of change, or change in direction.



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Table 6.35: Display Guidelines

Type of Display	Type	Guidelines
<p>Digital</p> 	Quantitative	<ul style="list-style-type: none"> Preferred for quantitative readings, as the employee does not have to consider scale markings. Not recommended if the values are frequently changing, as it takes longer for the employee to read. Unless only quantitative information is required, digital displays should be accompanied by a redundant analog display.
<p>Dial</p> 	Quantitative	<ul style="list-style-type: none"> Preferred when slight variable movements or changes in quantity are important to the observer. Prefer fixed scale with moving pointer over a moving scale with fixed pointer. To fit human movement stereotypes, direction of increasing value should be clockwise.
<p>Status Indicator</p> 	Qualitative	<ul style="list-style-type: none"> To display a discrete condition, for example: <ul style="list-style-type: none"> On/off Safe, caution, critical thresholds Traffic lights (red, yellow, green)
<p>Check Reading</p> 	Qualitative	<ul style="list-style-type: none"> To determine whether or not a reading is "normal." If several instruments for check reading are used together in panels, configure them so that any deviation from normal stands out from the others.

6.7.6 Push Buttons

Figure 6.65: Push button





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6.7.6.1. Guidelines

- Activation forces: maximum 2 lb (0.9 kg)
- Diameter: minimum 0.75" (19 mm), or 1.0" (25 mm) if employee wears gloves
- Separation between randomly pushed buttons: minimum 0.5" (13 mm), ideally 2" (51 mm)
- Separation between sequentially pushed buttons: minimum 0.25" (6 mm), ideally 1" (25 mm)
- Provide audible click when activated

6.7.6.2. Countermeasures

- Hand push-button surface should be concave or provide friction
- Place buttons near corresponding display
- Angle buttons to allow neutral hand/wrist posture during activation

6.7.6.3. Work Examples

- Activating cycle button on a machine
- Operating an overhead hoist
- Emergency stop buttons
- Clearing an alarm signal

6.7.6.4. Other Considerations

- Consider alternative controls:
 - Finger swipes (light sensor switches) when frequent activation required
 - Palm buttons where sustained depression required; diameter 1.5"–3.0" (38–76 mm)
- Provide guarding ring to prevent accidental activation (e.g., emergency stops)
- Color-coding and alternate shapes may be appropriate to distinguish operations
- If consecutive operation of multiple buttons, avoid vertical arrays

6.7.6.5. Measurement Tools

- Refer to push button manufacturer's specifications



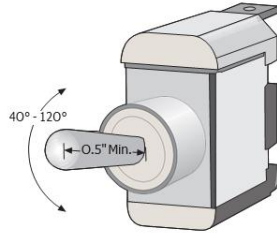
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- Force gauge to determine finger-push force
- Tape measure or micrometer to determine separation distance

6.7.7 Toggle Switches

Figure 6.66: Toggle switch



6.7.7.1. Guidelines

- Control activation forces: maximum 0.5 lb (0.3 kg)
- Toggle length: 0.5"– 2" (13–51 mm)
- Minimum separation between toggle switches:
 - Horizontal plane: 1" (25 mm)
 - Vertical plane: 3" (75 mm)
- Degrees of travel between settings: 40°–120°

6.7.7.2. Countermeasures

- For discrete operation only (not when employee must hold control in one position)
- Provide spring-loading near center position

6.7.7.3. Work Examples

- Powering on/off
- Designating high, medium, or low (or off, slow, fast) speed settings on a conveyor

6.7.7.4. Other Considerations

- Alternative shapes (e.g., rocker switches) may be appropriate when lower profile is needed
- Make toggle slightly longer if employee wears gloves
- Adhere to cultural conventions (e.g., toggle switch in the up position indicates “off” in Europe and Asia)



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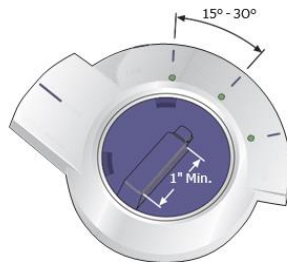
- Note shape/surface characteristics to prevent soft tissue compression

6.7.7.5. Measurement Tools

- Force gauge or transducers, to measure efforts
- Tape measure or micrometer, to measure distances and control dimensions

6.7.8 Rotary Selector Switches

Figure 6.67: Rotary selector switch



6.7.8.1. Guidelines

- Force to turn switch: ≤ 2 lb (0.9 kg)
- Minimum pointer diameter: 1.0" (25 mm), maximum 4.0" (102 mm)
- Switch height: 1"–2.8" (25–71 mm) from surface
- Switch width: 1" (25 mm)
- Detent positioning: 15° when knobs are easily visible, 30° when not, maximum 40°

6.7.8.2. Countermeasures

- Avoid selections that are 180° apart. Use only as much of the control's 360° as necessary to accommodate number of values required.
- Provide a detent or hard stop for each control position (setting).

6.7.8.3. Work Examples

- Designating high, medium, or low (or off, slow, fast) speed settings on a conveyor



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6.7.8.4. Other Considerations

- Label settings clearly, in large print or with picture representations
- Place in an easy-to-reach (and see) location

6.7.8.5. Measurement Tools

- Tape measure, to determine pointer diameter, length, width, and height
- Pinch-grip meter, to determine amount of force employee typically exerts to turn switch

6.7.9 Knobs

Figure 6.68: Knob separation



6.7.9.1. Guidelines

- Forces required to turn knobs:
 - Grip force: ≤ 2 lb (0.9 kg)
 - Turning force: 0.38 in-lb (9.65 mm-kg) of torque
- For precise movement (using a pinch grip):
 - Diameter: 0.4"–1" (10–25 mm)
 - Depth: 0.5"–1" (13–25 mm)
- Separation between knobs: 1"– 2" (25– 51 mm) for one hand, with gloves
- For higher force required, such as knobs opening a valve (using a palm grasp):
 - Diameter: 1.5"–3" (38–76 mm)
 - Depth: minimum 0.6" (15 mm)
 - Use a knurled knob for higher force exertions

6.7.9.2. Work Examples

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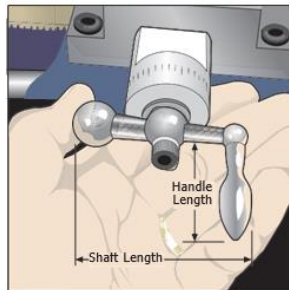
- Adjusting valve pressure
- Setting illumination levels

6.7.9.3. Measurement Tools

- Pinch-grip meter, to determine force required to turn knob
- Tape measure, to determine separation, diameter, height

6.7.10 Cranks

Figure 6.69: Crank measurement



6.7.10.1. Guidelines

- If rapid turning is required, keep force to turn < 10 lb (4.5 kg)
- Handle length for use with fingers: 1.5" (38 mm)
- Handle length for use with entire hand: 3.7" (95 mm)



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Table 3.35: Recommended Crank Shaft Length and Acceptable Torque Ranges

Vertical Crank on Side of Device at 36" (914 mm) Above Floor	
Shaft Length	Acceptable Torque Range
1.5" (38 mm)	0–20 lb-in (0–2.3 Nm)
4.5" (114 mm)	20–40 lb-in (> 2.3–4.5 Nm)
7.5" (190 mm)	40–90 lb-in (> 4.5–10.2 Nm)
7.5" (190 mm)	> 90 lb-in (> 10.2 Nm)
Vertical Crank on Front of Device at 36" (914 mm) Above Floor	
Shaft Length	Acceptable Torque Range
1.5" (38 mm)	0–20 lb-in (0–2.3 Nm)
2.5" (64 mm)	20–40 lb-in (> 2.3–4.5 Nm)
4.5" (114 mm)	40–90 lb-in (> 4.5–10.2 Nm)
4.5" (114 mm)	> 90 lb-in (> 10.2 Nm)
Vertical Crank on Front of Device at 48-56" (1.12-1.42 m) Above Floor	
Shaft Length	Acceptable Torque Range
2.5" (64 mm)	0–20 lb-in (0–2.3 Nm)
2.5" (64 mm)	20–40 lb-in (> 2.3–4.5 Nm)
4.5" (114 mm)	40–90 lb-in (> 4.5–10.2 Nm)
7.5" (190 mm)	> 90 lb-in (> 10.2 Nm)

6.7.10.2. Other Considerations

- If using larger cranks (> 10" or 254 mm), vertical cranks mounted on the side of equipment may require excessive reaches
- Provide cranks when fine and/or gross adjustment are necessary, and only one hand is available
- Handle should rotate for gross adjustments, but be fixed during fine adjustments

6.7.10.3. Work Examples

- Making fine adjustments on a press, lathe, and/or mill

6.7.10.4. Measurement Tools

- Force gauge, accelerometer, or torque wrench to determine force required to displace hand wheel
- Tape measure, to measure diameter and handle length

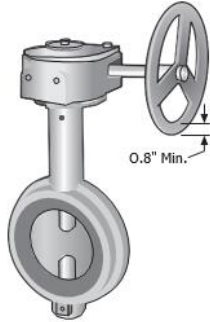


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6.7.11 Small Hand Wheels ($\leq 10''$ Diameter)

Figure 6.70: Small hand wheel



6.7.11.1. Guidelines

- Hand wheels are appropriate when
 - Significant force is required
 - Two hands are available
 - Fine adjustments are not required
- Maximum breaking force:
 - One-handed operation: ≤ 29 lb (13.2 kg)
 - Two-handed operation: ≤ 49 lb (22.2 kg)
- Rim diameter: 0.8"– 1.8" (20–46 mm)
- Hand wheel diameter: 5"–10" (127–254 mm)

6.7.11.2. Countermeasures

- Perform preventive maintenance (e.g., grease gear housings)
- Add a flange or notch into wheel handle to minimize slipping during forceful turns
- Use a crank instead when tasks involve two or more rotations

6.7.11.3. Work Examples

- Opening and closing a valve
- Operating a knife gate

6.7.11.4. Other Considerations

- Hand wheel orientation
 - Preferred: vertical
 - Acceptable: horizontal



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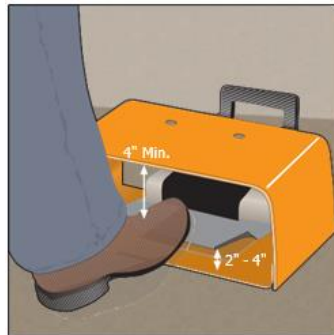
- Vertical hand wheel height (middle of wheel)
 - Preferred: 49"–62" (1.2–1.58 m)
 - Acceptable: 38"–74" (0.97–1.88 m)
- Horizontal hand wheel height
 - Preferred: 38"–47" (0.97–1.19 m)
 - Acceptable: 30"–57" (0.76– 1.45 m)
- After using a hand wheel to close a valve, turn it back one half turn to prevent metal-to-metal seizure

6.7.11.5. Measurement Tools

- Force gauge or accelerometer
- Tape measure

6.7.12 Foot Pedals

Figure 6.71: Foot pedal



6.7.12.1. Guidelines

- Activation force \leq 10 lb (4.5 kg)
- Vertical displacement:
 - Pedals operated by entire leg: 2"–4" (51–102 mm)
 - Pedals operated by ankle motion: maximum 2.5" (64 mm)
 - Automobile brake type pedals: 2"–3" (51–75 mm)
- Separate pedals by a minimum of 2" (51 mm)
- Provide minimum 4" (102 mm) toe clearance under guard
- Provide treads to avoid slips

6.7.12.2. Countermeasures

- Ensure proper foot pedal location
- Light curtains or pressure mats



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- Seated activation preferred, but standing activation permitted for infrequent, short-duration operations

6.7.12.3. Work Examples

- Cycling a machine (switching pedal)
- Controlling machine throttle (operating pedal)

6.7.12.4. Other Considerations

- Provide adequate accommodation for personal protective equipment
- Protective guard required to discourage accidental activation
- Ensure foot pedal adheres to safety requirements
- Determine appropriateness of foot pedal:
 - Not recommended for standing work, except very infrequent use
 - Very precise force exertion is best relegated to the hands

6.7.12.5. Measurement Tools

- Force gauge

6.8 Laboratory

6.8.1 Workbench

6.8.1.1. Guidelines

Standing

- Hand working height (from standing surface):
 - General activities: 38"–47" (0.97–1.19 m), or if fixed, 42" (1.07 m)
 - Precision or visually demanding tasks: 40"–51" (1.02–1.30 m), or if fixed, 45" (1.14 m)
 - Not-to-exceed hand working heights: $\leq 30"$ (0.76 m), $\geq 57"$ (1.45 m)
- Standing work surface depth: maximum 30" (762 mm) deep where employees must reach to access items
- Knee space depth: $\geq 6"$ (152 mm)



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- Hand working height for processes involving staging equipment: maximum 49" (1.25 m) above standing surface
- Rounded front edge of work surfaces or countertops
- Horizontal reach distance: $\leq 11"$ (279 mm)
- Vertical reach distance: $\leq 74"$ (1.88 m) above standing surface

Seated

- Hand working height (from standing surface):
 - Precision or visually demanding tasks: 27"–36" (686–914 mm), or if fixed, 36" (914 mm)
 - Not-to-exceed hand working height: 36" (914 mm)
- Knee space depth: $\geq 18"$ (457 mm)
- Knee space width: $\geq 30"$ (762 mm)

6.8.1.2. Countermeasures

- Provide height adjustable work benches
- For fixed-height workstations, account for use of staging equipment or fixtures
- Keep computers off the work surface to increase space and reduce clutter
- Provide flat panel monitors on adjustable height fixture to maximize work space
- Place all gas valves 33"–42" (0.84–1.07 m) above standing surface
- Ensure all tools and equipment meet recommended design guidelines as described in this handbook
- Extend sink faucets to minimize reaching

6.8.1.3. Other Considerations

- Automatic bottle-cap openers allow for one-handed operation (unscrewing and tightening bottle caps automatically)

6.8.1.4. Measurement Tools

- Tape measure (measure hand working height from standing surface to center of hands while performing lab tasks)

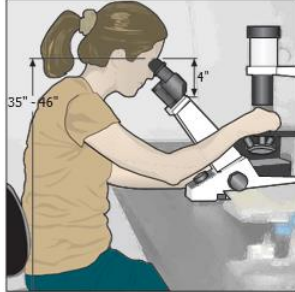
6.8.2 Microscope Work



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Figure 6.72: Microscope work



6.8.2.1. Guidelines

- Eyepiece height adjustability: ≥ 4 " (102 mm)
- Eyepiece extensions: 3.5" (90 mm)
- Eyepiece vertical displacement angle adjustability: 0° – 180°
- Recommend seated use, rather than standing
- Optimal seated eye height: 35"–46" (0.89–1.17 m) above floor surface, or if fixed, 46" (1.17 m)

6.8.2.2. Countermeasures

- Implement eyepieceless viewing system or video monitor systems for increased field of view, longer working distance, and freedom of head and body movement
- Motorized stage controllers integrate all X-Y adjustment knobs into one control
- Use stage armrests
- Use rubber eyecups
- Place microscope on anti-vibration platform to minimize vibration that may result at higher magnifications
- Provide horizontal and vertical adjustment stand
- Provide padded forearm rest
- Provide height adjustable chair to accommodate full range of employees
- Install height adjustable work bench if optimal eye height range (refer to guidelines) is not achieved with eyepiece height and chair height adjustability

6.8.2.3. Other Considerations

- Employees should receive annual eye exam



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6.8.2.4. Measurement Tools

- Tape measure

6.8.3 Ventilation Hoods

Figure 6.73: Ventilation hood



6.8.3.1. Guidelines

- Angle sash or work face of enclosure 10° away from user to minimize glare
- Place ventilated enclosures on height adjustable workbenches to allow different working heights for each user
- Provide recessed cavities inside enclosure to limit reaches to within 22" (559 mm)
- Sash opening width: minimum 30" (762 mm)
- Clearance criteria:
 - Work surface thickness: ≤ 2 " (51 mm)
 - Knee space depth: ≥ 18 " (457 mm)
 - Knee space width: ≥ 30 " (762 mm)
 - Thigh clearance between seat pan and underside of work surface: ≥ 8 " (203 mm)

6.8.3.2. Countermeasures

- Place frequently accessed items (trays, vials, containers, etc.) within an easy arm's reach or provide turntable inside work area to minimize reaches
- Alternate job tasks throughout shift to avoid sitting/standing for more than 2 hours at a time



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- Construct sashes of low-glare glass

6.8.3.3. Work Examples

- Conducting tests on slide samples
- Preparing solutions for testing

6.8.4 Pipetting

6.8.4.1. Guidelines

- Use electronic pipettes, rather than manual plunger-operated pipettes
- For repetitive use, choose multi-channel pipettes, repeating micropipette dispensers, or motorized pipette dispensers
- Use thin-walled pipette tips to reduce insertion forces to seal the tips and to lower the ejection forces
 - Tip insertion forces: ≤ 2 lb (0.9 kg)
 - Tip ejecting forces: ≤ 2 lb (0.9 kg)
 - Plunger actuation forces: ≤ 2 lb (0.9 kg)
- Provide a mechanical assist to reduce tip-ejection effort
- Triggers:
 - Aspirate using the index finger
 - Dispense using the thumb
- Use pipettes with finger trigger rather than thumb-activated plunger
- Use a non-axial design, rather than an axial (in-line) design to promote neutral postures
- Handle length: 4" to 6" (102 to 152 mm)
- Handle diameter: oval or cylindrical
- Handle surface: slightly soft composite or rubber surface
- Pipette weight: ≤ 6 lb (2.7 kg)
- Ensure the handle has a finger hook at the top to provide microbreaks from supporting the pipette
- If a curved-hilt handle is not provided, consider a pistol-grip attachment

6.8.4.2. Other Considerations



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- Mount forearm supports on work surface to facilitate neutral postures and reduce fatigue
- Provide a pipetting aid to enable user to grip pipette with power grip
- Limit time spent pipetting to 20 minutes followed by a 2-minute microbreak
- Limit pipetting to 2 hours daily
- Pipette should incorporate a positive stop to indicate when seal is made
- Clean pipettes regularly to reduce sticking

6.8.5 Gloveboxes

Figure 6.74: Glovebox



6.8.5.1. Guidelines

Standing glovebox criteria:

- Height of arm opening 48"–52" (1.22–1.32 m)
- Glove port opening 8" (203 mm)
- Port distance (centers) 15"–19" (381 mm–483 mm)
- Glove length 32" (813 mm)
- Window slope 10°

Seated glovebox criteria:

- Height of arm opening 48"–52" (1.22–1.32 m)
- Glove port opening 8" (203 mm)
- Port distance (centers) 15"–19" (381–483 mm)



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- Knee space depth $\geq 18"$ (457 mm)
- Knee space width $\geq 30"$ (762 mm)
- Thigh clearance between seat pan and underside of work surface $\geq 8"$ (203 mm)
- Window slope 10°

6.8.5.2. Other Considerations

- Ensure that window height, length, and angle are appropriate so that work can be comfortably performed in all areas of the glovebox

7. Safety and Environmental Information:

All safety and environmental information shall go in this section. Do not include safety related information in Section 6 (Content).

8. References:

This standard has been adapted from the The Handbook of Ergonomic Design Guidelines - Version 2.1, 2012 authored by Humantech, Inc. The Humantech System is Cummins preferred platform for ergonomic risk analysis and improvement. Access The Humantech System at ergonomics.cummins.com

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