

Part Two



Application Guide for

SEMI S8-95

5. Terminology

5.1

5.1.a. Administrative Controls include, but are not limited to, the following: job rotation, job enlargement, work-rest scheduling, microbreaks, and stretching exercises.

5.1.b. Engineering controls are preferred over administrative controls.

5.5

5.5.a Refer to Appendix G of this guide for definitions of awkward postures.

5.18.

5.18.a Redefined as an extended reach that may cause the user biomechanical or other stress. Excessive reaches may be a function of weight handled or frequency of the reach. A reach being classified as excessive will be determined by analysis of the manual handling aspects of the task (see Appendices A ,D) or repetition/duration/force components of the reach determined using an appropriate analysis tool.

5.19

5.19.a Redefined as reaches that require either (1) leaning, stretching, stooping, or crouching or (2) shoulder flexion or abduction greater than 45 degrees.

5.20

5.20.a Redefined as any task required by the routine operation or maintenance of the equipment. Simultaneous operation of multiple tools needs to be considered when deciding whether a task is frequent.

5.23

5.23.a Redefined as a task typically consisting of non-routine or non-planned operations or maintenance on equipment. Identified risk factors (e.g., heavy lifting) have to be resolved regardless of task frequency.

5.33

5.33.a Redefined as the 30 degree cone around the normal line of sight (15 degrees above and below a perpendicular line from the eye).

5.35

5.35.a Redefined as increased potential for injury/illness.

5.38

5.38.a Redefined as a fixed position or posture without movement of the particular body part. A differentiation is typically made between static postures involving unsupported versus supported body parts. A static unsupported posture is typically defined as a posture maintained for 20 seconds or more. Static supported postures can include standing or sitting. A static standing posture is defined as standing and/or walking continuously for 45 minutes or more. A static seated posture is defined as sitting for 1 hour or more.

5.40

5.40.a This definition pertains to single or multiple tools.

5.43

5.43.a An item's "effectiveness" is viewed in terms of its functional design, specific to **SEMI S8-95**.

8. General Guidelines

8.1.4.

8.1.4.a “Administrative controls” include, but are not limited to, job rotation, job enlargement, shift and break scheduling, and stretching and strengthening exercises.

8.3.1

8.3.1.a Refer to **SEMI S8-95**, section 15, **Documentation**.

8.4.1

8.4.1.a The supplier is responsible for identifying installation parameters (e.g., workspace envelope, maintenance access). For example, the supplier should specify clearance required for a hinged access door to fully open. When possible, the supplier should provide both overhead and side views of equipment.

9. Workstation Design

9.1.

9.1.a Refer to Appendix E in addition to the cited **S8-95** tables and figures.

9.1.1

9.1.1.a When using anthropometric data provided in **S8-95** (or other resources), use the following equipment/clothing adjustments:

- Cleanroom booties add 0.5” to all stature-related measures
- Contamination control helmets add 1.5” to all stature-related measures.

9.1.1.b Refer to Appendix E.

9.1.1.c Note that many anthropometric databases cite unclothed dimensions.

9.1.2.

9.1.2.a Refer to **S8-95**, Related Information 2, Table R24 for “Reach Distances.”

9.1.3

9.1.3.a Refer to **S8-95**, Related Information 1, Table R11, Figure R11 and R12.

9.1.4

9.1.4.a Refer to **S8-95**, section 5.3.3, for a definition of primary viewing area.

9.1.5

9.1.5.a Examples of materials/items include product boxes, wafer boxes, wafer orienters, maintenance manuals, and shop orders.

9.1.6.

9.1.6.a A rounded work surface edge is defined as having a radius of 0.25” or greater

9.2

9.2.1

9.2.1.a Refer to Appendix G of this guide for definitions of awkward postures.

9.2.1.b Refer to 5.38.a of this guide for definition of sustained (static) posture.

9.2.3

9.2.3.a Refer to 5.38.a of this application guide for a definition of static postures.

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9.2.5

- 9.2.5.a Standing touch screen monitor height (floor to top line) range from 36 to 54".
- 9.2.5.b Sitting touch screen monitor height (floor to top line) range from 30 to 42".
- 9.2.5.c. Acceptable height for a fixed standing keyboard (or other data entry device): 38 to 40" (reference is floor to home row or top of data entry device).
- 9.2.5.d. Acceptable height for a fixed seated keyboard (or other data entry device): 28-30" (ref. floor to home row of keyboard or top of data entry device).

9.2.6

- 9.2.6.a Refer to **SEMI S8-95**, Related Information 2, Tables R2 1,2,3.

9.3.

9.3.2

- 9.3.2.a Height of fixed VDT (floor to centerline of monitor) should range from 52 to 58".
- 9.3.2.b. Height of stacked monitors (floor to top line of top monitor) should not to exceed 66".
- 9.3.2.c The primary VDT in a stacked configuration should be the bottom monitor.
- 9.3.2.d Any touch screen with a top of screen height less than 48" should be tilted upward at least 30 degrees.
- 9.3.2.e Any touch screen with a top of screen height less than 41" should be tilted upward at least 45 degrees.
- 9.3.2.f See **S8-95**, section 14.2.6 (screen should be perpendicular to the user's line of sight).

9.3.3

- 9.3.3.a Horizontal reach to high use controls, tools, and materials (measured from shoulder joint) range 9 to 19". **Note:** The approximate distance from shoulder joint to front of body is 8" for a person standing erect.
- 9.3.3.b See **S8-95**, section 13.2.5.

9.3.4

- 9.3.4.a Refer to **S8-95**, Related Information 2, Table R2-5.
- 9.3.4.b Horizontal reach to low use controls (measured from shoulder joint) range 9 to 24". **Note:** The approximate distance from the shoulder joint to the front of the body is 8" for an individual standing erect.

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9.4

9.4.2

9.4.2.a Height of VDT (floor to centerline) single monitor ranges 37 to 47".

9.4.2.b Maximum height of two stacked VDTs = 55"; minimum 37" (floor to top line of top monitor).

9.4.2.c Any touch screen monitor with a top of screen height less than 42" should be tilted upward at least 30 degrees.

9.4.2.d Any VDT with a centerline height of 55" or greater should be tilted downward at least 15 degrees.

9.4.3

9.4.3.a Horizontal reach to high use controls (measured from shoulder joint) range 9 to 19". **Note:** The approximate distance from the shoulder joint to the front of the body is 8" for an individual standing erect.

9.4.4

9.4.4.a See **S8-95**, Related Information 2, Table R2-5.

9.4.4.b Horizontal reach (measured from shoulder joint) ranges 9 to 24".

Note: The approximate distance from the shoulder joint to the front of the body is 8" for an individual standing erect.

10. Design for Maintainability and Service

10.1.3

10.1.3.a Use of latex gloves reduces maximum allowable grip forces listed in Appendix H by 15%.

10.1.3.b Use of cotton gloves reduces maximum allowable grip forces listed in Appendix H by 26%.

10.1.3.c Use of acid gloves reduce maximum allowable grip forces listed in Appendix H by 19%.

10.1.3.d **Note:** that only female data should be used in **S8-95**, Related Information 2, Table R2-7.

10.1.7

10.1.7.a Integral lighting in maintenance areas is required where the operator has to read information (e.g., wire marking) and use a hand tool or make a connection in lighting levels less than 30 footcandles (Fc) at the task.

10.1.7.b Refer to **Illuminating Engineering Society of North America (IES)** for recommended illumination based on task characteristics. See **IES Industrial Lighting Committee (1983)**. Proposed American national standard practice for industrial lighting. **Lighting Design and Application, 13(7), 29-68**. Information available through **EPRI**, P.O. Box 10412, Palo Alto, CA 94303.

10.2

10.2.a For finger access, add 0.5" to access opening dimension for surgical type gloves; add 1.5" for other type gloves.

10.2.b See **S8-95**, Related Information 2, Table R2-6 and Appendix E for additional guidelines.

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10.2.4

10.2.4.a A pullout drawer should have at least three-side accessibility. Horizontal clearance should also be provided for the worker as follows: If the worker is standing upright, allow 20" of clearance. If the worker is bending or squatting, allow 30".

10.3.2

10.3.2.a If manual removal is intended, refer to Appendix E.

10.5

10.5.a "*Frequent*" here means *routine* (see section 5.20 of this guide).

10.5.2.

10.5.2.a Handle diameter, cylindrical type design = 0.75 - 1.5".

10.5.2.b Handle length, cylindrical type = 4.5" or greater (refer to 10.2 for glove allowances).

10.5.2.c Diameter, circular or triangular hand knob design = 2 - 3.5".

10.5.2.d Thickness (height) of circular or triangular hand knob = 0.75 - 1".

10.5.2.e Diameter, ball type design = 1.5 - 2.5".

10.5.2.f All edges smoothed (no contact stress due to sharp edges).

10.5.2.g Refer to **SEMI S8-95**, section 11.4.

11. Lifting, Strength, and Materials Handling

11.1.

11.1.a The supplier should conduct the appropriate manual handling analysis (see Appendix A-D).

11.1.b The supplier should demonstrate that the manual handling task meets the acceptability criteria as defined by the analysis tool (see Appendix B-D).

11.1.c. Acceptance criteria: If weight of lift > 51 lb for a one-person lift, the weight is not acceptable (automatic failure). Engineering or administrative controls are required.

11.1.d. Engineering controls are defined as methods of hazard prevention achieved through the initial design or retrofit of equipment. In general an engineering control is any control resulting from a physical change in the work environment. Administrative controls include, but are not limited to, job rotation, job enlargement, shift and break scheduling, and stretching and strengthening exercises.

11.2.

11.2.a. 11.2 should read *user's maximum grip strength*.

11.2.b. 11.2. should read as follows:

Infrequent effort up to 50% is acceptable

Occasional effort up to 30% is acceptable

Frequent effort should be kept at or below 15%

Continuous (static) effort should be kept at or below 5%.

11.2.c. Refer to **S8-95**, Related Information 2, Table R2-7 and Appendix H.

11.2.d. Refer to 5.38.a of this guide for definition of static posture.

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11.4.

11.4.a Refer to **Handle Design Guidelines** in Appendix F of this guide and **Awkward Postures** in Appendix G

11.4.b Refer to **SEMI S8-95**, section 10.5.2.

11.5.

11.5.a Stooping occurs when vertical material handling height is less than 33" or horizontal reach distance is greater than 18" in front of body.

11.5.b Two hand push/pull: floor to hand height should be between 38 and 44".

13. Controls and Displays

13.1.

13.1.a Refer to **MIL STD 1472D**.

13.2.5.

13.2.5.a Vertical location of low use controls (standing) 32 to 65".

13.2.5.b Vertical location of high use controls (standing) 37 to 54".

13.2.5.c Horizontal reach to low use controls (standing) 9 to 24".

13.2.5.d Horizontal reach to high use controls (standing) 9 to 19".

13.2.5.e Vertical location low use controls (seated) 21 to 55".

13.2.5.f Vertical location high use controls (seated) 30 to 42".

13.2.5.g Horizontal reach to low use controls (seated) 9 to 24".

13.2.5.h Horizontal reach to high use controls (seated) 9 to 19".

Note: Horizontal reaches are measured from the shoulder joint. The approximate distance from the shoulder joint to the front of the body is 8" for an individual standing erect.

13.2.5.i High use control panel width max 24".

13.2.5.j Low use control panel width max 46"

13.2.7.a Controls that require immediate access but are infrequently used should range between 33 to 64.5" for standing workstation; between 21 to 39" for sitting workstation measured from the floor.

13.3.2.

13.3.2.a Stroke width to height ratio for alphanumeric characters should be between 1:6 and 1:10.

13.3.2.b Width to height ratio for alphanumeric characters should be between 1:1 and 1:3.5.

13.3.2.c Recommended minimum character size should be based on the horizontal viewing distance using the following formula:

$H = D/200$, where

H = Character Height

D = Horizontal Viewing Distance.

13.3.3.

13.3.3.a Reference **MIL STD 1472D** for non VDT displays, and **ANSI/HFS 100 1988** for VDTs.

14. User-Computer Interface

14.2.4.

14.2.4.a If color coding is used, recommend using three colors but up to maximum 10 colors are allowed. (Grether and Baker, 1972).

14.2.4.b Refer to **ANSI HFS 100-1988**, section 6.6.

Appendix A Manual Material Handling Risk

1.0 Determining Manual Material Handling Risk

1.1 Introduction

Manual material handling (MH) consists of tasks including lifting, lowering, pushing, pulling, carrying, and holding under a nearly endless variety of postural and task-specific conditions. The injury risk associated with a MH task is a function of the level of physical strain placed on the body when performing the task. In this section, data are presented for use as guides in designing MH tasks and evaluating existing MH tasks.

At the end of this section, users will

- Understand what data need to be collected to describe a MH task.
- Understand, based on the data collected, which MH evaluation tool to use.
- Be able to use the tool mechanically and then be able to interpret the results from the analysis.

1.2 Procedure

Data Collection

The following data need to be determined to evaluate the acceptability of a manual handling task:

Task Variables

Task variables to be determined:

- Point of lift initiation
- Point of lift termination
- Asymmetric component (twisting)
- Distance object is held away from the body
- Container characteristics (size, handles)
- Floor-to-hand distance during push/pull motions
- Distance of push/pull/carry
- Frequency of handling
- Use of gloves
- One vs. two-hand handling.
- Force Data
 - The following data need to be determined:
 - Weight of object handled
 - Force exertion for push/pull tasks.

For object weights, the measurement is often as simple as reading the weight on a bag or can or placing the object on a scale. For push/pull tasks, calibrated force monitors or spring scales are necessary to obtain a force measurement.

2.0 Selecting the Appropriate Analysis Tool

2.1 Discussion

Three general MH evaluation tools are presented in the following sections. The three tools are the NIOSH (1991) lifting equation, biomechanical models, and psychophysical capacity tabular data. Table A1 was designed to assist in the analysis of MH jobs in the following areas:

- Provide a guide for collecting the necessary data.
- Select the appropriate evaluation tool based on the task characteristics and data collected.

2.2 Using the Table

MH task variables are gathered as the first step in the evaluation of the MH task. Based on the data gathered, Table A1 is used to determine the most appropriate evaluation tool(s) based on the task characteristics. For example, suppose an MH task with the following characteristics is being evaluated:

- MH Type = 2 hand lift performed in a standing posture.
- Frequency of lift = 4 lifts according to minute.
- Worker twists during the handling motion.
- Worker is required to wear gloves that may adversely impact handling capacity.
- In the summer, the worker is exposed to ambient temperatures exceeding 90° F when performing the task.

Going to Table A1, the frequency of lift eliminates the biomechanical model (BIO MODEL column) as an appropriate **single** analysis tool. The presence of heat stress conditions indicates that of the three evaluation tools, psychophysical capacity data (PSYCHO column) represents the evaluation tool that best "fits" the task variables (were heat stress not an issue, the NIOSH equation and psychophysical capacity data would be equally applicable).

Note: In many situations the use of **multiple tools** is appropriate. For those situations, use all of the appropriate tools and use the most conservative value as the design guideline.

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Table A1. Criteria to Determine the Most Appropriate MH Analysis Tool(s)

MH TYPE	"IF" CONDITION	NIOSH (1991)	BIO MODEL	PSYCHO
2 Hand Lift or Lower	F < 1 lift / 5 minutes	✓	✓	✓
	F > 1 lift / 5 minutes	✓		✓
	F > 9 lifts / minute	✓		
	Twisting Occurs	✓	✓ (3D)	✓
	Handle Design is an Issue	✓		✓
	Limited Headroom During Lift			✓
	Work Duration > 8 hours			✓
	Load Placement Clearance is an Issue	✓		✓
	Load Asymmetry is an Issue	✓	✓ (3D)	✓
	Length of Object Measured in Frontal Plane of Body > 26"			✓ (3D)
	Exposure to Heat Stress			✓
1 Hand Lifts	Posture = Standing		✓	✓
	Posture = Kneeling or Seated			✓
1 or 2 Hand Carry	Note: Carry is Operationally Defined as Horizontal Movement of Load \geq 7 feet			✓
1 or 2 Hand Push/Pull	Distance < 7 feet and F < 1 Push/Pull / 5 minutes		✓	✓
	Distance \geq 7 feet and F \geq 1 Push/Pull / 5 minutes			✓
	Push/Pull Task Requires Significant Sustained Forces (e.g., slide box along floor)			✓
Lift/Lower in Non-Standard Postures	Kneeling, Sitting, or Lying			✓

NOTE: Under BIO MODEL, 3D indicates that only a 3-dimensional biomechanical model can accommodate the task condition.

3.0A CHECKLIST FOR GATHERING MH TASK DATA

3.1 Purpose

Checklist data sheets are provided on the following pages. Checklists I and II are designed for lift/lower tasks. Checklist III is designed for push/pull/carry tasks. The checklists were designed to do the following:

- Provide a guide for collecting the appropriate data to analyze a MH task.
- Aid in the selection of the appropriate MH analysis tool (refer to Table A1).

3.2 Using the Checklists

The guidelines below are intended to assist in filling out the checklists. **However, the user needs to have a fundamental understanding of the MH analysis tools (NIOSH equation, etc., described in Appendices B through D) to effectively use the checklists.**

- Use Quantitative data unless otherwise specified by the checklist. If an estimate of quantitative data is being used, specify this.
- Checklist I and II both have to be filled out for a given MH task (Checklist II is simply an extension of the Checklist I).
- Note in Checklist I that a weight of lift > 51 lb is automatically considered unacceptable.
- After filling out the checklist(s), refer to Table A1 to select the appropriate MH analysis tool.

CHECKLIST I (LIFT/LOWER TASKS)

TASK	WEIGHT	POSTURE (SEE NOTE B)				CONTAINER CHARACTERISTICS (SEE NOTE C)			
		2 HAND LIFT STAND	2 HAND LIFT KNEEL, SIT, LYING	1 HAND LIFT STAND	1 HAND LIFT KNEEL, SIT, LYING	WIDTH	LENGTH	COUPLING	LOAD ASYM
DESCRIPTION	SEE NOTE A								
1.									
2.									
3.									

NOTE A.If weight of lift is > 51 lb, the weight is excessive and engineering or administrative controls should be evaluated immediately.

NOTE B.Place a checkmark in the column describing the posture (lift motion)

NOTE C.WIDTH is measured width of load in sagittal plane
 LENGTH is measured width of load in frontal plane
 COUPLING refers to categorization of hand/load coupling
 LOAD ASYM refers to imbalance in weight of load

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CHECKLIST II (LIFT/LOWER TASKS, CONTINUED)

TASK	HANDLING HEIGHTS (SEE NOTE D)				FREQ.	DURATION	ANGLE OF TWIST	HEAT > 90 F	
	START	END	DISTANCE	CLEARANCE (YES/NO)					
DESCRIPTION									
1.									
2.									
3.									

NOTE D. Measure START and END points of lift; DISTANCE is END minus START; CLEARANCE reflects a precision requirement when placing the load.

NOTE E. DURATION refers to continuous time handling task(s) is performed; range is less than 1 hour to >8 hours.

NOTE F. ANGLE OF TWIST measured in degrees off body mid-line.

CHECKLIST III (PUSH/PULL/CARRY TASKS)

TASK	WEIGHT /FORCE	TYPE OF MH (CHECK ONE)			FREQ.	DISTANCE FLOOR-HANDS	DISTANCE OF PUSH, PULL, CARRY	# HANDS (CHECK ONE)	
		PUSH	PULL	CARRY				PER MINUTE	1
DESCRIPTION	SEE NOTE A								
1.									
2.									
3.									

NOTE A. Force of push/pull should be measured using calibrated strain gauge.

Appendix B NIOSH Equation 1991 Draft

1.0 NIOSH Equation 1991 Draft

1.1 Introduction

In 1981, NIOSH incorporated epidemiological, biomechanical, physiological, and psychophysical data into the development of a lifting capacity guideline. NIOSH has recently revised the capacity equation based on additional data in the ergonomics literature and additional perceived needs on the part of users.

The 1991 draft equation (Waters, et al., 1993, 1994) considers the weight of the load, the dimensions of the lift, twisting, frequency, and hand/container coupling. Based on the data input into the equations, a recommended weight limit (RWL) is calculated.

1.2 RWL

The equation for calculating the recommended weight limit (RWL) is based on a multiplicative model that provides a weighting for each task variable. The weightings are expressed as coefficients that are used in the model to decrease the recommended load constant (i.e., maximum load weight to be lifted).

1.3 Equation $RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$

Table B1. Description of NIOSH Equation Multipliers

Multiplier	Multiplier Name	Equation (U.S. Customary Units)
LC	Load Constant	51 lbs
HM	Horizontal Multiplier	$(10 / H)$
VM	Vertical Multiplier	$(1 - (.0075 V-30))$
DM	Distance Multiplier	$(.82 + (1.8/D))$
AM	Asymmetric Multiplier	$(1 - (.0032 \times A))$
FM	Frequency Multiplier	F from Table B3
CM	Coupling Multiplier (hand-to-container)	from Table B4

Note. Refer to Figure B1 on the following page for a depiction of H, V, D.

1.4 Dimensions

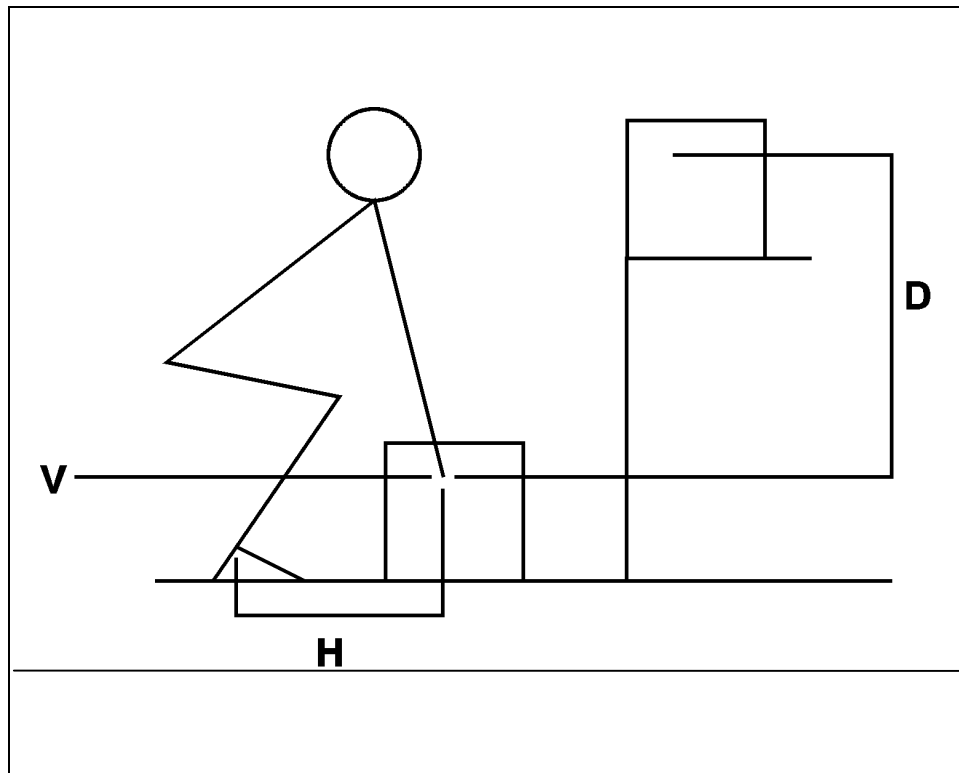


Figure B1. NIOSH (1991) Equation Variables

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1.5 Variables

Table B2. Description of NIOSH 1991 Equation Variables

Variable	Corresponding Measurement	Directions
H	Horizontal location of hands from midpoint between the ankles.	<ul style="list-style-type: none">• Measure at the origin and destination of lift (inches)• See accompanying text on next page• H can range from 10 to 25 inches• If H > 25 inches, HM = 0
V	Vertical location of the hands from the floor.	<ul style="list-style-type: none">• Measure at the origin of the lift (inches)• V can range from 0 to 70 inches• If V > 70 inches, VM = 0
D	Vertical travel distance between the origin and the destination of the lift.	<ul style="list-style-type: none">• D can range from 10 to 70 inches• If D > 70 inches, DM = 0
A	Angle of asymmetry - angular displacement of the load from the sagittal plane.	<ul style="list-style-type: none">• Measure at start and end of lift(degrees)• See accompanying text on next page• A can range from 0 to 135°• If A > 135°, AM = 0
CM	Coupling Multiplier - adjustment based on quality of handles on the object being lifted.	<ul style="list-style-type: none">• see Table B4 for descriptions.
FM	Frequency Multiplier - adjustment based on repetition of handling.	<ul style="list-style-type: none">• see Table B3 and accompanying text for descriptions.

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1.5.1 Horizontal Distance (H)

H is specifically defined as the horizontal distance from the large knuckle at the end of the third finger to the ankle midpoint. H should be measured at both the start and end points of the lift **if** the lift task has a precision component (i.e., there is a need to hold/support the weight of the object at the end point of the lift). The larger H would be used as the input variable in the equation. If the lifting task does not have a precision component, H at the origin of the lift is the selected input variable.

H can be estimated if a measurement of H is not available. H is estimated as follows:

- If $V < 10$ inches: $H = 10 + W/2$
- If $V \geq 10$ inches: $H = 8 + W/2$

where W = object width in the sagittal plane.

1.5.2 Asymmetry (A)

A is measured at the start and end of the lift in terms of degrees from the sagittal plane of the body. A will be measured at the start and end of the lift **if** there is a precision component to the lift (just like H discussed previously), and the larger value of A will be used as the input variable. If there is no precision component, measure A only at the start of the lift.

Note: For a given weight, asymmetric lifting is more likely to cause injury than symmetric lifting and should be avoided.

1.5.3 Frequency Multiplier (FM)

FM is determined based on three input variables: frequency of lift in lifts per minute, vertical start of lift (V), and continuous task duration.

Lifting frequency is defined as the mean number of lifts occurring in a 15 minute period. If the lifting is not continuous, add up the number of lifts occurring in the 15 minute period and divide by 15.

Duration is defined to be: ≤ 1 hour, ≤ 2 hours, or ≤ 8 hours assuming appropriate recovery allowances. NIOSH states that the equation is not appropriate for task durations > 8 hours.

Use the algorithms below to help determine the appropriate duration category for the task:

- Duration ≤ 1 hour: 001 to 1 hour with recovery time at least 1.2X the work time.
- Duration ≤ 2 hour: > 1 hour to 2 hours with recovery time at least .3X the work time.
- Duration ≤ 8 hour: > 2 hours to 8 hours with no recovery time other than scheduled work breaks.

Recovery time is defined as light work in which no lifting occurs. If the recovery criteria specified above are not met, work times are additive.

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**Table B3 NIOSH Equation Table 1991.1;
Frequency Multiplier (FM) Table**

FREQUENCY	WORK DURATION (Continuous)					
	≤ 8 HRS		≤ 2 HRS		≤ 1 HR	
	V<30	V≥30	V<30	V≥30	V<30	V≥30
Lifts/min						
0.2	0.85	0.85	0.95	0.95	1.00	1.00
0.5	0.81	0.81	0.92	0.92	0.97	0.97
1	0.75	0.75	0.88	0.88	0.94	0.94
2	0.65	0.65	0.84	0.84	0.91	0.91
3	0.55	0.55	0.79	0.79	0.88	0.88
4	0.45	0.45	0.72	0.72	0.84	0.84
5	0.35	0.35	0.60	0.60	0.80	0.80
6	0.27	0.27	0.50	0.50	0.75	0.75
7	0.22	0.22	0.42	0.42	0.70	0.70
8	0.18	0.18	0.35	0.35	0.60	0.60
9	0.00	0.15	0.30	0.30	0.52	0.52
10	0.00	0.13	0.26	0.26	0.45	0.45
11	0.00	0.00	0.00	0.23	0.41	0.41
12	0.00	0.00	0.00	0.21	0.37	0.37
13	0.00	0.00	0.00	0.00	0.00	0.34
14	0.00	0.00	0.00	0.00	0.00	0.31
15	0.00	0.00	0.00	0.00	0.00	0.28
>15	0.00	0.00	0.00	0.00	0.00	0.00

- F = Frequency in Lifts / minute
- Values of V are in inches

1.6 Coupling

For the 1991 equation, couplings are classified as "good," "fair," or "poor." If there is any doubt about classifying a particular coupling design, the analyst should select the *more stressful* classification. The three categories are defined in Table B5 and B6. Based on the classification, the appropriate coupling multiplier is used based on Table B4.

Table B4. Coupling Multiplier

Couplin	V < 30"	V ≥ 30"
GOOD	1.00	1.00
FAIR	.95	1.00
POOR	.90	.90

1.6.1 Discussion

In general, a "good" coupling will reduce the maximum grasp forces required and increase the acceptable weight for lifting. On the other hand, a "poor" coupling will generally require higher maximum grasp forces and decrease the acceptable weight for lifting.

Use of cleanroom gloves automatically results in a "poor" coupling categorization.

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1.7 Lifting Index

The lifting index (LI) provides a simple estimate of the hazard of overexertion injury for a manual lifting job.

LI = load weight/RWL

1.8 Validation

Note:The NIOSH 1991 equation *still requires validation*. This means that how well the equation can predict injuries in the workplace still needs to be determined.

Table B5. NIOSH Table 1991.2: Hand-to-Container Coupling Classification

Hand-to-Object Coupling Classification	Part/Container Description	Definition / Reference Note
GOOD	<ul style="list-style-type: none"> containers of optimal design, such as some boxes, crates, etc. 	handles or hand-hold cut-outs of optimal design (see notes 1 to 3 on the following page)
	<ul style="list-style-type: none"> loose parts or irregular objects which are not usually containerized, such as castings, stock, supply materials, etc. 	a comfortable grip in which the hand can be easily wrapped around the object (see note 6 on the following page)
FAIR	<ul style="list-style-type: none"> containers of optimal design 	handles or hand-hold cut-outs of less than optimal design (see notes 1 to 4 on the following page)
	<ul style="list-style-type: none"> containers of optimal design with no handles or hand-hold cut-outs loose parts or irregular objects 	a grip in which the hand can be flexed about 90 degrees (see note 4 on the following page)
POOR	<ul style="list-style-type: none"> containers of less than optimal design with no handles or hand-hold cut-outs loose parts or irregular objects that are bulky or hard to handle 	(see note 5 on the following page)

Table B6. Description of Handle Design Classifications

Note	Feature	Characteristics
1	optimal handle design	<ul style="list-style-type: none"> • .75 - 1.5 inch diameter • >= 4.5 inches in length • 2 inches in clearance • cylindrical shape • smooth, non-slip surface
2	optimal hand-hold cut-out	<ul style="list-style-type: none"> • >= 3 inches in height • 4.5 inches in length • semi-oval shape • >= 2 inches clearance • smooth, non-slip surface • >=0.43 inches in container thickness
3	optimal container design	<ul style="list-style-type: none"> • <= 16 inches frontal length • <= 12 inches in height • smooth, non-slip surface
4	finger hold	<ul style="list-style-type: none"> • a worker should be capable of clamping the fingers at nearly 90 degrees under the container, such as required when lifting a cardboard box from the floor
5	less than optimal container design	<ul style="list-style-type: none"> • >= 16 inches frontal length • >= 12 inches in height • rough or slippery surface • sharp edges • asymmetric center of mass • unstable contents • requires gloves
6	wrist deviation / awkward posture / force	<ul style="list-style-type: none"> • a worker should be able to comfortably wrap the hand around the object without causing excessive wrist deviations or awkward postures • the grip should not require excessive force

2.0 Example of Equation Use

2.1 Description of Lifting Task

A worker is required to install a monitor weighing 35 lb onto a workstation. The monitor is lifted from a cart 36" high; the hands are positioned 3" above the cart when grasping the monitor. The monitor is lifted onto a shelf 43" high (again, the hand position is 3" above the shelf height). The monitor is 18" wide and is held close to the body during the lift. No twisting occurs during the lift. The weight of the monitor is not evenly distributed (it is heavier on the screen side of the monitor); the hands can be clamped underneath the monitor during the lift, and wrist deviation will be exhibited because of the working heights. The monitor is

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handled only once during the day, but the worker performs various other manual handling tasks throughout the day on an infrequent basis.

2.2 Determining the Variables for Inclusion in the Equation

H (Horizontal Location of Object) = 17"

- The monitor width is 18", and $V = 39$ " (see below). Based on this, H is estimated as follows: $H = 8 + 18/2 = 17$.

V (Vertical Start of Lift) = 39"

- Cart is 36" high, and hands are 3" above this point at start of lift.

D (Distance of Lift) = 10"

- The end point of the lift is 46". The minimum value for D is 10"; this is inserted in the equation.

A (Angle of Asymmetry) = 0°

- No twisting occurs during the lift.

CM (Coupling Multiplier) = .90

- The load is asymmetric, and wrist deviation occurs. Based on this, the coupling is defined as "poor," and a CM of .90 is used. Refer to tables B5 and B6.

FM (Frequency Multiplier) = 0.85

- The task was defined as infrequent, so the 0.2 lifts/minute row in Table B3 is referenced. The worker performs handling tasks throughout the day in addition to the task being analyzed, so the 8 hours duration column is used. $V \geq 30$ " as defined previously; therefore, FM is equal to 0.85.

2.4 Calculating the RWL

Once determined, the variables are entered into the equation as follows:

$$RWL = 51 \times (10/17) \times (1 - (.0075|39-30|)) \times (.82 + (1.8/10)) \times (1 - (.0032 \times 0)) \times 0.85 \times 0.90$$

$$RWL = 51 \times 0.59 \times .955 \times 1 \times 1 \times 0.85 \times 0.90$$

Based on the calculated RWL, it is concluded that the actual weight handled by the workers (35 lb) is unacceptable given the task conditions. Ergonomic controls would now be explored.

2.5 Multi-Task Procedure

A procedure is proposed by NIOSH for the analysis of multi-task lifts (e.g., palletizing task where loads are handled to several different levels on pallet). The new method involves the calculation of a composite lifting index (CLI), which represents the collective physical demands of the job.

To compute the CLI, a single task lifting index (STLI) is calculated for each task composing the job. The STLI is computed for each task by dividing the average weight handled for that task by the corresponding RWL for that task (referred to as the STRWL, or single task recommended weight limit).

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The CLI is equal to the sum of the largest STLI, plus the incremental increases in CLI as each subsequent task is added to the job.

2.6 When to Use the Multi-Task Analysis Procedure

The following job characteristics suggest the need for a multi-task analysis as proposed by NIOSH (**Note:** these guidelines are provided by the author; NIOSH does not provide operational guidelines):

- Lifting frequency varies between sessions by more than 2 lifts per minute.
- Vertical start point of lift (V) or distance of lift (D) varies within a session or between sessions by more than 10".
- Horizontal reach distances (H) vary within a session or between sessions by more than 5". This may be driven by different objects being handled or different handling locations (e.g., loading front and opposite sides of a pallet without a turntable attachment).
- Twisting (A) is present in only some lift sessions.
- Different objects handled with different coupling characteristics (CM).

3.0 NIOSH Equation Software

Manual calculation of the CLI can become very cumbersome. There are a number of software packages available that can perform the calculation. A few of them are listed below:

Product Name: LIFTCALC
Safeco Insurance Companies
SAFECO Plaza
Seattle Washington 98185
phone: (206)545-5782

Product Name: LiftLimit
UES Ergonomics Services Group
4401 Dayton-Xenia Road
Dayton, Ohio 45432-1894
phone: (513) 426-6900

APPENDIX C Biomechanical Models

1.0 Introduction

Biomechanics is the study of the effects of internal and external forces on the human body in movement and at rest.

A *biomechanical model* establishes the physical stresses imposed on the musculoskeletal system during manual handling. Both static and dynamic biomechanical models have been developed.

The stresses imposed on the musculoskeletal system

- Include reactive forces and torques on the various joints of the body
- Include compressive and shear forces on the low back
- Serve as the criteria upon which capacity of lift data are based

2.0 Using Biomechanical Models

“Simple” biomechanical models require the user to input data regarding the task (joint angles, vertical start point of lift, etc.), from which the biomechanical model calculates stresses at the joints. More “complex” biomechanical models allow a job to be videotaped and joint angles can be directly entered from the videotape through a digitization process. The advantage of the simpler biomechanical models is their use during the design stage of equipment when a videotape of the task may not exist.

Biomechanical models are typically 2D or 3D. Asymmetric motions and postures and asymmetric loading on the body can not be accommodated through 2D analysis. The use of 3D biomechanical analysis is recommended for tasks with the following characteristics:

- Twisting motions at the trunk.
- Asymmetric arm/leg placement during the lift.
- Asymmetric loading on the body due to an unstable load (e.g., of load not centered).
- Length of object measured in frontal plane of body exceeding 26” (shoulder abduction resulting).

3.0 Guidelines

Biomechanical models provide criteria upon which decisions can be made regarding the acceptability of a handling task. The criteria include strength requirement characteristics of the task (expressed in terms of percentage of the population able to perform the lift), and compressive forces acting on the low back. Table C1 provides some of the commonly used criteria seen with biomechanical analyses.

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Table C1. Description of Biomechanical Model Output Variables

Limit	Characteristic
Strength Design Limit (SDL)	tasks that can be safely performed by 75% of females and 99% of males do not exceed the SDL
Strength Upper Limit (SUL)	tasks exceeding the SUL have strength requirements that can be met by only 25% of males and 1% of females
Back Compression Design Limit (BCDL)	back compression above 770 lbs exceeds the BCDL (up to a threefold increase risk of injury)
Back Compression Upper Limit 2(BCUL)	back compression above 1440 lbs exceeds the BCUL (up to an eightfold increase risk of injury)

4.0 Resources

Listed below are some commercially available biomechanical models:

BCA

1800 Walt Whitman Road, Mellville, NY 11747
516-752-3550

Vision Occupational Health Systems
P.O. Box 3792, Joliet, IL 60434-3792
800-999-1899

University of Michigan Software
Wolverine Tower, Room 2071, 3003 S. State Street, Ann Arbor, MI 48109-1248
313-764-8202

Isotechnologies
328 Elizabeth Brady Road, Hillsborough NC 27278
800-487-5438

The Joyce Institute, a unit of Arthur D. Little, Inc.
1313 Plaza 600 Building, Seattle, Washington 98101
800-645-6045

APPENDIX D Force Data

1.0 Two-Hand Lift/Lower Data

1.1 Introduction

Psychophysical approach: Subject adjusts the weight of the load based on described task parameters and his/her perception of exertion so that the weight of the load does not result in overexertion or exercise fatigue. This information is developed into tables based on task type.

The remaining capacity data presented in this chapter is based on the psychophysical methodology.

1.2 Background

The data appearing in Table III.20 represents the maximum acceptable weight that 75% of the female workforce can be expected to handle **without increased injury risk** under various task conditions. This population was selected based on research indicating that MMH tasks that can accommodate 75% of the female workforce minimizes injury risk for the worker population as a whole. Regulatory guidelines have been established based on this.

The data in this section was adapted from Mital, et al *A Guide to Manual Materials Handling* (1993).

1.3 Using the Tables

The MMH capacity data in the table are determined based on 3 task factors:

- Box Size (29.5, 19, 13 inches). Defined as the width of the box measured out from the body. If the task causes the box to be held away from the body farther than the size of the box itself, the box size selection should be box size + additional horizontal distance. It is acceptable to interpolate data across the box sizes.
- Frequency of Lift (one lift according to 8 hours to 16 lifts according to minute). Interpolation of frequency data is acceptable.
- Range of Lift (floor to 31.5 inches ... 52.0 to 72.0 inches). The ranges selected in the tables approximate significant body landmarks: 31.5 = knuckle height, 52.0 = shoulder height, 72.0 = overhead reach. Use the range of lift that most closely approximates the lifting range of the task being analyzed.

1.3.1 Guidelines

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Table III.20. Recommended Weight of Lift [lb] for Two-Handed Symmetrical Lifting for 8H.

Frequency of Lift							
Box Size (inch)	1/8 h	1/30 min	1/5 min	1/min	4/min	8/min	
Floor to 31.5 inch height							
29.5	30.8	24.2	21.5	19.8	19.8	17.6	
19	35.2	26.4	22.0	22.0	19.8	17.6	
13	41.8	30.8	28.6	26.4	24.2	19.8	
Floor to 52.0 inch height							
29.5	26.4	19.8	17.6	16.5	16.5	14.3	
19	28.6	22.0	17.6	17.6	16.5	14.3	
13	35.2	25.3	24.2	22.0	19.8	17.6	
Floor to 72.0 inch height							
29.5	24.2	17.6	15.4	15.4	15.4	13.2	
19	26.4	19.8	15.4	15.4	15.4	13.2	
13	30.8	22.0	22.0	19.8	17.6	15.4	
31.5 inch to 52.0 inch height							
29.5	33.0	28.6	26.4	24.2	19.8	15.4	
19	33.0	28.6	26.4	24.2	19.8	15.4	
13	37.4	30.8	28.6	26.4	24.2	18.7	
31.5 inch to 72.0 inch height							
29.5	28.6	24.2	23.1	20.9	17.6	13.2	
19	28.6	24.2	23.1	20.9	17.6	13.2	
13	33.0	26.4	24.2	23.1	22.0	16.5	
52.0 inch to 72.0 inch height							
29.5	24.2	19.8	19.8	17.6	17.6	13.2	
19	26.4	22.0	19.8	19.8	17.6	13.2	
13	30.8	26.4	24.2	24.2	19.8	15.4	

1.4 Example

An example is presented below to help you in using Table III.20 on the preceding page.

You are being asked to design a work area. At its initial design stage, the task requires the following:

1. WEIGHT: Lifting 40 lb bags
2. RANGE OF LIFT: Bags lifted from a 36" up to a 48" height
3. FREQUENCY OF LIFT: Bags are lifted once according to minute
4. BOX SIZE (INCHES): The width of the box measured out from the body is 18". It is assumed that the box is held close to the body during the lift.

Based on the above information, Table III.20 can tell you whether the task as presently designed is acceptable, and, if not acceptable, what changes can be made to make the task acceptable.

- Step 1. Locate the appropriate RANGE OF LIFT section in Table III.20. For the defined task, the section "**31.5 in. to 52.0 in. height**" most closely approximates the task you are evaluating.

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- Step 2. Locate the appropriate FREQUENCY OF LIFT column in the table. For the defined task, you will select the column that says "1/min".
- Step 3. Locate the appropriate BOX SIZE row in the RANGE OF LIFT section you identified in step 1. The appropriate box size selection would be "19", given how close it is to the actual bag size. If the actual bag size fell more between 19 and 13, interpolation of values would be acceptable.
- Step 4. Determine the RECOMMENDED WEIGHT OF LIFT. For the defined task, the recommended design weight is "24.2" lb.
- Step 5. Draw appropriate conclusions and take necessary action. The recommended weight of lift is less than the 40 lb proposed weight. The task is judged to be unacceptable. As a designer, your next step is to look for engineering controls to make it acceptable.

1.5 Lift vs. Lower

Some research suggests that people have an increased capacity when lowering vs. lifting (about 10% increased capacity). More conservatively, some researchers argue that lifting and lowering are identical in terms of physical stresses on the low back. For purposes of establishing design guidelines, we will take the more conservative route and assume that lifting and lowering are essentially identical. This means that, **for a lowering task, use the lifting capacity data given in Table III.20**. The "range of lift" variables would simply be used in reverse (e.g. lower from 31.5 inches to floor).

1.6 Combination Tasks

Very often the lifting job will be composed of a combination of lifting tasks. Palletizing operations are a good example of this. The palletizing task can consist of lifts and lowers representing several different handling ranges. To evaluate a combination task:

- Step 1. Go to Table III.20 and determine the handling ranges that make up the task based on the stated frequency of lift and box size.
- Step 2. Select the handling range that has the lowest associated MMH capacity. This is the "weakest link" in the task.
- Step 3. To establish the design weight, use the lifting frequency for the task **as a whole**, for the weakest link handling range.

2.0 Adjustment Factors for Lifting Capacity Data

2.1 Background

The data in Table III.20 does not capture every possible working condition scenario that occurs in the work environment. To make the data in Table III.20 more useable, adjustment factors are presented in this section, which will allow the designer to better fine-tune the design weight. The adjustment factors are all multipliers that would be multiplied to the value obtained in Table III.20.

The data in this section was adapted from Mital, et al *A Guide to Manual Materials Handling* (1993).

2.2 Guidelines

2.2.1 Working Duration (hours) Multiplier

Not all MH tasks are performed across the entire duration of the shift, and shift lengths differ. Use the multipliers below to adjust for this. Interpolate as required.

Table III.21. Working Duration Multipliers

Duration (hours)			
1	4	8	12
1.140	1.080	1.000	0.920

Note. The working duration multiplier should **not** be used when dealing with a lift/lower that occurs only once in 8 hours (first frequency of lift column in Table III.20).

2.2.2 Limited Headroom Multiplier

If the work environment does not permit the worker to assume a fully upright posture during handling, use the limited headroom multipliers in the table below. Interpolate as required. The figure at the bottom of the page depicts limited headroom as defined by the multipliers. Note that the limited headroom multiplier would be applied only for situations where the lift would permit the worker to stand upright if there was not a headroom restriction.

Table III.22. Limited Headroom Multiplier

Stature	Fully Upright	95% Upright	90% Upright	85% Upright	80% Upright
Multiplier	1.00	0.60	0.40	0.38	0.36

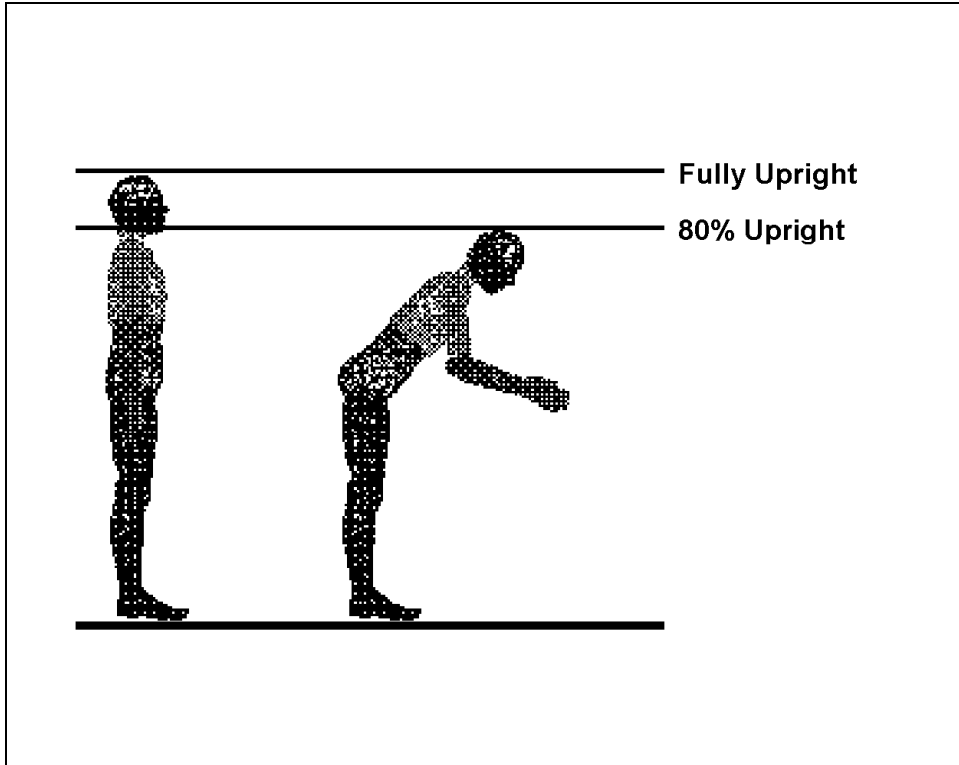


Figure III.13. Depiction of Headroom

2.2.3 Asymmetrical Lifting (Twisting) Multiplier

Table III.20 assumes the lift is performed in the sagittal plane, which means no twisting occurs. If twisting occurs, use the adjustment factors presented in the table below (see the figure below for a description). The following assumptions/constraints are associated with the use of this table:

- Angle of twist is measured based on a straight line drawn from between the ankles to the location of the hands on the container. Both start and end points of the lift must be considered.
- Interpolate for intermediate values.
- The 30–90 corrections assume the feet do not move and may be too high if the feet move.
- The "Above 90" correction factor assumes people move their feet.

Table III.25. Twisting Multiplier

Angle of turn (deg)	Multiplier
0-30	1.0000
30-60	0.924
60-90	0.848
Above 90	0.800

Note: Twisting is extremely stressful on the lower back and should be avoided whenever designing a work area or equipment.

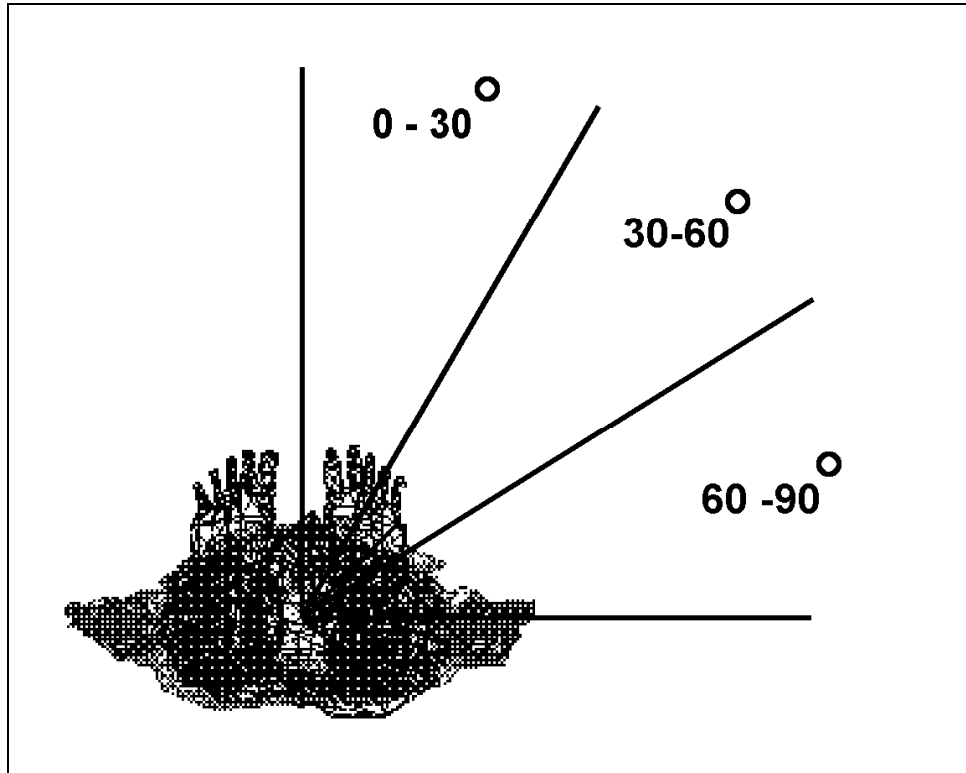


Figure III.14. Angle of Twist

2.2.4 Couplings (Handles) Multiplier

Table III.26. Couplings Multiplier

Couplings (Handles)	Multiplier
Good and comfortable handles/firm holds to initiate the lift	1.000
Poor quality handles/limited or slippery hold	0.925
No handles/holds to initiate the lift	0.850

2.2.5 Load Placement Clearance Multiplier

If a load has to be positioned in a location where the clearance around the object is limited, a precision component is added to the task that effectively reduces capacity. An example would be placing an object into a designated slot. When using the table below, a clearance of (for example) 0.6" refers to the clearance on both sides of the object being handled. Interpolate for intermediate values.

Table III.27. Load Placement Clearance Multiplier

Load Clearance (inches)	Multiplier
Unlimited to 1.2 inches	1.00
0.6 inches	0.91
0.1 inches	0.87

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2.2.6 Load Asymmetry (e.g., shift sideways in the frontal plane) Multiplier

Table III.28 provides adjustment for load asymmetry away from the body (container width). The table below allows users to adjust for loads where the weight of load is concentrated sideways in the box (i.e., differential load across the two hands). To use the table below, the center of gravity shift is measured from the physical midpoint of the object being handled. Interpolate for intermediate values.

Table III.28. Load Asymmetry Multiplier

Load asymmetry (inches)	Multiplier
0	1.00
3.9	0.96
7.9	0.89
11.8	0.84

3.0 One Hand Lift Data

3.1 Background

Relatively little data have been collected in the area of one-hand lifts. One of the most comprehensive sources for one-hand lift data is Davis and Stubbs (1980), which is presented on the next two pages.

3.2 Using the Tables

The one-hand lift forces take into account posture of the worker (stand/squat/sit/kneel), reach distance (acromial-grip distance; see figure III.15 below), handling frequency (F greater than or less than 1 lift according to minute) and age.

The forces listed in the tables can be applied when the arm is in front of the body in the horizontal plane of the shoulder and when the arm is held to the side of the body.

3.3 Guidelines

The forces in the table are for the preferred hand; for the non-dominant hand reduce the tabled values by 10%.

The data are for the 50th percentile male only; for females reduce the tabled values by 35%. Please note that this adjustment factor is based on generic differences between males and females in upper body strength. There is no available one-hand lift data for females comparable to the Davis and Stubbs data.

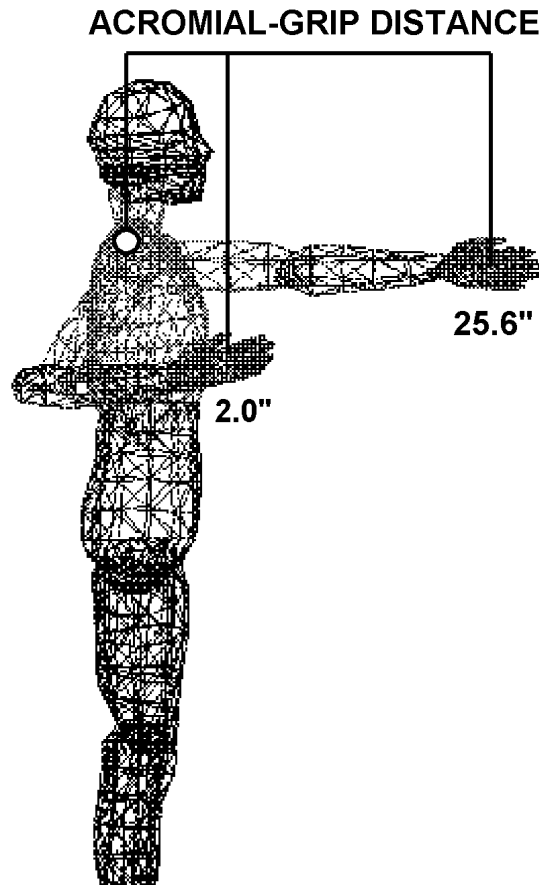


Figure III.15.Acromial Grip Distance

Note: See Table III.29 below.

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**Table III.29. One Hand Lift Data for Males, Infrequent Lifts
(F < 1 lift according to minute)**

Lifting forces (lbs) for one-handed lift with arm in the front of the body in the horizontal plane of the shoulder (Davis and Stubbs, 1980)

Position	Acromial-grip Distance (inches)*	Age (years)		
		Up to 40	41-50	51-60
Standing/Squatting	25.6	22.0	22.0	19.8
	23.6	26.4	26.4	24.2
	19.7	33.0	33.0	28.6
	13.8	44.0	44.0	39.6
	7.9	55.0	55.0	48.4
	2.0	66.0	66.0	59.4
Sitting	25.6	22.0	19.8	17.6
	19.7	33.0	30.8	26.4
	15.7	44.0	39.6	35.2
	11.8	55.0	50.6	44.0
	5.9	66.0	59.4	52.8
	2.0	77.0	70.4	61.6
Kneeling	25.6	26.4	22.0	19.8
	23.6	33.0	26.4	24.2
	21.6	37.4	28.6	26.4
	11.8	44.0	35.2	33.0
	9.8	55.0	44.0	39.6
	5.9	66.0	50.6	48.4

Note: Acromial-Grip distance is measured from shoulder joint (acromial process) to grip

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**Table III.29., cont.: One Hand Lift Data, Frequent Lifts
(F > 1 according to minute)**

Position	Acromial-grip Distance (inches)*	Age (years)		
		Up to 40	41-50	51-60
Standing/Squatting	25.6	15.4	15.4	13.9
	23.6	18.5	18.5	16.9
	19.7	23.1	23.1	20.0
	13.8	30.8	30.8	27.7
	7.9	38.5	38.5	33.9
	2.0	46.2	46.2	41.6
Sitting	25.6	15.4	13.9	12.3
	19.7	23.1	21.8	18.5
	15.7	30.8	27.7	24.6
	11.8	38.5	35.4	30.8
	5.9	46.2	41.6	37.0
	2.0	53.9	49.3	43.1
Kneeling	25.6	18.5	15.4	13.9
	23.6	23.1	18.5	16.9
	21.6	26.2	20.0	18.5
	11.8	30.8	24.6	23.1
	9.8	38.5	30.8	27.7
	5.9	46.2	35.4	33.9

Note: Acromial-Grip distance is measured from shoulder joint (acromial process) to grip

4.0 Two Hand Carry Data

4.1 Using the Table

The data presented in Table III.30 represents the weight of carry acceptable to 75% of the female industrial population. The variables contained in the table include the following:

- Distance of carry (7, 14, 28 feet)
- Frequency of carry (ranging from once according to 8 hours, to 1 carry according to 6 seconds)
- Floor-to-hand distance (knuckle level, elbow level; see figure on next page for description).

4.1.2 Source

The MH capacity data for carry tasks are presented in Table III.30 (Snook and Ciriello, 1991) and Figure III.16.

4.2 Guidelines

Table III.30 Maximum Acceptable Weights of Carry (lbs)

Floor-to-Hand Height	Carry Distance	Frequency: One Carry Every...						
		6 sec	12 sec	1 min	2 min	5 min	30 min	8 hrs
Elbow Level	7 ft	29	31	33	33	35	35	46
	14 ft	24	26	33	33	35	35	46
	28 ft	24	26	31	31	31	31	42
Knuckle Level	7 ft	33	37	40	40	42	42	55
	14 ft	24	29	35	35	37	37	51
	28 ft	24	29	35	35	37	37	51

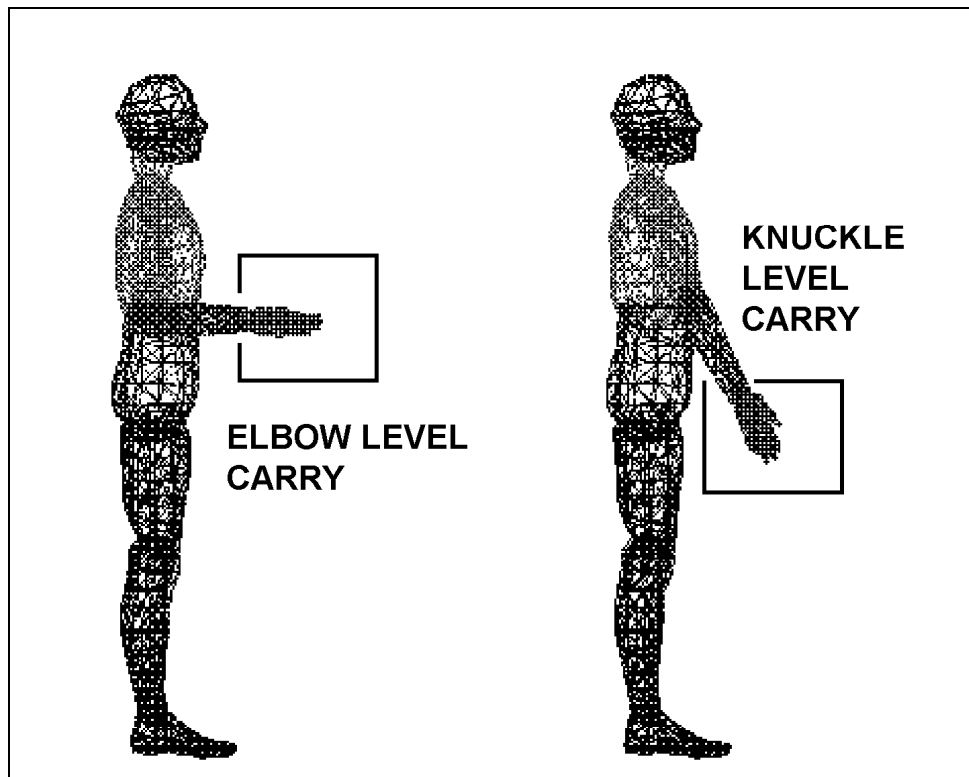


Figure III.16 Elbow and Knuckle Level Carry

5.0 One Hand Carry Data

5.1 Using the Table

Table III.31 presents one-hand carry data based on 75% of the female population.

- The data are for the dominant (stronger) hand; if the non-dominant hand is used, reduce the values in Table III.31 by 10%.
- The carry is performed with the hand at the side (e.g., a suitcase carry).

Table III.31 allows one hand carry weights to be determined based on frequency of handling and carry distance. For carry distance, interpolation of values is acceptable.

5.2 Guidelines

Table III.31. Recommended Weights (lb) for One-hand Carry Tasks, Mital, et al, 1993.

Carry Distance (feet)	Frequency: One Carry Every	
	less than once according to minute	greater than once according to minute
100	15.4	10.8
200	14.3	10.0
300	13.2	9.2

6.0 Two-Hand Push Data

6.1 Using the Table

Table III.32 presents the maximum **initial and sustained** forces that can be exerted by 75% of the female population based on the task characteristics. The variables in the table are described below:

- Push distance (7 feet ... 200 feet)
- Frequency of push (once every 6 seconds to once in an 8 hour period)
- Floor to hand height (knee level, elbow level, shoulder level). For pushing and pulling tasks, the position of the hands during the force exertion will have a significant effect on the amount of force that can be exerted.
- Initial vs. Sustained Forces. Each table cell gives two values. The first number is the maximum acceptable **initial** push force that can be exerted. The number in parentheses is the **sustained** push force that can be acceptably maintained across the distance/duration of the push. Initial force is defined as the force required to get the object in motion; sustained force is defined as the force required to keep the object in motion.
- Empty cells indicate that the push distance cannot be accomplished for the push frequency.

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6.2 Guidelines

Table III.32. Maximum Acceptable Two-Hand Push Forces (lb) Initial (Sustained) Forces, (Snook and Ciriello, 1991; Mital, et. al., 1993).

Floor-to-Hand Height	Push Distance (feet)	Frequency: One Push Every ...						
		6 sec	12 sec	1 min	2 min	5 min	30 min	8 hr
Shoulder Level	7	37(18)	40(22)	46(31)	48(31)	53(35)	55(37)	59(46)
	25	X	X	42(24)	44(24)	48(26)	51(29)	53(35)
	50	X	X	37(18)	37(20)	42(22)	44(24)	46(29)
	100	X	X	33(13)	35(18)	37(20)	42(20)	46(26)
	150	X	X	33(13)	35(18)	37(18)	42(18)	46(24)
	200	X	X	X	31(9)	33(13)	37(13)	42(20)
Elbow Level	7	37(15)	40(20)	46(29)	48(29)	53(33)	55(35)	59(42)
	25	X	X	44(24)	44(24)	48(29)	51(29)	55(37)
	50	X	X	37(18)	37(22)	42(24)	44(24)	46(31)
	100	X	X	33(15)	35(20)	40(20)	42(22)	46(29)
	150	X	X	33(13)	35(18)	40(18)	42(20)	46(26)
	200	X	X	X	33(9)	35(13)	37(15)	42(20)
Knee Level	7	31(13)	33(18)	37(24)	37(24)	42(29)	44(31)	46(37)
	25	X	X	37(22)	37(24)	42(26)	44(26)	46(33)
	50	X	X	31(18)	33(20)	35(22)	37(22)	40(29)
	100	X	X	29(13)	31(18)	33(18)	35(20)	40(26)
	150	X	X	29(13)	31(15)	33(18)	35(18)	40(24)
	200	X	X	X	26(9)	29(13)	31(13)	35(18)
	Note: An "X" in a cell indicates the push distance cannot be performed for the push frequency							

7.0 Two-Hand Pull Data

7.1 Using the Table

Table III.33 presents the maximum **initial and sustained** forces that can be exerted by 75% of the female population based on the task characteristics. The variables in the table are described below:

- Pull distance (7 feet ... 200 feet)
- Frequency of pull (once every 6 seconds in an 8 hour period)

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- Floor to hand height (knee level, elbow level, shoulder level). For pushing and pulling tasks, the position of the hands during the force exertion will have a significant effect on the amount of force that can be exerted.
- Initial vs. sustained forces. Each table cell gives two values. The first number is the maximum acceptable **initial** pull force that can be exerted. The number in parentheses is the **sustained** pull force that can be acceptably maintained across the distance/duration of the pull. Initial force is defined as the force required to get the object in motion; sustained force is defined as the force required to keep the object in motion.
- Empty cells indicate that the pull distance cannot be accomplished for the pull frequency.

7.2 Guidelines

Table III.33. Maximum Acceptable Two-Hand Pull Forces (lb) Initial (Sustained) Forces (Snook and Ciriello, 1991; Mital, et. al., 1993)

Floor-to-Hand Height	Pull Distance (feet)	Frequency: One Pull Every...						
		6 sec	12 sec	1 min	2 min	5 min	30 min	8 hr
Shoulder Level	7	35(15)	42(22)	44(29)	46(31)	53(33)	55(35)	57(44)
	25	X	X	42(26)	42(26)	46(29)	48(31)	53(40)
	50	X	X	35(20)	35(22)	40(24)	42(26)	44(33)
	100	X	X	31(15)	35(20)	37(22)	40(22)	44(31)
	150	X	X	31(13)	35(20)	37(20)	40(20)	44(26)
	200	X	X	X	31(13)	33(15)	35(15)	40(22)
Elbow Level	7	35(15)	42(22)	46(29)	48(29)	55(33)	57(35)	59(42)
	25	X	X	42(24)	44(26)	48(29)	51(31)	55(37)
	50	X	X	37(20)	37(22)	42(24)	44(26)	46(31)
	100	X	X	33(15)	35(20)	40(20)	42(22)	46(29)
	150	X	X	33(13)	35(18)	40(20)	42(20)	46(26)
	200	X	X	X	33(11)	35(15)	37(15)	42(20)
Knee Level	7	37(13)	44(20)	48(26)	51(26)	57(29)	59(31)	62(40)
	25	X	X	44(24)	46(24)	51(26)	53(29)	57(35)
	50	X	X	37(18)	40(20)	44(22)	46(24)	48(29)
	100	X	X	35(13)	37(18)	40(20)	44(20)	48(26)
	150	X	X	35(13)	37(18)	40(18)	44(18)	48(24)
	200	X	X	X	33(11)	35(13)	40(13)	44(20)
Note: An "X" in a cell indicates the pull distance cannot be performed for the push frequency								

8.0 One Hand Push/Pull Forces

8.1 Background

The data in this section was adapted from Mital, et al, *A Guide to Manual Materials Handling* (1993)

The capacity data presented below assume

- Worker is in standing posture
- Dominant (stronger) hand is being used. If the non-dominant hand is being used, consider reducing the above values by 10%.

8.2 Guidelines

8.2.1 One Hand Push

- If the push force is exerted less than once per minute, the recommended value is 24 lb.
- If the push force is exerted more frequently than once per minute, the recommended value is 16.5 lb.

8.2.2 One Hand Pull

- If the pull force is exerted less than once per minute, the recommended value is 22 lb.
- If the pull force is exerted more frequently than once per minute, the recommended value is 15 lb.

9.0 MMH Data for Awkward Postures

9.1 Background

The data described in this section was compiled by Smith, et al (1992) based on several years of research with (primarily) the U.S. Air Force. The data represent several different experiments. Each experiment and the MH data are described separately.

Note: The data that appear in this section can be extremely useful when evaluating and designing maintenance tasks, since awkward postures occur so routinely during maintenance activities.

9.2 Using the Tables

9.2.1 Kneeling Tasks

The recommended weight of lift is based on the lifting capacity of 75% of the female population. Descriptions of the kneeling tasks are presented below, followed by Table III.34 summarizing the recommended weight of lift for the tasks.

Task Description

1. **Lift kneeling on two knees floor to 24"**: The subject was positioned on both knees between the box and the shelf. The subject twisted 90° to

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the left, picked up the box, twisted 180° to the right, and lifted the box onto the shelf. Frequency of lift was 6 lifts/minute.

2. **Lift kneeling on one knee floor to 24"**: The subject was positioned in a kneeling posture (left knee on the floor) between the box and the shelf. The subject twisted 90° to the left, picked up the box, twisted 180° to the right, and lifted the box onto the shelf. Frequency of lift was 6 lifts/minute.
3. **Horizontal transfer kneeling on two knees**: Subject knelt on both knees, twisted 90° to the left, picked the box up from the floor, twisted 180° to the right, and lowered the box back onto the floor. Frequency of lift was 6 lifts/minute.
4. **Lower kneeling on two knees 23.6" to floor**: Reverse of #1.
5. **Kneeling one knee lifts using two hands**: The subject was instructed to kneel with the left knee on the floor and the right knee up. The subject bent over, picked the box up off the floor, lifted the box and placed it on a shelf that was adjusted in height to 35, 60, and 85% of the subject's kneeling vertical reach. The subject was required to place precisely the box on the shelf without touching the clearance guides. The box size was 24 x 12 x 6", and the lift was repeated for each of the three possible box orientations. Frequency of lift was one lift in 8 hours.
6. **Kneeling two knee lifts using two hands**: The subject was instructed to kneel with both the knees on the floor. The box was located in front of the subject with the box as close to the knees as was comfortable to the subject. The subject bent over, picked the box up off the floor, lifted the box, and placed it on a shelf that was adjusted in height to 35, 60, and 85% of the subject's kneeling vertical reach. The subject was required to place precisely the box on the shelf without touching the clearance guides. The box size was 24 x 12 x 6", and the lift was repeated for each of the three possible box orientations. Frequency of lift was one lift in 8 hours.
7. **Kneeling one knee lifts using one hand**: The subject was instructed to kneel with the left knee on the floor and the right knee up. The subject bent over, grasped the handle of the box with one hand, picked the box up off the floor, lifted the box, and placed it on a shelf that was adjusted in height to 35, 60, and 85% of the subject's kneeling vertical reach. The subject was required to place precisely the box on the shelf without touching the clearance guides. Frequency of lift was one lift in 8 hours.
8. **Kneeling two knee lifts using one hand**: The subject was instructed to kneel with both the knees on the floor. The subject bent over, grasped the handle of the box with one hand, picked the box up off the floor, lifted the box, and placed it on a shelf that was adjusted in height to 35, 60, and 85% of the subject's kneeling vertical reach. The subject was required to precisely place the box on the shelf without touching the clearance guides. Frequency of lift was one lift in 8 hours.

9.2.2 Guidelines

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**Table III.34. Recommended Weight of Lifts for Kneeling Tasks
(tasks described in detail in body of text; recommended weight of lift based on 75% female population) (Smith, et al. 1992)**

Task Description	Recommended Weight of Lift (lb)
1. Lift kneeling on 2 knees floor to 24" *	17.2
2. Lift kneeling on 1 knee floor to 24" *	17.0
3. Horizontal transfer kneeling on 2 knees *	17.9
4. Lower kneeling on 2 knees 24" to floor *	17.9
5. Kneeling 1 knee, 2 hands lift floor to:	
35% Fn Rch (flat container 24x12x6") **	44.0
60% Fn Rch	35.6
85% Fn Rch	30.5
35% Fn Rch (vertical container 12x6x24") **	44.0
60% Fn Rch	35.6
85% Fn Rch	26.9
35% Fn Rch (deep container 6x25x12")**	44.0
60% Fn Rch	40.5
85% Fn Rch	30.5
6. Kneeling 2 knees, 2 hands lift floor to:	
35% Fn Rch (flat container 24x12x6") **	44.0
60% Fn Rch	35.2
85% Fn Rch	30.5
35% Fn Rch (vertical container 12x6x24") **	40.5
60% Fn Rch	35.6
85% Fn Rch	27.3
35% Fn Rch (deep container 6x24x12") **	44.0
60% Fn Rch	40.5
85% Fn Rch	31.9
7. Kneeling 1 knee, 1 hand lift floor to:	
35% Fn Rch	13.0
60% Fn Rch	13.0
85% Fn Rch	13.0
8. Kneeling 2 knees, 1 hand lift floor to:	
35% Fn Rch	13.0
60% Fn Rch	13.0
85% Fn Rch	13.0

Note: frequency = 6 lifts/minute**frequency = 1 lift/8 hoursNote.Fn Rch = Functional Reach

9.3 Using the Table

9.3.1 Seated Tasks

The recommended weight of lift is based on the lifting capacity of 75% of the female population. Descriptions of the sitting tasks are presented below, followed by Table III.35 summarizing the recommended weight of lift for the tasks.

Task Description and Recommended Weight of Lift

1. **Horizontal transfer seated:** The subjects sat on the floor with legs extended straight in front of them, twisted 90° to the left, picked the box up off the floor, twisted 180° to the right, and placed the box back onto the floor. Frequency of handling was 6 lifts per minute.

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2. **Sitting lifts using 2 hands:** The subject was instructed to sit on a 12" high surface. The subject bent over, picked the box up off the floor, lifted the box, and placed it on a shelf that was adjusted 35, 60, and 85% of the subject's sitting vertical reach. The subject was required to place precisely the box on the shelf without touching the clearance guides. The box size was 24 x 12 x 6", and the lift was repeated for each of the three possible box orientations. Frequency of lift was one lift in 8 hours.
3. **Sitting lifts using 1 hand:** The subject was instructed to sit on a 12" high surface. The subject bent over, grasped the handle of the box with one hand, picked the box up off the floor, lifted the box, and placed it on a shelf that was adjusted 35, 60, and 85% of the subject's sitting vertical reach. The subject was required to place precisely the box on the shelf without touching the clearance guides. Frequency of lift was one lift in 8 hours.

9.4 Guidelines

**Table III.35. Recommended Weight of Lifts for Sitting Tasks
(tasks described in detail in body of text; recommended weight
of lift based on 75% female population) (Smith, et al. 1992)**

Task Description	Recommended Weight of Lift (lb)
1. Horizontal transfer seated *	16.6
2. Sitting 2 hands lift floor to:	
35% Fn Rch (flat container 24x12x6") **	44.0
60% Fn Rch	35.6
85% Fn Rch	30.5
35% Fn Rch (vertical container 12x6x24") **	40.5
60% Fn Rch	30.5
85% Fn Rch	24.4
35% Fn Rch (deep container 6x24x12") **	40.5
60% Fn Rch	35.6
85% Fn Rch	30.5
3. Sitting 1 hand lift floor to 35%, 60%, or 85% Fn Rch**	13.0

Note: *frequency = 6 lifts/minute

**frequency = 1 lift/8 hours

Note. Fn Rch = Functional Reach

9.4.1 Lying Tasks

The recommended weight of lift is based on the lifting capacity of 75% of the female population. Descriptions of the lying tasks are presented below, followed by Table III.36 summarizing the recommended weight of lift for the tasks.

Task Description and Recommended Weight of Lift

1. **Lying face down, lift with one hand:** The subject lay prone on a 48" high platform and extended his or her arm through a 14 x 14" opening in the platform. With the arm fully extended, the subject grasped the pipe handle of a 10 x 10" box (12" high) and lifted it through the opening and placed it on the platform. The container with the pipe handle was similar

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to a small tool box or tray with a handle extending the full width of the container. The subject was allowed to prop up his or her body using the forearms. The task was repeated for both the left and right arm. Frequency of lift was one lift in 8 hours.

2. **One hand lying side lift:** The subject was instructed to lay on his or her left side on the floor with the body parallel to a 10" high platform. The distance between the platform and the subject was defined as the functional reach of the subject. Using the right hand, the subject grasped the handle of a 14 x 8 x 5" box and lifted it onto the platform. Two starting positions for the box were used, designated as close and far. For the close position, the rear edge of the box was placed against the body of the subject. For the far position, the subject extended his or her right hand so that the radiale (elbow) could be located. The box was positioned such that the rear edge of the box was in line with the radiale. Frequency of lift was one lift in 8 hours.
3. **Two hands lying side lift:** The subject was instructed to lie on his or her left side with the body parallel to a 10" high platform. The distance between the platform and the subject was defined as the functional reach of the subject. Using both hands, the subject grasped an 8 x 8 x 8" box and lifted it onto the platform. Two starting positions for the box were used, designated as close and far. For the close position, the rear edge of the box was placed against the body of the subject. For the far position, the subject extended his or her right hand so that the radiale (elbow) could be located. The box was positioned such that the rear edge of the box was in line with the radiale. Frequency of lift was one lift in 8 hours.
4. **One hand lying face up lift:** The subject was asked to lie flat on his or her back on an exercise bench. The subject placed the palm of his or her hand on the bottom of a 10 x 10 X 8" box suspended over the right shoulder of the subject. The subject lifted the box until the arm was fully extended. Two starting positions for the box were used, designated as close and far. For the close position, the box was suspended approximately 4" above the subject's right shoulder. For the far position, the subject extended the right arm so that the radiale (elbow) could be located. The box was suspended such that the bottom of the box was at the height of the radiale. Frequency of lift was one lift in 8 hours.
5. **Two hand and lying face up lift:** The subject was asked to lie flat on his or her back on an exercise bench. The subject placed his or her hands on the bottom of a 18 x 12 X 10" box suspended over the subject's chest. The subject lifted the box until the arms were fully extended. Two starting positions for the box were used, designated as close and far. For the close position, the box was suspended as close to the subject's chest as possible, still allowing the subject to grasp the bottom edge of the box. For the far position, the subject extended the right arm so that the radiale (elbow) could be located. The box was suspended such that the bottom of the box was at the height of the radiale. Frequency of lift was one lift in 8 hours.

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**Table III.36. Recommended Weight of Lifts for Lying Tasks
(tasks described in detail in body of text; recommended weight
of lift based on 75% female population) (Smith, et al. 1992)**

Task Description		Recommended Weight of Lift (lb)
1.	Lying face down, lift with one hand:	
	lift with left hand	16.8
	lift with right hand	16.8
2.	One hand lying side lift:	
	close	12.1
	far	12.8
3.	Two hands lying side lift:	
	close	14.8
	far	16.8
4.	One hand lying face up lift:	
	close	16.8
	far	23.3
5.	Two hands lying face up lift:	
	close	46.8
	far	58.5

Note: frequency for all tasks = 1 lift/8 hours

APPENDIX E Clothed Access Dimensions

This table contains data to be used with **S8-95** Table R2-6.

Finger Access	FAB Glove		Work Glove/Acid Glove	
	HxW (inches)	D (inches)	HxW	D
Finger Access		1.5		2.5
Flat Hand to wrist access	4x5	5	5x6	6
Fist to wrist access	5.5x4	5.5	6.5x5	6.5
Hand to Wrist Using:				
screwdriver	5.5x5.1	5.5	6.5x6.1	6.5
pliers	5.7x5	5.7	6.7x6	6.7
wrench	11.1x8.5	11.1	12.1x9.5	12.1
CLEANROOM ATTIRE WORN				
One Arm Reach to:				
elbow	5.2x5.2	5.2		
shoulder	5.7x5.7	5.7		
2 Hand Reach to:				
wrist	5x8			
shoulder	19.5x5			

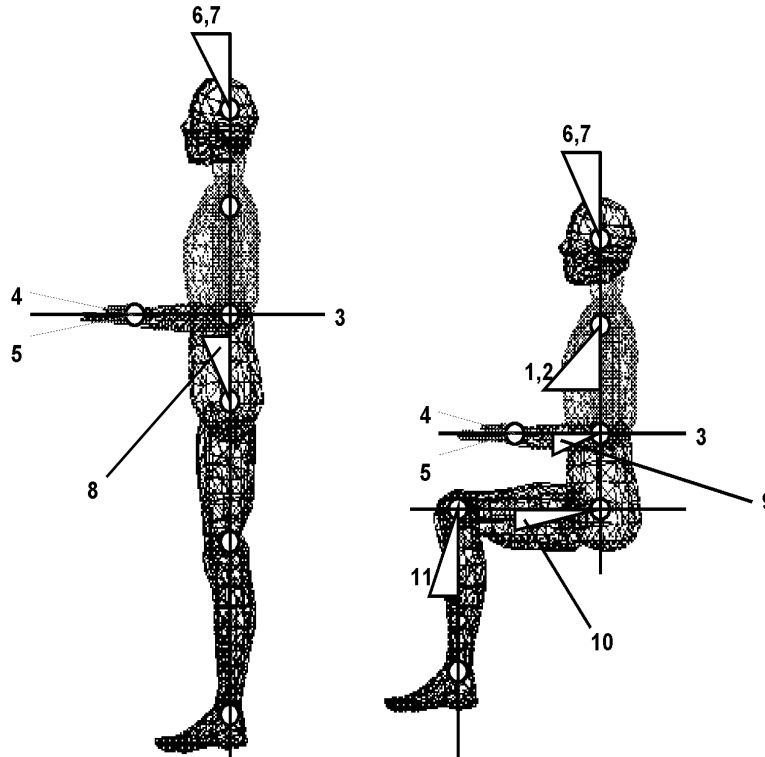
Note: These dimensions do not necessarily allow for visibility of the work.

APPENDIX F Handle Design Guideline

Sources: MIT Humanscale 5a, Ergonomic Design for People at Work. Eastman Kodak, 1986, Intel Ergonomics Guidelines, 1994.

TYPE	MINIMUM	MAXIMUM
Cyndrical handle	0.75", diameter	1.5", diameter
Plier handle	1.5, spread-closed	3.5" spread-open
Pistol grip handle	1.5", diameter	2.5", diameter
Enclosed handle-e.g., Suitcase handle	.25 handle diameter lift weight < 15 lbs .5 handle diameter, lift weight < 20 lbs .75 handle diameter, lift weight < 40 lbs 5" inside length x 2.5" width	1.0", diameter
Finger pull handles	1" dia. .75" depth .75" lip	1.5" dia 2." depth 2." lip

APPENDIX G AWKWARD POSTURES



BODY PART	AWKWARD POSTURE (angle in degrees)	COMMENTS
UPPER EXTREMITIES:		
SHOULDER FLEXION (1)*	> 45	Shoulder Flexion defined as reach in front of body mid-line
SHOULDER EXTENSION (2)	> 0	Shoulder Extension defined as reach behind body mid-line
SHOULDER ABDUCTION	> 45	NOT SHOWN. Abduction is movement of elbow away from body
FOREARM ROTATION	NA **	NOT SHOWN. Forearm rotation is rotational movement at elbow (e.g. turning knob)
FOREARM PRONATION	NA	NOT SHOWN. Pronation means "palm facing down". Note that forearm pronation is less stressful than either forearm rotation or supination
FOREARM SUPINATION (3)	NA	Supination means "palm facing up" (note that forearm is supinated in figure)
WRIST FLEXION (4)	> 10	Flexion defined as closing (reducing) the angle of the wrist
WRIST EXTENSION (5)	> 15	Extension defined as opening (increasing) the angle of the wrist
WRIST ULNAR / RADIAL DEVIATION	> 10	Deviation refers to side to side movements of the wrist

* Number in parentheses refers to number in drawing at top of page

** Angle in degrees not available

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BODY PART	AWKWARD POSTURE (angle in degrees)	COMMENTS
UPPER EXTREMITIES (continued from previous page):		
NECK FLEXION (6)	> 20	Neck flexion refers to (e.g.) looking down by bending (flexing) the neck
NECK EXTENSION (7)	> 0	Neck extension refers to (e.g.) looking up by extending the neck
NECK ROTATION	> 45	Neck rotation refers to (e.g.) looking to the side by turning at the neck
BACK (STANDING):		
BACK BEND (8)	> 20	Definition of Awkward Posture applies if posture is static
BACK TWIST	> 30	Measured from mid-sagittal plane of body *
SEATED POSTURES:		
ELBOW FLEXION (9)	< 90, OR > 120	A 90 elbow angle is defined as the theoretical "neutral" position
BACK (TRUNK-THIGH ANGLE; 10)	< 90	Increasing the trunk-thigh angle reduces pressure on the lower back
KNEES (11)	< 90	Increasing the angle at the knees reduces stresses at the knees

* Mid-sagittal plane is defined as a vertical line drawn down the mid-line of the body.

APPENDIX H MAXIMUM GRIP FORCES (lb)

This table is intended as a supplement to S8-95 Table R2-7

Grip Type	Females (% of one time grip)				
	100%	50%	30%	15%	5%
Power Grip The fingers of the hand wrap around the object, and the thumb overlaps the index finger (ex. gripping a hammer)	61.7	30.9	18.5	9.4	3.09
Lateral Pinch Object is held between the thumb and the side of the index finger (often referred to as key grip)	15.9	7.9	4.9	2.4	0.80
Tip Pinch Object held between the tips of the thumb and index finger	11.0	5.5	3.3	1.7	0.55
Palmar Pinch Fingers pressed against the palm of the hand, with the object held between the fingers and the palm. Thumb is not used. (ex. picking up a sheet of plywood)	16.0	8.2	4.85	2.5	0.80

Notes:

- Static Grips: Force should not exceed 5%
- Repetitive Tasks: Force should not exceed 15%
- Occasional Tasks: Force should not exceed 30%
- Infrequent Tasks: Force should not exceed 50%

