Ahsanullah University of Science and Technology (AUST)
Department of Mechanical and Production Engineering

LABORATORY MANUAL

For the students of

Department of Mechanical and Production Engineering

1^{st} Year, 1^{st} Semester

Student Name :

Student ID :

Department of Mechanical and Production Engineering
Ahsanullah University of Science and Technology (AUST)

IPE 3202: Ergonomics and Productivity Engineering
Credit Hour: 1.5

General Guidelines:

1. Students shall not be allowed to perform any experiment without apron and shoes.
2. Students must be prepared for the experiment prior to the class.
3. Report of an experiment must be submitted in the next class.
4. The report should include the following:
    - Top sheet with necessary information
    - Main objectives
    - Work material/machine/tool/equipment used (with their specifications)
    - Experimental procedures
    - Experimental results and discussions (Experimental setup, Experimental conditions, Data, Graph, calculation etc.)
    - Conclusions
    - Acknowledgements
    - References
5. A quiz will be taken on the experiments at the end of the semester.
6. Marks distribution:

Total Marks		
Report	Attendance	Quiz
40	10	50

Experiment No: 1

Experiment Name: Anthropometry Measurement

Introduction:

The term anthropometry is derived from two Greek words, anthropos, meaning man, and metros, meaning measurement. In other words, anthropometry is concerned with the measurements of human dimensions. Hundreds of these dimensions are possible, everything from common measurement of stature, or height, to the size of u human fingernail, but of these, a hundred or more have been defined as being useful for various purposes.

In using anthropometric measurements there are several things to bear in mind. One of these is the source of the measurements. All anthropometric tables present values that are statistical in nature. In other words they are derived as averages of multiple samples, sometimes from hundreds, sometimes from thousands of subjects. The larger the sample, the more representative it is or in statistical terms the greater is the accuracy of confidence in the measured value. The subjects in these simples are measured under standard conditions.

Objective:

The objectives off this lab are:

* To know how to perform anthropometrics measurement
* To process the measurements so as to be useful
* To apply the data in the design of workplace, workstation, tools and equipment to fit to the human body.

Methodology:

To calculate a percentile value, simply multiply the standard deviation S by a factor k, selected from table 1. Then add the product to the mean m:

$$p = m + k*S$$

If the desire d percentile is above the 50th percentile, the factor k has a positive sign and the product k*S is added to the mean m; if the p-value is below 50th percentile, k is negative and the product k*S is subtracted from the mean m. 1 the equation of mean m:

$$m = \left(\frac{\sum x}{n} \right)$$

m = mean

x = sample value

n = total of samples

The distribution of the data is described by the equation:

$$S = \sqrt{\frac{\sum (x-m)^2}{n}}$$

$$m_z = m_x - m_y$$

$$S_z = \sqrt{\left[S_z^2 + S_y^2 - 2r * S_x * S_y\right]}$$

Table 1: Percentile Values and Associated k Factors

Below Mean				Above Mean			
Percentile	Factor K	Percentile	Factor K	Percentile	Factor K	Percentile	Factor K
0.001	-4.25	31	-0.50	50	0	85	1.04
0.01	-3.72	32	-0.47	51	0.03	86	1.08
0.1	-3.09	33	-0.44	52	0.05	87	1.13
0.5	-2.58	34	-0.41	53	0.08	88	1.18
1	-2.33	35	-0.39	54	0.10	89	1.23
2	-2.05	36	-0.36	55	0.13	90	1.28
2.5	-1.96	37	-0.33	56	0.15	91	1.34
3	-1.88	38	-0.31	57	0.18	92	1.41
4	-1.75	39	-0.28	58	0.20	93	1.48
5	-1.64	40	-0.25	59	0.23	94	1.55
6	-1.55	41	-0.23	60	0.25	95	1.64
7	-1.48	42	-0.20	61	0.28	96	1.75
8	-1.41	43	-0.18	62	0.31	97	1.88
9	-1.34	44	-0.15	63	0.33	97.5	1.96
10	-1.24	45	-0.13	64	0.36	98	2.05
11	-1.23	46	-0.10	65	0.39	99	2.33
12	-1.18	47	-0.08	66	0.41	99.5	2.58
13	-1.13	48	-0.05	67	0.44	99.9	3.09
14	-1.08	49	-0.03	68	0.47	99.99	3.72
15	-1.04	50	0	69	0.50	99.999	4.26
16	-0.99			70	0.52		
17	-0.95			71	0.55		
18	-0.92			72	0.58		
19	-0.88			73	0.61		
20	-0.84			74	0.64		
21	-0.81			75	0.67		
22	-0.77			76	0.71		
23	-0.74			77	0.74		
24	-0.71			78	0.77		
25	-0.67			79	0.81		
26	-0.64			80	0.84		
27	-0.61			81	0.88		

28	-0.58			82	0.92		
29	-0.55			83	0.95		
30	-0.52			84	0.99		

Any percentile value p can be calculated from the mean m and the standard deviation.

<u>Result:</u> Anthropometry measurement

Dimentsion	Men				Women			
	5th % ile	Mean	95th % ile	SD	5th % ile	Mean	95th % ile	SD
Stature								
Eye Height, Standing								
Shoulder Height (Acromion), Standing								
Elbow Height, Standing								
Hip Height (Trochanter)								
Knuckle Height, Standing								
Finger Height, Standing								
Sitting Height								
Sitting Eye Height								
Sitting Shoulder Height								
Sittings Elbow Height								
Sitting Thigh Height								
Sittings Knee Height								
Sittings Popliteal Height								
Shoulder Elbow Length								
Elbow-Fingertip Length								
Overhead Grip Reach,								
Overhead Grip Reach,								
Forward Grip Reach								
Arm Length, Vertical								
Downward Grip Reach								
Chest Depth								
Abdominal Depth, Sitting								
Buttock-Knee Depth, Sitting								
Buttock-Popliteal Depth,								
Shoulder Breadth								
Shoulder Breadth (Bideltoid)								
Hip Breadth, Sitting								
Span								
Elbow Span								
Hand Length								
Hand Breadth								

See appendix for detail of anthropometric measurement

Appendix: <u>Body Dimensions:</u>

The required dimensions are as follows::
1. Stature: The vertical distance from to top of the head, when standing.
2. Eye Height, Standing: The vertical distance form the floor to the outer corner of the right eye, when standing.
3. Shoulder Height (Acromion), Standing: The vertical distance from the floor to the tip (acromion) of the shoulder, when standing.
4. Elbow Height, standing: The vertical distance from the floor to the lowest point of the right elbow, when standing
5. Hip Height (Trochanter), Standing: The vertical distance from the floor to the trochanter landmark on the upper side of the right thigh, when standing.
6. Knuckle Height, Standing: The vertical distance from the floor to the knuckle (metacarpal bone) of the middle finger of the right hand, when standing.

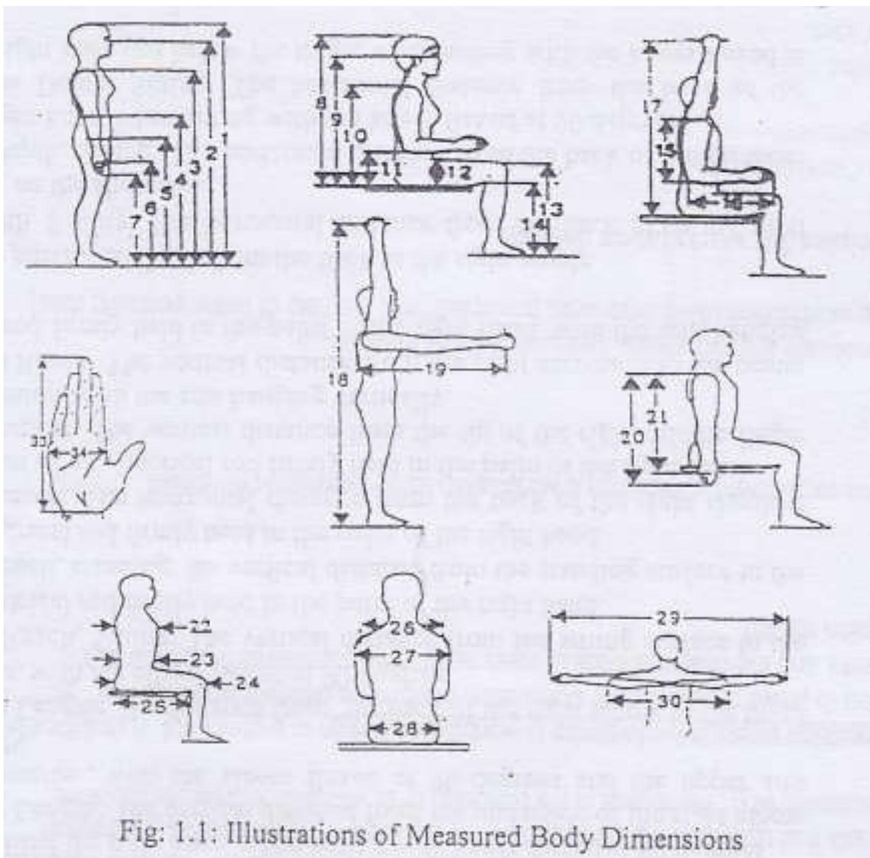


Fig: 1.1: Illustrations of Measured Body Dimensions

7. Fingertip Height, Standing: The vertical distance from the floor to the tip of the index finger of the right hand, when standing.
8. Sitting Height: the vertical distance form the sitting surface to the top of the head, when sitting.
9.Sitting Eye Height: The vertical distance from the sitting surface to the outer corner of the right eye, when sitting.

10. Sitting Shoulder Height (Acromion) : The vertical distance from the sitting surface to the tip (acromion) of the shoulder.
11. Sitting Elbow Height: The vertical distance from the sitting surface to the lowest point of the right elbow, when sitting.

12. Sitting Thigh Height (Clearance) : The vertical distance from the sitting surface to the highest point of the right thigh, when sitting.

13. Sitting Knee Height: The vertical distance from the floor to the top of the right knee cap, when sitting with knees flexed at 90 degrees

14. Sitting Popliteal Height: The vertical distance from the floor to the underside of the thigh directly behind the right knee, when sitting with knees flexed at 90 degrees.
15. Shoulder-Elbow Length: The vertical distance from the underside of the right elbow to the right acromion., with the elbow flexed at 90 degrees and the upper arm hanging vertically.
16. Elbow-Fingertip Length: The distance from the back of the right elbow to the tip of the middle finger, with the elbow flexed at 90 degress.
17. Overhead Grip Reach, Sitting: The vertical distance from the sitting surface to the center of a cylindrical rod firmly held in the palm of the right hand.
18. Overhead grip reach, standing: the vertical distance from the standing surface to the center of a cylindrical rod firmly held in the palm of the right hand.
19. Forward Grip Reach: The horizontal distance from the back of the right shoulder blade to the center of a cylindrical rod firmly held in the palm of the right hand.
20. Arm Length, Vertical: The vertical distance from the tip of the right middle finger to the right acromion, with the arm hanging vertically.
21. Downward Grip Reach: The vertical distance from the right acromion to the center of a cylindrical rod firmly held in the palm of the right hand, with the arm hanging vertically.
22. Chest depth: the horizontal depth from the back to the right nipple.
23.Abdominal Depth, Sitting: The horizontal distance from the back of to the most protruding point on the abdomen.
24. Buttock-Knee Depth, Sitting: The horizontal distance from the back of the buttocks to the back of right knee, when sitting with the knees flexed at 90 degrees.
25. Buttock-Popliteal Depth, Sitting: The horizontal distance from the back of the buttocks to the right knee just below the thigh, when sitting with the knees flexed at 90 degrees.
26. Shoulder Breadth, Biacromial: The distance between the right and left acromion.
27. Shoulder Breadth, Bideltoid: The maximal horizontal breadth across the shoulders between the lateral margins of the right and left deltoid muscles.
28. Hip Breadth, Sitting: The maximal horizontal breadth across the hips or thighs, whatever is greater, when sitting.
29. Span: The distance between the tips of the middle fingers of the horizontally outstretched arms and hands.
30. Elbow Span: The distance between the tips of the elbows of the horizontally outstretched upper arms flexed so that the fingertips of the hands meet in front of the hunk.
31. Hand Length: The length of the right hand between the crease of the wrist and the tip of the middle finger, with right hand flat.
32. Hand Breadth: The breadth of the right hand across the knuckles of the four fingers.

Experiment No: 2

Experiment Name: Study and Design of Different Types of Hand Tools

Introduction:

Hand tools extend capability of the hand. Greater capability can be more impact (hammer), more grip strength (pliers), more torque (wrench, screw-driver) or even new functions (hand saw, soldering iron). This experiment will aid one in selecting from available tools and even, in some cases, to design a new tool. The design principles are grouped into General Principles, Grip Principles, Precision Principles and Geometry Principles.

Objective:

The objectives of this experiment to:

* Study ergonomic principles in designing of hand tools.
* Observe some existing hand tools and machines.
* Designing hand tools and machines using ergonomic principles. to eliminate the existing shortcoming.

Methodology:

1. Identify the major components, their functions, dimensions and their relative position of the hand tools and machines mentioned in the following paragraph.
2. Use the tool or operate the machine for a typical job.
3. Carefully observe the working posture of the body and the interaction between the body and different parts of the tool or machine.
4. Conduct a survey for noting down the general feeling of the user.
5. From the above mentioned steps identify shortcomings (Geometry, dimension, alignment, material, and shape etc of parts of the tool or machine that are not designed ergonomically resulting in discomfort and risk of musculoskeletal disorders from long time use) with reasons.
6. Propose improved design (with neat sketch) explaining the modifications made.

Tools and Machines to be studied:

Hand drill, Soldering iron, Electrode Holder of Arc-welding, Cutting Torch, Chisel, Snip, Die, Hack-saw, Pliers, Jack Planner, Tanner saw, Slide Wrench, Screw driver.

<u>Ergonomic Principles in Designing of Hand Tools</u>

Hand Tools:
Hammer, pliers, wrench, hand saw, screw driver, soldering iron, hack saw, scissors, knives, bottle opener etc.

<u>Principles of Hand Tool & Devices Design:</u>

* Maintain a straight wrist -
    * Avoid ulnar Deviation.

Flexion --------> Decreasing angle at the joint
Extension --------> opposite
Abduction --------> movement of body segment in lateral plane away from the midline of the body.
Adduction --------> opposite

* Avoid radial deviation with pronation & dorsiflexion.
* Design to neutral position. (wrist angle) (bent handle)

*** Grip strength is maximum at**

Neutral → Ulnar dev. → Radial dev → Dorsi flexion → Palmer flexion } Supination → Mid → Pronation

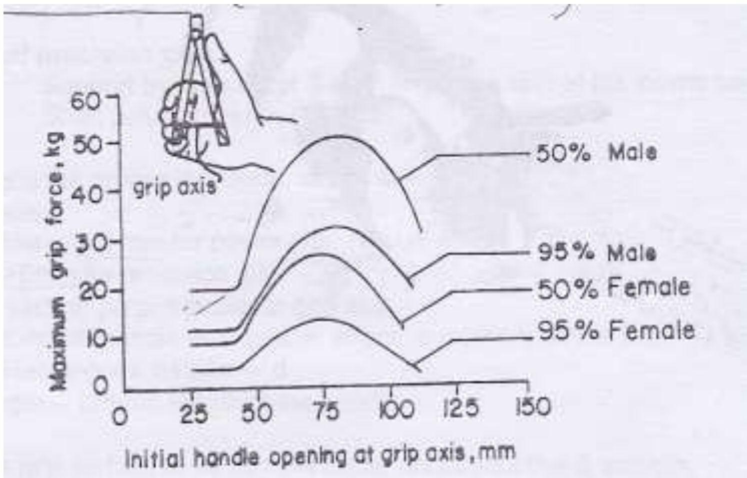
To increase high friction material, special design to gain mechanical advantage.

*** Avoid tissue compression stresses-**

- Avoid compressive force on the palm of the hand (obstructs blood flow, numbness of the fingers).
- Handles with large contact surfaces with palm so that force is distributed over larger area & is directed to less-sensitive tissues (between thumb & index finger).

* Avoid repetitive finger action -

 * Avoid frequent use of index finger. Thumb operated controls should be used.
 * Even better Finger-strip control (load shared by more than one finger)
 * Maximum grip strength grip axis opening (axis opening) between
 2.5 inch -3.5 inch



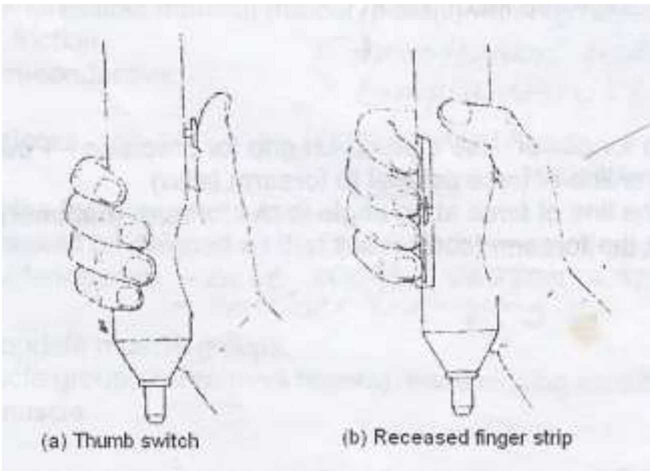
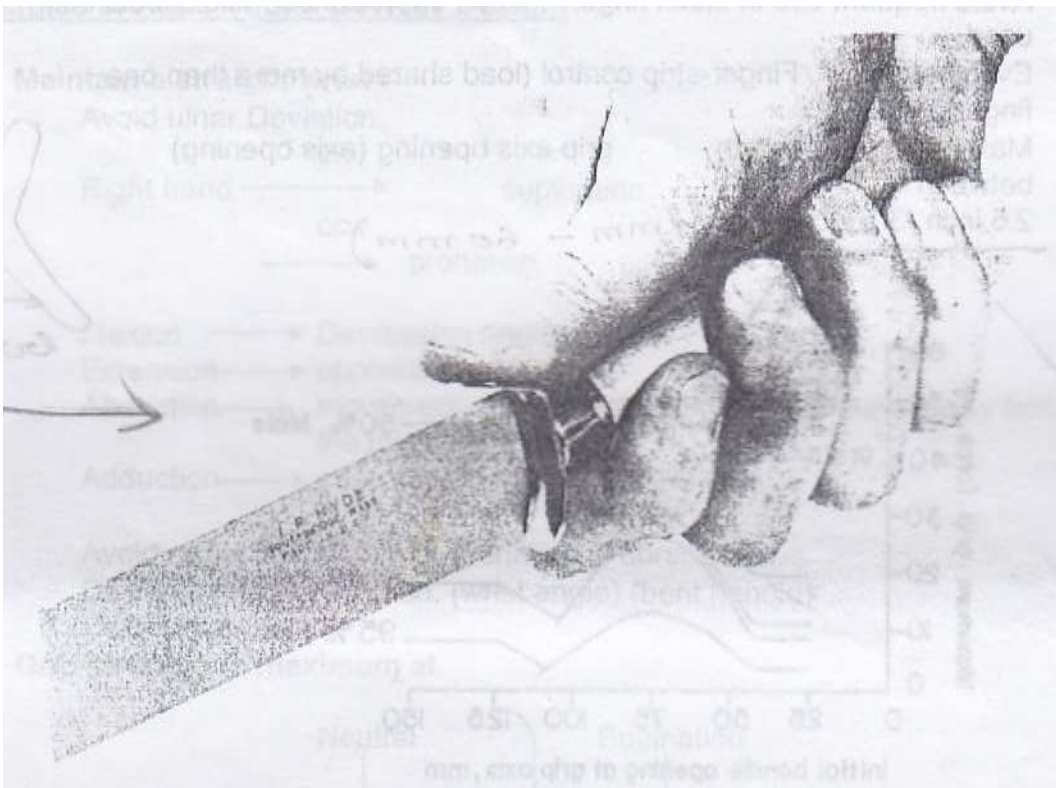


Figure: Thumb-operated and finger-strip operated pneumatic tool. Thumb operation results in overextension of the thumb. Finger strip control allows all the fingers to share the load and the thumb to grip and guide the tool

Design for safe operation -

* Eliminate pinching hazards (putting guards over pinch points, stops to prevent handles from fully closing & pinching the palm)
* Eliminate sharp corners & edges (rounding)
* Power tools --- design with brake devices.



Women & left handles -

* Vibration --- page 398 McCormick
* Gloves.

Grip Principles

Use a power grip for power. Use a precision grip for precision –

Power Grip:

1. Direction of the line of force parallel to forearm (saw).
2. Direction of the line of force at an angle to the forearm (hammer).
3. Torque about the forearm (corkscrew).

Precision Principles

1. Internal precision grips. Three characteristics

- A pinch grip by the thumb versus 1st finger (or 1st + 2nd finger)
- Support to reduce tool tremor by the little finger & side of the hand.
- The shaft passes under the thumb.

In pushing/pulling -- tool handle parallel to the work surface.
Rotation/torque ------ tool shaft perpendicular to the work surface (screw driver).

End of the tool grip should be long enough to extend beyond the palm.
Use Spherical end.

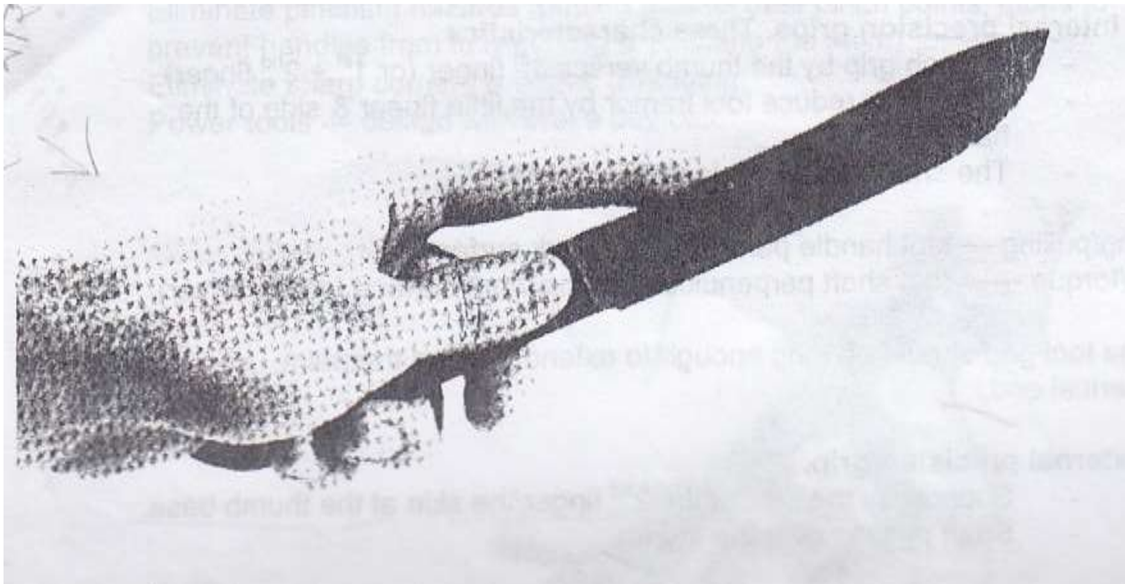
2. External precision grip.

- Support by the side of the 2nd finger/the skin at the thumb base.
- Shaft passes over the thumb.

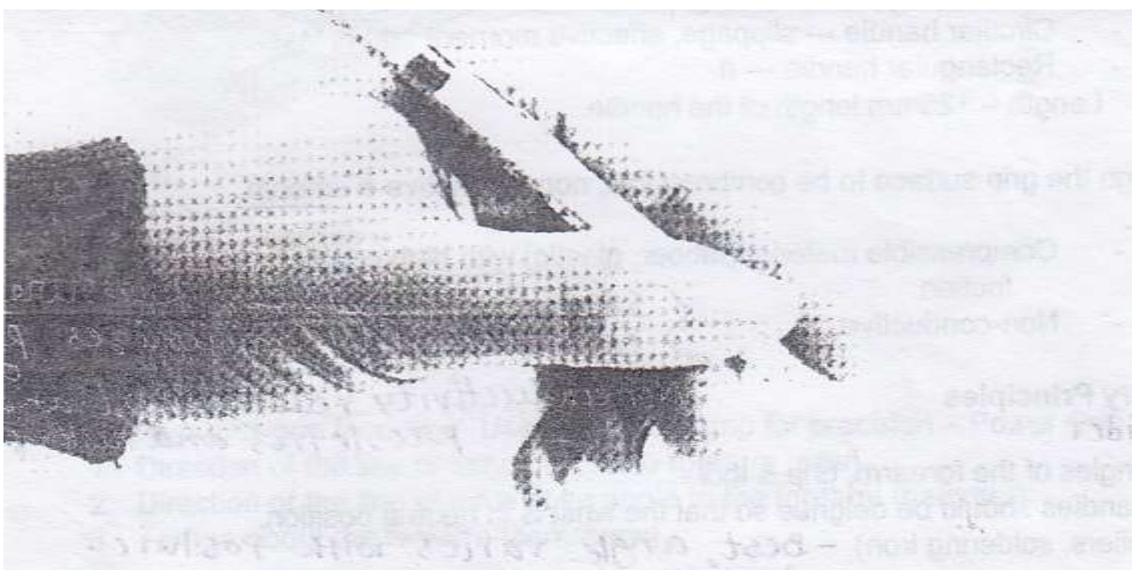
* Make grip the proper thickness, shape & length.
    * Thickness
    - Dia --- 40 mm for power grip.
    - >6mm for precision grip.
* Shape section perpendicular to grip axis-
    - Circular handle --- slippage, effective moment arm is less.
    - Rectangular handle --- pressure high
* Length – 125mm length of the handle.
* Design the grip surface to be compressible, nonconductive & smooth.
    - Compressible material (rubber, plastic) with high coefficient of friction.
    - Non conductive

Geometry Principles

* Angles of the forearm, grip & tool-
- Handles should be designed so that the wrist is in neutral position.
(pliers, soldering iron)
* Use appropriate muscle groups.
large muscle group, (forearm vs fingers), hand closing muscles vs hand opening muscle.



Internal precision grips have three characteristics: (1) a pinch grip, (2) support by the little finger or side of the hand, and (3) the shaft is "internal" to the hand.



External precision grips have three characteristics: (1) a pinch grip, (2) support by the side of the 2nd finger or skin at the thumb base, and (3) the shaft is "external" to the hand.

As with the power grip, thumb or little finger can be repositioned. Pointing along the top surface of a knife gives more power as well as additional precision. Patkin (1969) mentions pointing along a surgeon's needle holder with the thumb to gain additional precision.

Experiment No: 3

Experiment Name: Determination of Sound Level in different workplaces

Introduction:

Sound is created by the vibrating motion of displaced molecule in an elastic medium like air, wood, steel or other materials. This vibration produces waves which radiate in all directions. As these waves travel through the medium, a small pressure change above atmospheric pressure is created. Human ear is able to sense this small change , enabling to hear. This change in pressure is known as sound pressure level. The sound pressire level is the measure of sound most commonly reffered to when discussing industrial noise control. People are able to hear sound pressure level between about 1×10^-9 psi and 15 psi (or 1atm). Since this represents 10 orders of magnitude change, logarithmic scales are used to measure sound pressure level in desibels (dB). The level of sound plays a vital role in design of workplaces. Human comfort and productivity is affected by noise level greatly. Based on job profile and other requirements, in different types of workplaces, different standards of sound level has been set to define human comfort.

Objective: In this experiment, students have to construct a noise contour map of a sound emitting source. They are also required to critically analyze the findings and comment for improvements (if any).

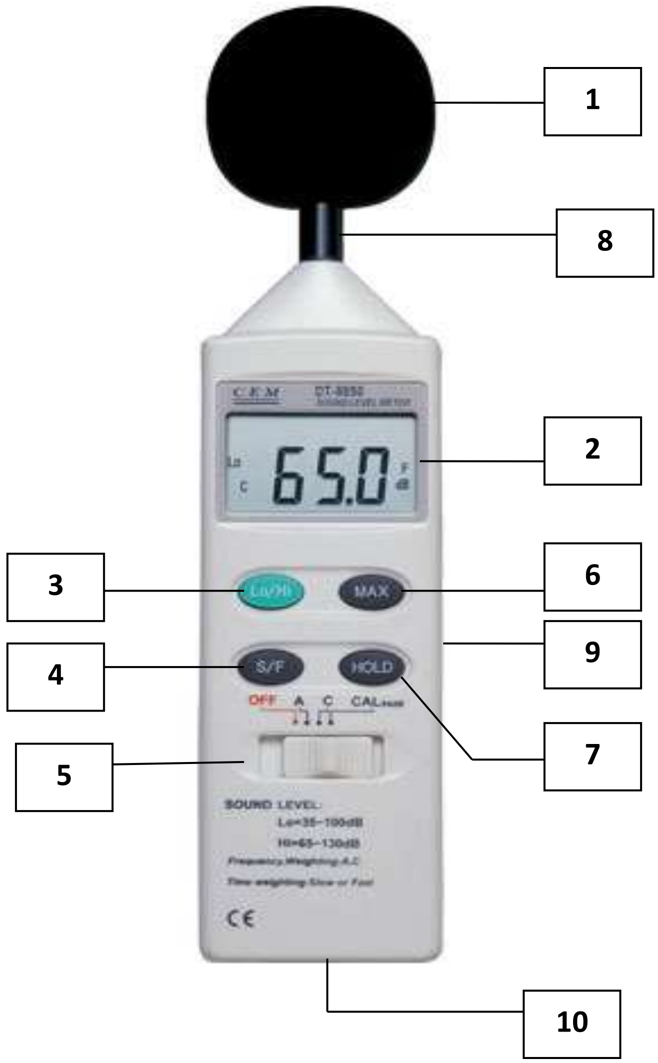
Apparatus:

1. Sound Level Meter

Procedure:

1. Using slow response setting on a sound level meter, walk around the sound source, maintaining a constant reading (e.g. 80dBA). Record your path until it closes on itself, forming a loop. Or until the path exits the area to be surveyed.
2. Trace the path followed on a plant layout or area map. This can be easily done by a second person following the surveyor.
3. Repeat the process for as many contours as desired or needed. At a minimum, seven contours forming eight hearing hazard zones are recommended.

Digital Sound Level Meter:



1. Windscreen
2. Display
3. Level Range Select Button: Lo: 35~100dB; Hi: 65~130dB
4. Time Weighting Select Button:
   F (Fast response): For Normal measurement.
   S (Slow response): For checking average level of fluctuating noise.
5. Power and Function Switch:
   Turn power ON/OFF and select A/C weighting & calibration function
   A: A- Weighting for general sound level measurements.

C: C- Weighting for checking the low frequency content of noise.

6. Max Hold Button: To measure maximum level of sounds.
7. Data Hold Button: Freezes the reading in the display.
8. Microphone
9. DC, AC Output jack
10. Calibration potentiometer

Operation:

1. Power the meter by pressing the power button. The meter will begin displaying sound level readings. If the LCD does not switch on, check the 9V battery located in the rear battery compartment.
2. Hold the meter away from the body.
3. View the measurement on the meter's display. If the meter is in the auto ranging mode, the display may briefly indicate "HI" or "LO" if the noise level is above or below the currently selected range. The meter will change the range as needed to display the dB level.
4. 'A' and 'C' Frequency Weighting Use the 'A/C' button to select 'A' or 'C' frequency weighting. With 'A' weighting selected, the frequency response of the meter is similar to the response of the human ear. 'A' weighting is commonly used for environmental or hearing conservation programs such as OSHA regulatory testing and noise ordinance law enforcement. 'C' weighting is a much flatter response and is suitable for the sound level analysis of machines, engines, etc. "A" or "C" icons will appear in the display. Most noise measurements are performed using 'A' Weighting and SLOW Response.
5. 'FAST' and 'SLOW' Response Time Use the 'F/S' button to select FAST (125 ms) or SLOW (1 second) response time. Select FAST to capture noise peaks and noises that occur very quickly. Select the SLOW response to monitor a sound source that has a consistent noise level or to average quickly changing levels. "FAST" or "SLOW" icons will appear in the display. Select SLOW response for most applications.
6. Max hold: In this mode the meter only updates the LCD when a higher reading than the one presently on the display is detected.
   Press the MAX HOLD button to enter the Max Hold mode. The "MAX HOLD" icon will appear in the display. Press the MAX HOLD button again to exit this mode.

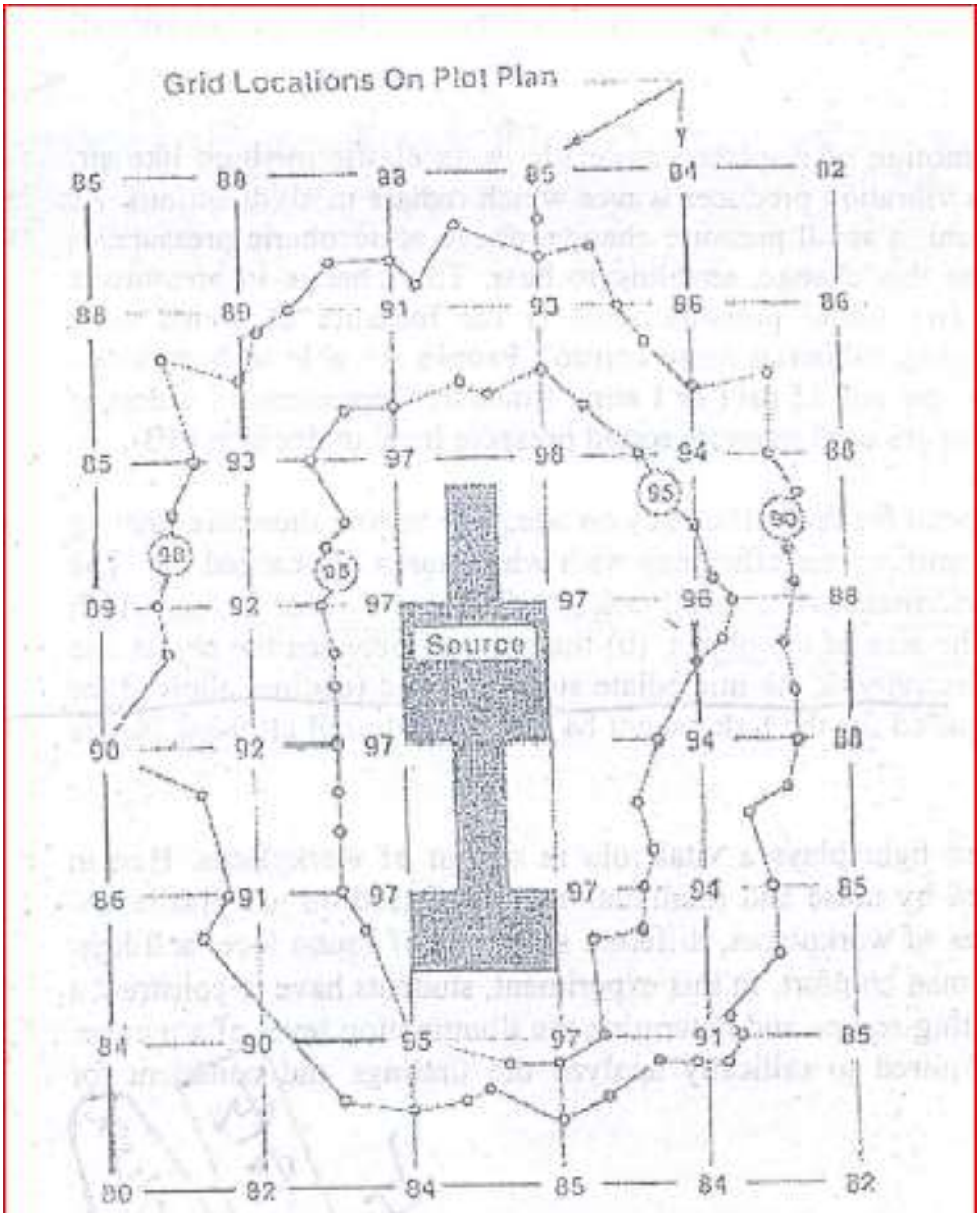


Figure 3.1: Noise Contour Map

Experiment No: 4

Experiment Name: Study of manual lifting operation and determination of the recommended weight limit using the NIOSH lifting equation

Introduction:

Manual handling is an important application of ergonomic principles that particularly addresses back injury prevention. A large proportion of the accidents which occurs in industry involve the manual handling of goods. In the United Sates, the report by the National Institute for Occupational Safety and Health (NIOSH,l981) stated that back pain was attributed to overexertion by 60% of back pain sufferers. About 500,000 workers in the US suffer some type of overexertion injury per year. Approximately 60% if the overexertion injury claims involve lifting and 20% involve pushing or pulling.
The main contribution of ergonomics to the reduction of hazards in manual handling is to redesign tasks and to identify techniques and specify workloads which are safe. NIOSH has produced a work practice guide for the design of manual handling tasks and an equation for determining safe loads. In Europe, a new directive for design of these task has been issued in 1990 and the U.K. Health and Safety Commission Consultative Document (Health and Safety Commission, 1991) provides interesting proposals for the design of manual handling tasks.

Objective:

The objective of this experiment is to study manual lifting operation and determination of recommended weight by using the NIOSH lifting equation.

The Revised Lifting Equation
1 Definition of Terms
1.1 Recommended Weight Limit (RWL)

The RWL is the principal product of the revised NIOSH lifting equation. The RWL is defined for a specific set of task conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time (e.g., up to 8 hours) without an increased risk of developing lifting-related LBP. By healthy workers, we mean workers who are free of adverse health conditions that would increase their risk of musculoskeletal injury.

The RWL is defined by the following equation:
RWL : LC X HM X VM X DM X AM X FM X CM

1.2 Lifting Index (LI)

The LI is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the relationship of the weight of the load lifted and the recommended weight limit.

The LI is defined by the following equation:

LI= Load Weight/ Recommended weight Limit RWL = $\frac{L}{RWL}$

1.3 Terminology and Data Definitions

The following list of brief definitions is useful in applying the revised NIOSH lifting equation. For detailed descriptions of these terms, refer to the individual sections where each is discussed. Methods for measuring these variables and examples are provided in Sections 1 and 2.

Lifting Task Defined as the act of manually grasping an object of definable size and mass with two hands, and vertically moving the object without mechanical assistance.

Load Weight (L) Weight of the object to be lifted, in pounds or kilograms, including the container.

Horizontal Distance of the hands away from the mid-point between the ankles, in inches **Locations (H)** or centimeter (measure at the origin and destination of lift). See Figure 1.

Vertical Location (V) Distance of the hands above the floor, in inches or centimeters (measure at the origin and destination of lift). See Figure l.

Vertical Travel Distance (D) Absolute value of the difference between the vertical heights at the destination and origin of the lift, in inches or centimeters.

Asymmetry Angle (A) Angular measure of how far the object is displaced from the front (mid sagittal plane) or the worker’s body at the beginning or ending of the lift, in degrees (measure at the origin and destination of lift). See Figure 2. The asymmetry angle is defined by the location of the load relative to the workers’ mid- sagittal plane, as defined by the neutral body posture, rather than the position of the feet or the extent of body twist.

Neutral Body Describes the position of the body when the hands are directly in front of the

Position	body and there is minimal twisting at the legs, torso, or shoulders.
Lifting Frequency (F)	Average number of lifts per minute over a 15 minute period.
Lifting Duration	Three-tiered classification of lifting duration specified by the distribution of work-time and recovery-time (work pattern). Duration is classified as earlier short (1 hour), moderate (1-2 hours), or long (2-8 hours), depending on the work pattern.
Coupling Classification	Classification of the quality of the hand-to-object coupling (e.g., handles, cut- out, or grip). Coupling quality is classified as good, fair, or poor.
Significant Control	Significant control is defined as a condition requiring precision placement of the load at the destination of the lift. This is usually the case when (1) the worker has to re-grasp the load near the destination of the lift, or (2) the worker has to momentarily hold the object at the destination, or (3) the worker has to carefully position or guide the load at the destination

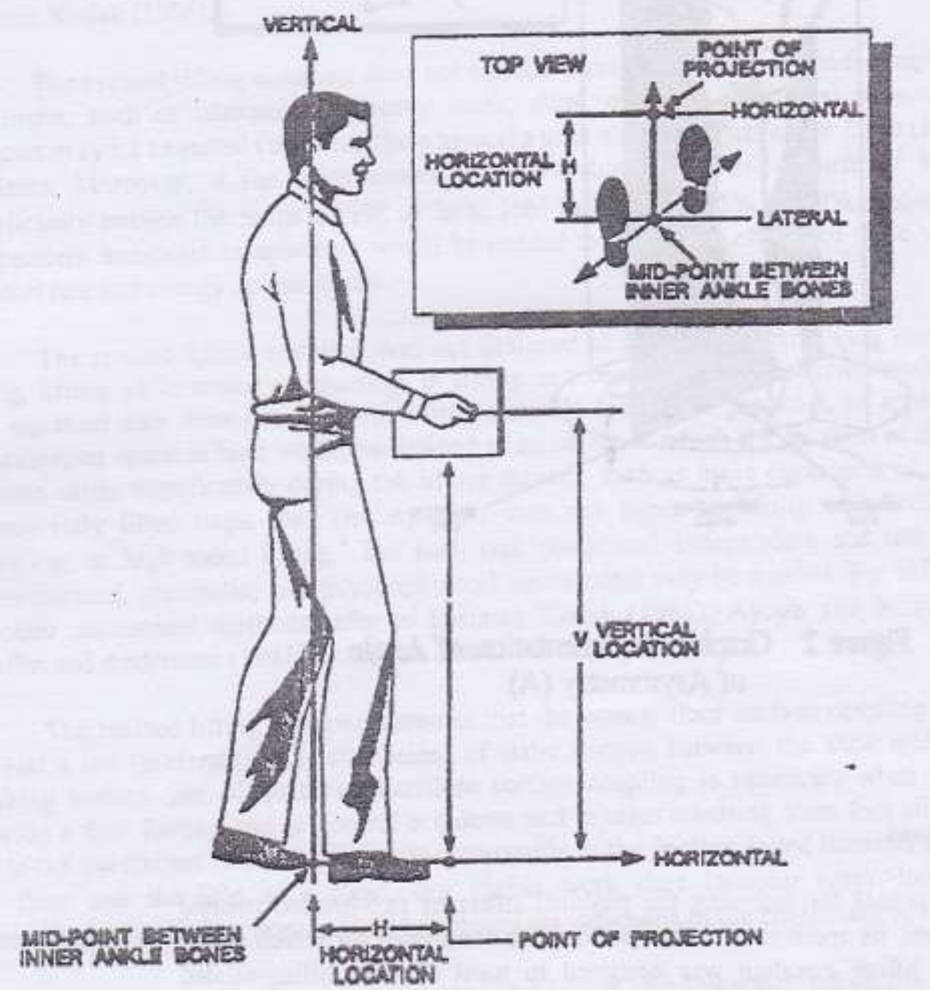


Figure 1 Graphic Representation of Hand Location

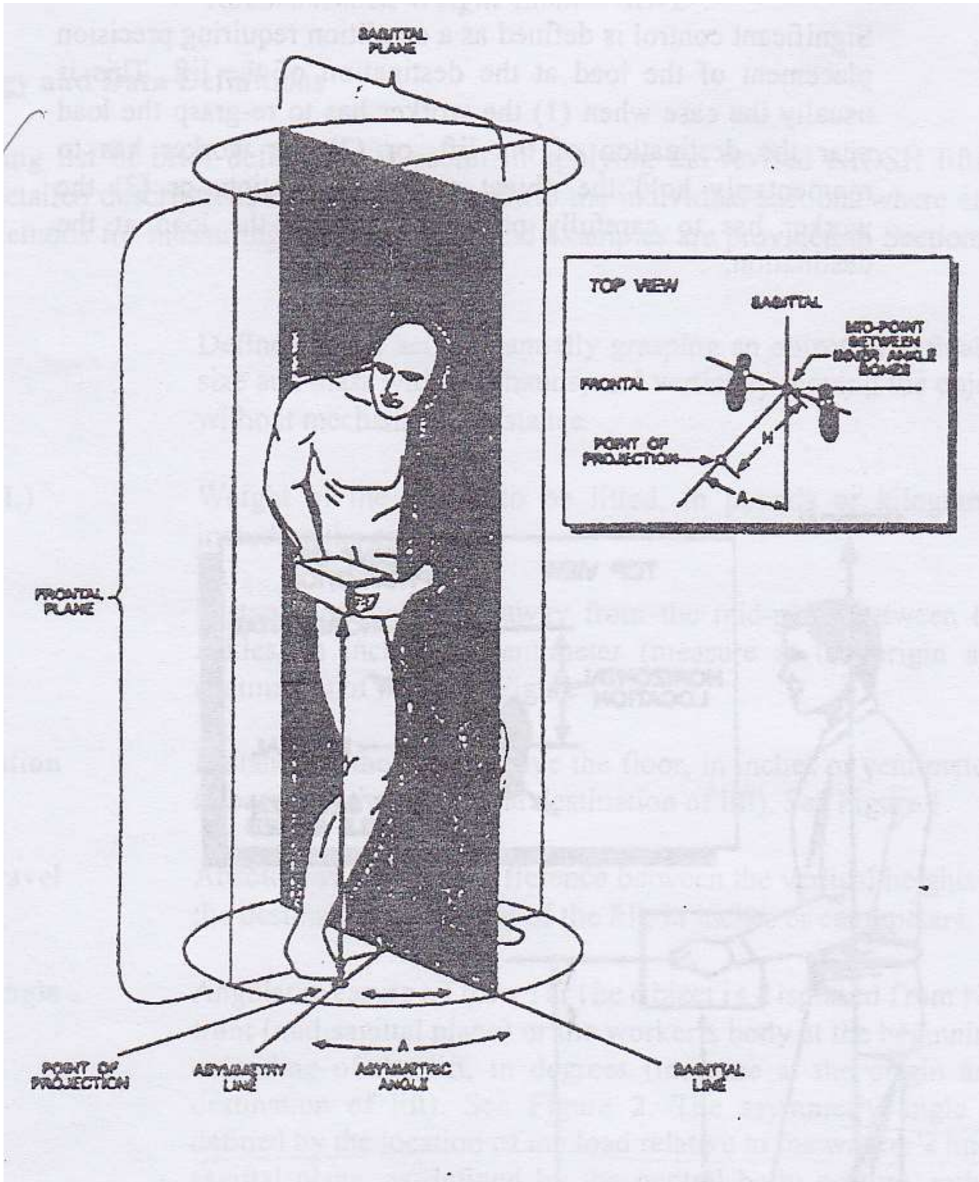


Figure 2 Graphic Representation of Angle of Asymmetry (A)

2 Lifting Task Limitations

The lifting equation is a tool for assessing the physical stress of two-handed manual lifting tasks. As with any tool, its application is limited to those conditions for which it was designed. Specifically, the lifting equation was designed to meet specific lifting-related criteria that encompass biomechanical, work physiology, and psychophysical assumption and data, identified above. To the extent that a given lifting task accurately reflects these underlying conditions and criteria, this lifting equation may be appropriately applied.

The following list identified a set of work conditions in which the application of the lifting equation could either-or over-estimate the extent of physical stress associated with a particular work-related activity. Each of the following task limitations also highlight research topics in need of further research to extend the application of the lifting equation to a greater range of real world lifting tasks.

1. The revised NIOSH lifting equation is based on the assumption that manual handling activities other than lifting are minimal and do not require significant energy expenditure, especially when repetitive lifting tasks are performed. Examples of non-lifting tasks include holding, pushing, pulling, carrying, walking, and climbing. If such non-lifting activities account for more than about 10% of the total worker activity, then measures or workers' energy expenditures and/or heart rate may be required to assess the metabolic demands of the different tasks. The equation will still apply if there is a small amount of holding and carrying, but carrying should be limited to one or two steps and holding should not exceed a few seconds. For more information on assessing metabolic demand, see Garg et al. (1978) or Eastman Kodak (1986).

2. The revised lifting equation does not include tasks factors to account for unpredicted conditions, such as unexpectedly heavy loads, slips, or falls. Additional biomechanical analyses may be required to assess the physical stress on joints that occur from traumatic incidents. Moreover, if the environment is unfavorable (e.g., temperatures or humidity significantly outside the range of l9^{o} to 26^{o}C [66^{o} to 79^{o}F] or 35% to 50%, respectively), independent metabolic assessments would be needed to gauge the effects of these variables on heart rate and energy consumption.

3. The revised lifting equation was not designed to assess tasks involving one-handed lifting, lifting while seated or kneeling, or lifting in a constrained or restricted work space.[3] The equation also does not apply to lifting unstable loads, For purposes of applying the equations, an unstable load would be defined as an object in which the location of the center of mass varies significantly during the lifting activity, such as more containers of liquid or incompletely filled bags, etc. The equation does not apply to lifting of wheelbarrows, shoveling, or high-speed lifting.[4] For such task conditions, independent and task specific biomechanical, metabolic, and psychophysical assessments may be needed. For information on other assessment methods refer to Eastman Kodak (1986), Ayoub and Mital (1989), Chaffin and Andersson (1991), or Snook and Ciriellos (1991).

4. The revised lifting equation assumes that the worker/floor surface coupling provides at least a 0.4 (preferably 0.5) coefficient of static friction between the shoe sole and the working surface. An adequate worker/floor surface coupling is necessary when lifting to provide a firm footing and to control accidents and injuries resulting from foot slippage. A 0.4 to 0.5 coefficient of static friction is comparable to the friction found between a smooth, dry floor and the sole of a clean, dry leather work shoe (nonslip type). Independent biomechanical modeling may be used to account for variations in the coefficient of friction,

5. The revised lifting equation assumes that lifting and lowering tasks have the same level of risk for low back injuries (i.e. that lifting a box from a table to the floor). This assumption may not be

true if the worker actually drops the box rather than lowering it all the way to the destination. Independent metabolic, biomechanical, or psychophysical assessments may be needed to assess worker capacity for various lowering conditions. (See references provided above.)

In summary, the Revised NIOSH Lifting Equation does not apply if \f any of the following occur.

* Lifting/lowering with one hand
* Lifting/lowering for over 8 hours
* Lifting/lowering while seated or kneeling
* Lifting/lowering in a restricted work space
* Lifting/lowering unstable objects
* Lifting/lowering while carrying, pushing or pulling
* Lifting/lowering with wheelbarrows or shovels
* Lifting/lowering with high speed motion (faster than about 30 inches/second)
* Lifting/lowering with unreasonable foot/floor coupling, (<0.4 coefficient of friction between the sole and the floor)
* Lifting/lowering in an unfavorable environment (i.e., temperature significantly outside 66-79^{o}F (19-26^{o}C) range; relative humidity outside 35-50% range)

For those lifting tasks in which the applications of the revised lifting equation is not appropriate, a more comprehensive ergonomic evaluation may be needed to quantify the extent of other physical stressors, such as prolonged or frequent non-neutral back postures or seated postures, cyclic loading (whole body vibration), or unfavorable environmental factors (e.g., extreme heat, cold, humidity, etc.).
Any of the above factors, alone or in combination with manual lifting, may exacerbate or initiate the onset of low back pain.

2. The Equation and Its Function

The revised lifting equation for calculating the Recommended Weight Limit (RWL) is based on a multiplicative model that provides a weighting for each of six task variables. The weightings are expressed as coefficients that serve to decrease the load constant, which represents the maximum recommended load weight to be lifted under ideal conditions. The RWL is defined by the following equation:

RWL : LC X HM X VM X DM X AM X FM X CM

Where

		METRIC	U.S. CUSTOMARY
Load Constant	LC	23 kg	51 lb
Horizontal Multiplier	HM	(25/H)	(10/H)
Vertical Multiplier	VM	1-(.003 V-75)	1-(.0075 V-30)
Distance Multiplier	DM	.82 + (4.5/D)	.82 + (1.8/D)
Asymmetric Multiplier	AM	1-(.0032A)	1-(.0032A)
Frequency Multiplier	FM	From Table 5	From Table 5
Coupling Multiplier	CM	From Table 7	From Table 7

The term task variables refers to the measurable task descriptors (i.e., H, V, D, A, F, and C); whereas, the term multipliers refers to reduction coefficients in the equation (i.e., HM, VM, DM, AM, FM, and CM).

Each multiplier should be computed from the appropriate formula, but in some cases it will be necessary to use linear interpolation to determine the value of a multiplier, especially when the value of a variable is not directly Available from a table. For example, when the measured frequency is not a whole number, the appropriate multiplier must be interpolated between the frequency values in the table for the two values that are closest to the actual frequency.

3.1 Horizontal Component

3.1.1 Definition and Measurement

Horizontal Location (H) is measured from the mid-point of the line joining the inner ankle bones to a point projected on the floor directly below the mid-point of the hand grasps (i.e., load center), as defined by the large middle knuckle of the hand (Figure 1). Typically, the worker's feet are not aligned with the mid-sagittal plane, as shown in Figure l, but may be rotated inward or outward. If this is the case, then the mid-satittal plane is defined by the worker's neutral body posture as defined above.

If significant control is required at the destination (i.e., precision placement), then H should be measured at both the origin and destination of the lift.

Horizontal Location (H) should be measured. In those situations where the H value can not be measured, then H may be approximated from the following equations:

Metric [All distances in cm]	U.S. Customary [All distances in inches]
H = 20 + W/2 for V $\geq$ 25 cm	H = 8 + W/2 for 10 inches
H = 25 + W/2 for V < 25 cm	H = 10 + W/2 for V<10 inches

Where: W is the width of the container in the sagittal plane and V is the vertical location of the hands from the floor.

3.1 .2 Horizontal Restrictions

If the horizontal distance is less than 10inches (25 cm), then H is set to 10 inches (25 cm). Although objects can be carried or held closer than l0 inches from the ankles, most objects that are closer than this cannot be lifted without encountering interference from the abdomen or hyper extending the shoulders. While 25 inches (63cm) was chosen as the maximum value for H, it is probably too large for shorter workers, particularly when lifting asymmetrically. Furthermore objects at a distance of more than 25 inches from the ankles normally cannot be lifted vertically without some loss of balance.

3.1.3 Horizontal Multiplier

The Horizontal Multiplier (HM) is l0/H, for H measured in inches, and HM is 25/H, for H measured in centimeters. If H is less than or equal to 10 inches (25 cm), then the multiplier is 1.0, HM decreases with an increase in H value. The multiplier for H is reduced to 0.4 when H is 25 inches (63 cm). If H is greater than 25 inches, then HM = 0. The HM value can be computed directly or determined from Table l.

Table I
Horizontal Multiplier

H	HM	H	HM
in		cm	
≤10	1.00	≤25	1.00
11	.91	28	.89
12	.83	30	.83
13	.77	32	.78
14	.71	34	.74
15	.67	36	.69
16	.63	38	.66
17	.59	40	.63
18	.56	42	.60
19	.53	44	.57
20	.50	46	.54
21	.48	48	.52
22	.46	50	.50
23	.44	52	.48
24	.42	54	.46
25	.40	56	.45

>25	.00	58	.43
		60	.42
		63	.40
		>63	.00

3.2 Vertical Component

3.2.1 Definition and Measurement

Vertical Location (V) is defined as the vertical height of the hands above the floor. V is measured vertically from the floor to the mid-point between the hand grasps, as defined by the large middle knuckle. The coordinate system is illustrated in Figure 1 (page 7).

3.2.2 Vertical Restrictions

The vertical location (v) is limited by the floor surface and the upper limit of vertical reach for lifting {i.e.,70 inches or 175 cm). The vertical location should be measured at the origin and the destination of the lift to determine the travel distance (D).

3.2.3 vertical Multiplier

To determine the vertical Multiplier (VM), the absolute value or deviation of v from an optimum height of 30 inches (75cm) is calculated. A height of 20 inches above floor revel is considered "knuckle height" (66 inches or 165 cm). The Vertical Multiplier (VM) is {1-.0075*(V-30)} for V measured in inches, and VM is {1-.003*(V-75)}, for measured in centimeters.

When v is at.3-0 inches (75 cm), the vertical multiplier (VM) is- 1.0. The value of VM decreases linearly with an increase or decrease in height from the position. At floor level, VM is 0.78, and at 70 inches (175 cm) height VM is 0.7. If V is greater than 70 inches, then VM= 0. The VM value can be computed directly or determined from Table 2.

Table 2
Vertical Multiplier

V	VM	V	VM
in		cm	
0	.78	0	.78
5	.81	10	.81
10	.85	20	.84
15	.89	30	.87
20	.93	40	.90
25	.96	50	.93
30	1.00	60	.96
35	.96	70	.99
40	.93	80	.99

45	.89	90	.96
50	.85	100	.93
55	.81	110	.90
60	.78	120	.87
65	.74	130	.84
70	.70	140	.81
>70	.00	150	.78
		160	.75
		170	.72
		175	.70
		>175	.00

3.3 Distance Component

3.3.1 Definition and Measurement

The vertical Travel Distance variable (D) is defined as the vertical travel distance of the hands between the origin and destination of the lift. For lifting, D can be computed by subtracting the vertical location (V) at the origin of the lift from the corresponding V at the destination of the lift (i.e., D is equal to V at the destination minus V at the origin). For a lowering task, D is equal to V at the origin minus V at the destination.

3.3.2 Distance Restrictions

The variable (D) is assumed to be at least 10 inches (25 cm), and no greater than 70 inches [75 cm]. If the vertical travel distance is less than 10 inches (25 cm), then D should be set to the minimum distance of l0 inches (25 cm).

3.3.3 Distance Multiplier

The Distance Multiplier (DM) is (.82 + (1.8/D)) for D measured in inches, and DM is (.82 + (4.5/D)) for D measured in centimeters. For D less than 10 inches (25 cm) D is assumed to be l0 inches (25 cm), and DM is 1.0. The Distance Multiplier, therefore, decreases gradually with an increase in travel distance. The DM is 1.0 when D is set at 10 inches, (25 cm); DM is 0.85 when D = 70 inches (175 cm). Thus, DM ranges from 1.0 to 0.85 ad the D varies from 0 inches (0 cm) to 70 inches (175 cm). The DM value can be computed directly or determined from Table 3.

3.4 Asymmetry Component

3.4.1 Definition and Measurement

Asymmetry refers to a lift that begins or ends outside the mid-sagittal plane as shown in Figure 2 on page 8. In general, asymmetric lifting should be avoided. If asymmetric lifting cannot be avoided, however, the recommended weight limits are significantly less than those limits used for symmetrical lifting.5

Table 3
Distance Multiplier

D	DM	DM	DM
in		cm	
10	1.00	25	1.00
15	.94	40	.93
20	.91	55	.90
25	.89	70	.88
30	.88	85	.87
35	.87	100	.87
40	.87	115	.86
45	.86	130	.86
50	.86	145	.85
55	.85	160	.85
60	.85	175	.85
70	.85	>175	.00
>70	.00		

An asymmetric lift may be required under the following task or workplace conditions:

1.The origin and destination of the lift are oriented at an angle to each another.
4 The lifting motion is across the body, such as occurs in swinging bags or boxes from one location to another.
5 The lifting is done to maintain body balance in obstructed workplaces, on rough terrain, or on littered floors.
6 Productivity standards require reduced time per lift.

The asymmetric angle (A), which is depicted graphically in Figure 2, is operationally defined as the angle between the asymmetry the and the mid-sagittal line. The asymmetry line is defined as horizontal line that join the midpoint between the inner ankle bones and the point projected on the floor directly below the midpoint of the hand grasps, as defined by the large middle knuckle.

The sagittal line is defined as the line passing through the mid-point between the inner ankle bones and lying in the mid-sagittal plane, as defined by the neutral body position (i.e., hands directly in front of the body, with no twisting at the legs, torso, or shoulders). Note: The asymmetry angle is not defined by foot position or the angle of torso twist, but by the location of the load relative to the worker's mid-sagittal plane.

In many cases of asymmetric lifting, the worker will pivot or use a step turn to complete the lift. Since this may vary significantly between workers and between lifts, we have assumed that no pivoting or stepping occurs. Although this assumption may overestimate the reduction in acceptable load weight, it will provide the greatest protection for the worker.

The asymmetry angle (A) must always be measured at the origin of the lift. If significant control is required at the destination, however, then angle A should be measured at both the origin and the destination of the lift.

3.4.2 Asymmetry Restrictions

The angle A is limited to the range from 0^0 to 135^0 . If A> 135^0 , then AM is set equal to zero, which results in a RWL of zero, or no load.

3.4.3 Asymmetric Multiplier

The Asymmetric Multiplier (AM) is 1-(.00324). The AM has a maximum value of 1.0 when the load is lifted directly in front of the body. The AM decreases linearly as the angle of asymmetry (A) increases. The range is from a value of 0.57 at 135^0 of asymmetry to a value of 1.0 at 0^0 of asymmetry (i.e., symmetric lift).

If A is greater than 135^0 , then AM: 0, and the load is zero. The AM value can be computed directly or determined from Table 4.

Table 4
Asymmetric Multiplier

A	AM
deg	
0	1.00
15	.95
30	.90
45	.86
60	.81
75	.76
90	.71
105	.66
120	.62
135	.57
>135	.00

3.5 Frequency Component
3.5.1 Definition and Measurement

The frequency multiplier is defined by (a) the number of lifts per minute (frequency), (b) the amount of time engaged in the lifting activity (duration), and (c) the vertical height of the lift from the floor. Lifting frequency (F) refers to the average number of lifts made per minute, as measured over a 15-minute period. Because of the potential variation in work patterns, analysis may have difficulty obtaining an accurate or representative 15-minute work sample for computing the lifting frequency (F). If significant variation exists in the frequency of lifting over the course of the day, analyst should employ standard work sampling techniques to obtain a representative work sample for determining the number of lifts per minute. For those jobs where the frequency varies from session to session, each session should be analyzed separately, but the overall work pattern must still be considered. For more information, most standard industrial engineering or ergonomics texts provide guidance for establishing a representative job sampling strategy (e.g., Eastman Kodak Company, 1986).

3.5.2 Lifting Duration

Lifting duration is classified into three categories-short-duration moderate-duration and long-duration. These categories are based on the pattern of continuous work-time and recovery-time (i.e., light work) periods. A continuous work-time period is defined as a period of uninterrupted work. Recovery-time is defined as the duration of light work activity following a period of continuous lifting. Examples of light work include activities such as sitting at a desk or table, monitoring operations, light assembly work, etc.

1. Short-duration defines lifting tasks that have a work duration of one hour of less, followed by a recovery time equal to 1.2 times the work time [i.e., at least a 1.2 recover-time to work-time ratio (RT/WT)].

For example, to be classified as short-duration, a 45-minute lifting job must be followed by at least a 54-minute recovery period prior to initiating a subsequent lifting session. If the required recovery time is not met for a job of one hour or less, and subsequent lifting session is required, then the total lifting time must be combined to correctly determine the duration category. Moreover, if the recovery period does not meet the time requirement, it is disregarded for purposes of determining the appropriate duration category.
As another example, assume a worker lifts continuously for 30 minutes, then performs a light work task for 10 minutes, and then lifts for an additional 45-minute period. In this case, the recovery time between lifting sessions (10 minutes) is less than 1.2 times the initial 30-minute work time (36 minutes). Thus, the two work times (30 minutes and 45 minutes) must be added together to determine the duration. Since the total work time (75 minutes) exceeds 1 hour, the job is classified as moderate-duration. On the other hand, if the recovery period between lifting sessions was increased to 36 minutes, then the short-duration category would apply, which would result in a larger FM value.

2. **Moderate-duration** defines lifting tasks that have a duration of more than one hour, but not more than two hours, followed by recovery period of at least 0.3 times the work time [i.e., at least a 0.3 recovery time to work-time ratio (RT/WT)].

For example, if a worker continuously lifts for 2 hours, then a recovery period of at least 36 minutes would be required before initiating a subsequent lifting session. If the recovery time requirement is not met, and a subsequent lifting session is required, then the total work time must be added together. If the total works time exceeds 2 hours, then the job must be classified as a long-duration lifting task.

3. Long-duration defines lifting tasks that have a duration of between two and eight hours, with standard industrial rest allowances (e.g., morning, lunch, and afternoon rest breaks).

Note : No weight limits are provided more than eight hours of work.

The difference in the required RT/WT ratio for the short-duration category (less than 1 hour), which is 1.2, and the moderate-duration category (1-2 hours), which is 3, is due to the difference in the magnitudes of the frequency multiplier values associated with each of the duration categories. Since the moderate-duration category results in larger reductions in the RWL than the short-duration category, there is less need for a recovery period between sessions than for the short duration category. In other words, the short duration category would result in higher weight limits than the moderate duration category, so larger recovery periods would be needed.

3.5.3 Frequency Restrictions

Lifting frequency (F) for repetitive lifting may range from 0.2 lifts/min to a maximum frequency that is dependent on the vertical location of the object (V) and the duration of lifting (Table 5). Lifting above the maximum frequency results in a RWL of 0.0. (Except for the special case of discontinuous lifting discussed above, where the maximum frequency is 15 lifts/minute.)

3.5.4 Frequency Multiplier

The FM value depends upon the average number of lifts/min (F), the vertical location (V) of the hands at the origin, and the duration of continuous lifting. For lifting tasks with a frequency less than 2 lifts per minute, set the frequency equal to 2 lifts/minute. For infrequent lifting (i.e., F > 1 lift/minute), however, the recovery period will usually be sufficient to use the 1-hour duration category. The FM value is determined from Table 5.

Table 5
Frequency Multiplier Table (FM)

Frequency Lifts/min (F)	Work Duration					
	≤1 Hour		1 but ≤ 2 Hours		2 but ≤ 8 Hours	
	V < 30 t	V ≥30	V< 30	V ≥30	V< 30	V≥ 30
≤0.2	1.00	1.00	.95	.95	85	.85
0.5	.97	.97	.92	.92	81	.81
1	.94	.94	.88	.88	75	.75
2	.91	.91	.84	.84	65	.65
3	.88	.88	.79	.79	55	.55
4	.84	.84	.72	.72	45	.45
5	.80	.80	.60	.60	35	.35
6	.75	.75	.50	.50	27	.27
7	.70	.70	.42	.42	22	.22
8	.60	.60	.35	.35	18	.18
9	.52	.52	.30	.30	00	.15
10	.45	.45	.26	.26	00	.13
11	.41	.41	.00	.23	00	.00
12	.37	.37	.00	.21	00	.00

13	.00	.34	.00	.00	00	.00
14	.00	.31	.00	.00	00	.00
15	.00	.28	.00	.00	00	.00
>15	.00	.00	.00	.00	00	.00

Va1lues of V are in inches For lifting less frequently than once per 5 minutes, set F =0. 2 lifts/minute.

3.5.5 Special Frequency Adjustment Procedure

A special procedure has been developed for determining the appropriate lifting frequency(F) for certain repetitive lifting tasks in which workers do not lift continuously during the 15 minute sampling period. This occurs when the work pattern is such that the worker lifts repetitively for a short time and then performs light work for a short time before starting another cycle, As long as the actual lifting frequency does not exceed 15 lifts per minute, the lifting frequency (F) may be determined for tasks such as this as follows:

1. Compute the total number of lifts performed for the 15 minute period (i.e., lift rate times work time).
2. Divide the total number of lifts by 15.
3. Use the resulting value as the frequency (F) to determine the frequency multiplier (FM) from Table 5.,

For example, if the work pattern for a job consists of a series of cyclic sessions requiring 8 minutes of lifting followed by 7 minutes of light work, and the lifting rate during the work sessions is l0 lifts per minute, then the frequency rate (F) that is used to determine the frequency multiplier for this job is equal to (10 x 8)/15 or 5.33 lifts/minute. If the worker lifted continuously for more than 15 minutes, however, then the actual lifting frequency (10 lifts per minutes) would be used.

When using this special procedure, the duration category is based on the magnitude of the recovery periods between work sessions, not within work sessions. In other words, if the work pattern is intermittent and the special procedure applies, then the intermittent recovery periods for purposes of determining the duration category. For example, if the work pattern for a manual lifting at a rate of 10 lifts/minute, followed by 2 minutes of recovery, the correct procedure would be to adjust the frequency according to the special procedure [i.e., F = (10 lifts/minute X 5 minutes)/ 15 minutes = 50/15 = 3.4 lifts/minute/]. the 2 minute recovery periods would not count towards the WT/RT ratio, however, and additional recovery periods would have to be provided as described above.

3.6 Coupling Component

3.6.1 Definition & Measurement

The nature of the hand to object coupling or gripping method can affect not only the maximum force a worker can or must exert on the object, but also the vertical location of the hands during the lift. A good coupling will reduce the maximum grasp forces required and increase the acceptable weight for lifting, while a poor coupling will generally require higher maximum grasp forces and decrease the acceptable weight for lifting.

The effectiveness of the coupling is not static, but may vary with the distance of the object, from the ground, so that a good coupling could become a poor coupling during a single lift. The entire range of the lift should be considered when classifying hand-to-object couplings with classification based pm overall effectiveness. The analyst must classify the coupling as good, fair, or poor. The classifying a particular coupling design, the more stressful classification should be selected.

Table 6
Hand-to-Container Coupling Classification

1. For Containers of optimal design, such as some boxes, crates, etc., a "Good" hand-to-object coupling would be defined as handles or hand-hold cut-outs of optimal design [see notes 1 to 3 below]	1. For containers of optimal design, a "Fair" hand-to-object coupling would be defined as handles or hand-hold cut-outs of less than optimal design [see notes 1 to 4 below.]	1. Containers of less than optimal design or irregular objects that are bulky, hard to handle, or have sharp edges [see note 5 below.]
2. For loose parts or irregular objects, which are not usually containerized, such as castings, stock, and supply materials, a "Good" hand-to-object coupling would be defined as a comfortable grip in which the hand can be easily wrapped around the object [see not 6 below.]	2. For containers of optimal design with no handles or hand-hold cut-outs or for loose parts or irregular objects, a "Fair" hand-to-object coupling is defined as a grip in which the hand can be fixed about 90 degrees [see note 4 below.]	2. Lifting non-rigid bags (i.e., bags that sag in the middle).

1. An optimal handle design has .75 - 1.5 inches (1.9 to 3.8 cm) diameter, > 4.5 inches (11.5 cm) length, 2 inches (5 cm) clearance, cylindrical shape, and a smooth, non-slip surface.

2. An optimal hand-hold cut-out has the following approximate characteristics: ≥ 1.5 inch (3.8 cm) height, 4.5 inch (11.5 cm) length, semi-oval shape, ≥ 2 inch (5 cm) clearance, smooth non-slip surface, and ≥ 0.25 inches (0.60 cm) container thickness (e.g., double thickness cardboard)

3. An optimal container design has ≤ 16 inches (40 cm) frontal length, ≤ 12 inches (30 cm) height, and a smooth non-slip surface.

4. A worker should be capable of clamping the fingers at nearly 90^0 under the container, such as required when lifting a cardboard box from the floor.

5. A container is considered less than optimal if it has a frontal length > l6 inches (40 cm), height > 12 inches (30 cm), rough or slippery surfaces, sharp edges, asymmetric center of mass, unstable considered bulky if the load cannot easily be balances between the hand-grasps.

6. A worker should be able to comfortably wrap the hand around the object without causing excessive wrist deviations or awkward postures, and the grip should not require excessive force.

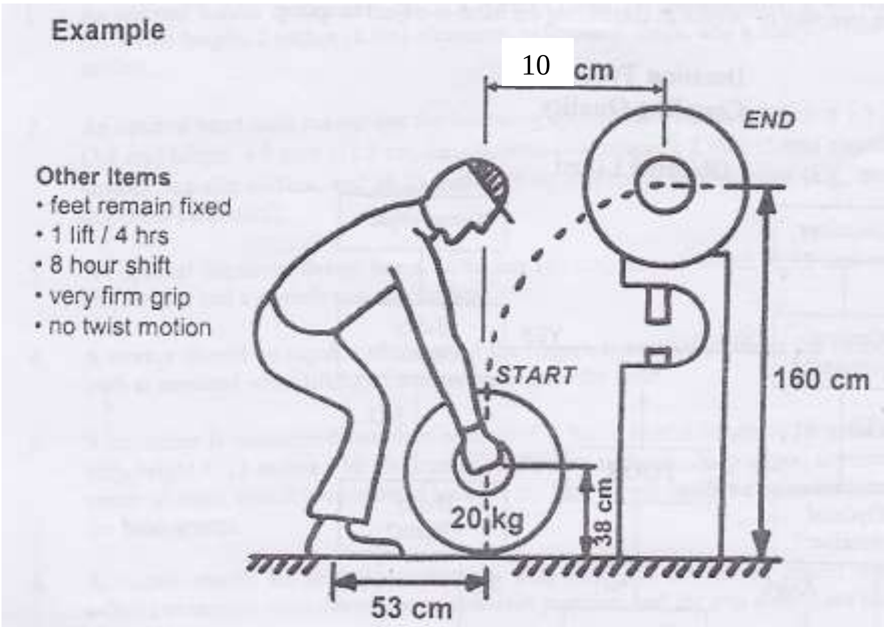
3.6.2 Coupling Multiplier 3

Based on the coupling classification and vertical location of the lift, the Coupling Multiplier (CM) is determined from Table 7.

Table 7
Coupling Multiplier

Coupling Type	Coupling Multiplier	
	V < 30 inches (75 cm)	V ≥ 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

Example



Other Items

* feet remain fixed
* 1 lift/4 hrs
* 8 hour shift
* very firm grip
* no twist motion

Job analysis Worksheet

Department.. Job Description.......................................

Job Title.. ....

Analyst's Name.. ....

Date.. ....

Step 1. Measure and Record Task Variables

Object Weight		Hand Location				Vert. Dist.	Angle		Freq	Time	Object Coupling
		Origin		Dest.			Origin	Dest.	Lifts/min	HRS	
Avg	Max	H	V	H	V	D	A	A	F		C
20	20	53	38	63	160	122	0	0	0.2	8	Good

Horizontal Body-to-Hand Distance (feet are locked in place)
= 53 cm + 10 cm

Total Vertical Lift
= Dest. – Origin
= 160 cm – 38 cm
= 122 cm

Minimum NIOSH Value Reportable

= 63 cm

Step 2. Determine Multipliers and Compute RWL

	RWL = LC x HM x VM x DM x AM x FM x CM
Origin	RWL = 23 x 0.47 x0.889 x 0.856 x 1 x 0.85 x 1 = 7.02kg
Destination	RWL = 23 x 0.4 x 0.745x 0.856 x 1 x 0.85 x 1 =4.99 kg

Origin of Lift
LC = 23 kg = fixed factor
HM = 25/H = 25/53 = 0.47
VM = 1-0.003(V-75) = 1-0.003(38-75) = 0.889
DM = 0.82 + (4.5/D) = 0.82 + (4.5/122) = 0.856
AM = 1 - 0.0032A = 1 - 0.0032(0) = 1
FM : 0.85 (since l lift/4 hrs = 0.004 lifts/min = approx. 0 on graph)
CM : 1.0, (since V = 75 cm and "good" grip)

Destination of Lift
LC = 23 kg = fixed factor
HM = 25/H = 25/63 = 0.4
VM = 1 - 0.003(V-75) = 1 - 0.003 (160 - 75) = 0.889
DM = 0.82 + (4.5/D) = 0.82 + (4.5/122)= 0.856
FM = 0.85 (since 1lift/4 hrs = 0.004 lifts/min = approx.0 on graph)
CM = 1.0, (since V = 75 cm and "good" grip

Step 3. Compute the Lifting index
Origin Lifting Index = Weight / RWL = 20/7.02 = 2.85
Destination Lifting Index : Weight / RWL. = 20/4.99 = 4

Conclusion
* Origin: the start of the lift is acceptable and safe since L1 < 3
* Destination : the end of the lift is dangerous since L1> 3. The "stress level" is LI : 4, the larger of the values. This could be the point where serious low back injury will occur. The task setup must be changed at the destination, or increased job screening, medical monitoring, and training must be introduced.

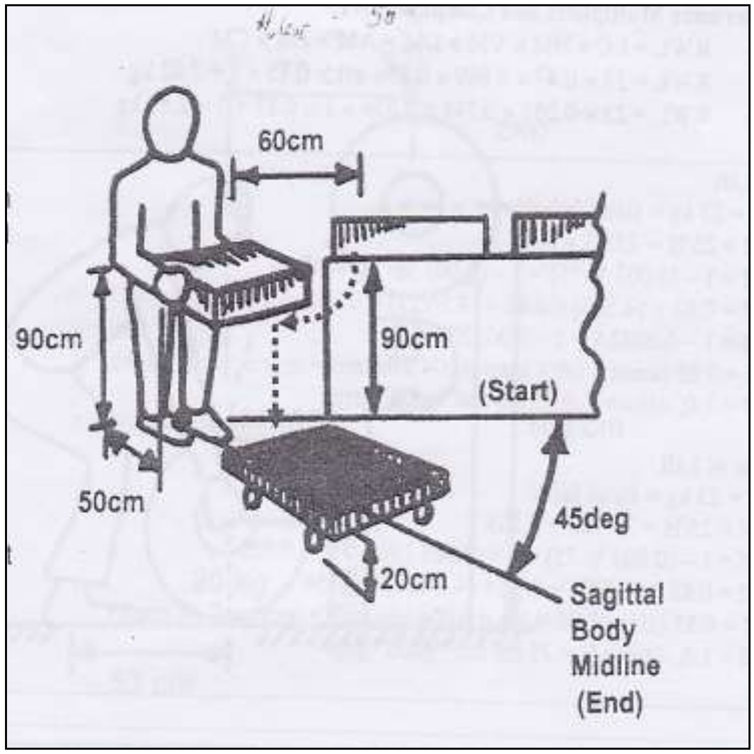
Problem 1

Task

Moving trays from conveyor belt and putting them on the cart

Other Items

* 10 kg trays
* 1 lift/min
* 4 hour shift
* feet are fixed ,
* “fair” grip
* upper body twist motion at START
* tray placed straight down onto cart at END



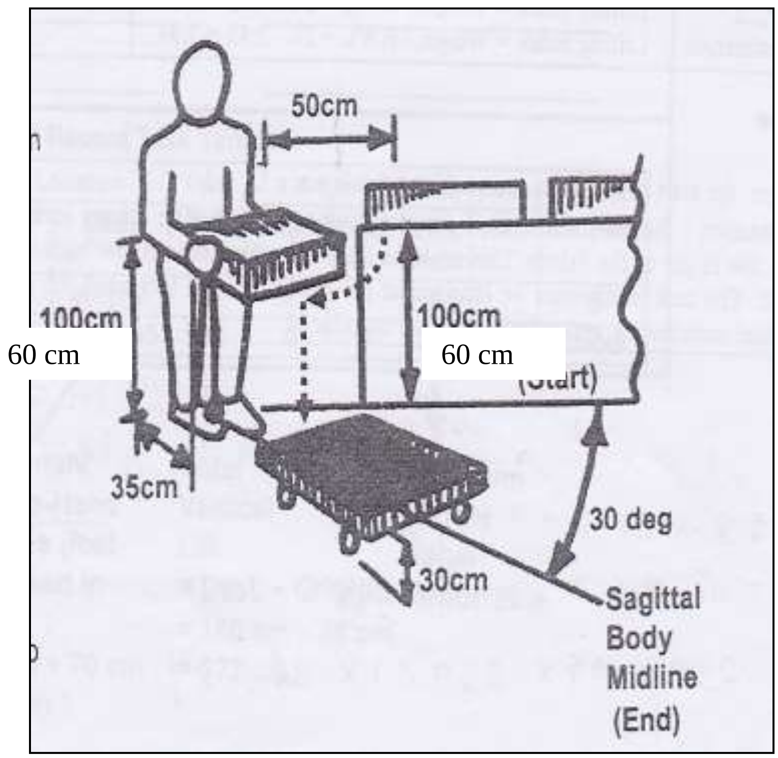
Problem 2

Task

Moving boxes from conveyor belt & placing them onto a cart

Other Items

* 15 kg boxes
* 3 lifts/min
* 3 hour shift
* feet are fixed
* “pool'” grip
* upper body twist motion at START
* boxes placed straight down onto cart at END



Job analysis Worksheet

Department.. Job Description..

Job Title... ....

Analyst's Name... ....

Date... ....

Measure and Record Task Variables

Object Weight		Hand Location				Vert. Dist.	Angle		Freq	Time	Object Coupling
		Origin		Dest.			Origin	Dest.	Lifts/min	HRS	
Avg	Max	H	V	H	V	D	A	A	F		C

Experiment No: 5

Experiment Name: Design of workstation by Applying Ergonomic Principles

Introduction:

Ergonomic considerations in workspace design helps to achieve a "transparent' interface between the user and the task that users are not distracted by the equipment they are using, Distraction may be due to discomfort (e.g., numbness in the buttocks)or to workstation usability problem.

The reduction of postural stress is fundamental to workstation design in ergonomics. A multifaceted approach is needed to arrive at appropriate workstation designs for different workers. The requirements of tasks and the characteristics of users need to be considered in relation to the options of workstation design.

Objective:

The objective of this experiment is to design a workstation using ergonomic principles.

Methodology:

1. Take the relevant anthropometric measurements of the user.
2. Design the assigned workstation using ergonomic principles (with the help of anthropometric data)

Ergonomic principles for workstation design:

Ergonomic Design Consideration:

- Product/ Equipment
- Job aids
- User selection
- Training of user

Follow the 14 guidelines given below for designing ergonomic workstation:

Guideline 1:

Avoid Static Loads and Fixed Work Postures:

- ✓ Static load increases systolic and diastolic blood pressure,
- ✓ Metabolic wastes accumulate in the muscles
- ✓ Consider increasing recovery time,

Standing:

- ✓ Shoes affect center of gravity and forward bending moment,
- ✓ Have hips parallel to the floor,
- ✓ Provide bar rail to vary work posture.
- ✓ Hard floors cause standing fatigue and increase heart rate,

Falls

- ✓ Slips and falls are a major cause of unintentional injury deaths and have annual direct cost/capita of $50-400.

Causes of falls:

- Slips: unexpected horizontal foot movement
- Trips: restriction of foot movement
- Stepping-on-air: unexpected vertical foot movement

Solutions for fall:

* **Prevent the fall:**

-Use well-designed ladders, scaffolds, and ramps properly.

- Provide safe steps.

-Use the three-contact rule.

-Provide good friction and reduce lubricants.

* **Reduce the consequences of the fall:**

- Interrupt the fall.
- Soften the impact.

Head Weight

* The head weighs about the same as a bowling ball.

* Keep the line of sight below the horizontal.

* Maintain forward head tilt of 100-150°

* Avoid backward and sideward tilts.

Hands/Arms

* An arm weighs about 4.4 kg.

* Avoid using the hand to hold up a tool or work piece,
* Avoid working with elevated hands,
* Support the arms on the work surface or chair arms.
* Consider using magnification.

Guideline 2

Reduce Musculoskeletal Disorders

* Set the work height at 50 mm below the elbow.
* Don't bend your wrist.
* Don't lift your elbow.
* Don't reach behind your back.
* Fallow guidelines for hand and arm motions.

Guideline 3

Set the Work Height at 50 mm below the Elbow

* Work height is defined in terms of elbow height.
* Optimum height is slightly below the elbow.
* Optimum height from the elbow is the same for sitting and standing
* Work height is not table height.

Solutions for Work Height

* Change machine height.
* Adjust elbow height.
* Adjust work height on machine.

Multiple-level tables permit easy work height adjustment. In the top view, parts with the same thickness can be processed by different people using different portions of the table. In the lower view. The same person can process parts with different thicknesses using different portions o the table.

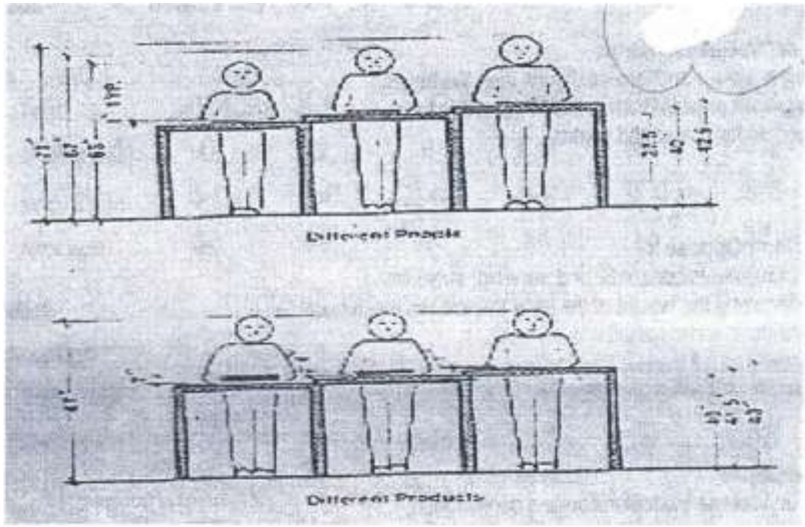


Fig: Multiple Level Tables

VDT Workstations:

* Key items: screen, keyboard, document, eyes, hands
* Workstation furniture must be adjustable.
* Locate the primary visual element first: ahead of the eye, perpendicular to the line of sight.
* Train the operation in adjusting the equipment.
* Provide a wrist rest.

Guideline 4:

Furnish Every Employee with an Adjustable Chair

* The cost of an adjustable chair is very low compared to labor cost.
* Allow users to try chairs in their specific jobs.
* Buy chairs that are easily adjustable.
* Train people in proper adjustment.

Chair Design:

* Seats
  - seat height from floor
  - seat length
  - seat width
  - seat slope
  - seat shape

Recommended dimensions for office chairs (Chaffin eta!., 1999). Dimensions are in cm, angles in degrees.

FEATURE	BRITISH STD. (BS 3079&	EUROPEA N (CEN)	DIFFERENT ET AL.	DANERO & ZELNI	GRAND JEAN	GERMAN STD. (DEN)	SWEDISH STD.
Seat							
Height	43-51	39-54	35-52	36-51	38-53	42-54	39-51
Width	4	40	4	43-48	40-45	40-45	42
Length	*36-41*	38-47	33-41	39-41	38-42	38-42	38-43
Skyic angle	0-5	0-5	0-5	0-5	4-6	0-4	0-4
Backtest							
Top height	3				48-50	32	
Botttom	20						
Center height		17-26	23-25	19-25	30	17-23	17-22
Height		10	15-23	10-20		22	22
Width	30-36	36-40	33	25	32-36	36-40	36-40
Horizontal	31-46	40mm	31-46		40-50	40-70	40-60
Vertical	convex						
Backrest seal angle	95-105		35-100	95-105			
Armtest							
Length	22	20	15-21			20-28	20
Width (breadth)	4	4	6-9 .				4
Height	16-23	21-25	18-25	20-25		21-25	21-25
Intearm rest	47-56	46-50	48-56	46-51		48-50	46

*Backrests

- position of backrest
- molded chair back position & curvature

*Armrests

* Legs/pedestals

- clearance of feet and calves under chair

Guideline 5

Use the Feet as Well as the Hands

* The leg is slower and less dexterous than the hands.
* The legs can provide 3 times the power of the arms.
* Use pedals for power and control.

Guideline 6

Use Gravity; Don't oppose it

* Make movements horizontal or downward; avoid lifting.
* Consider using the weight of the body to increase mechanical force.
*Use gravity to move material to the work.
*Use gravity as a fixture.
* Use gravity in feeding and disposal.

Guideline 7

Conserve Momentum

* Avoid unnecessary acceleration and deceleration.
* Use circular motion for stirring and polishing.
*Follow through in disposal motions.
*Eliminate grasping motions by providing lips, rolled edges, and holes.

Avoid transporting weight in the hand,

Guideline 8

Use 2-Hand Motions Rather Than 1-Hand Motions·

* Cranking with 2 arms is 25% more efficient than with one.
*Using 2 hands is more productive despite taking more time and effort
* Don't use the hand as a fixture.

Guideline 9

Use Parallel Motions for Eye Control of 2-Hand Motions

* Minimize the degree of spread rather than worry about symmetry.
* Estimate the cost of eye control with predetermined time systems.

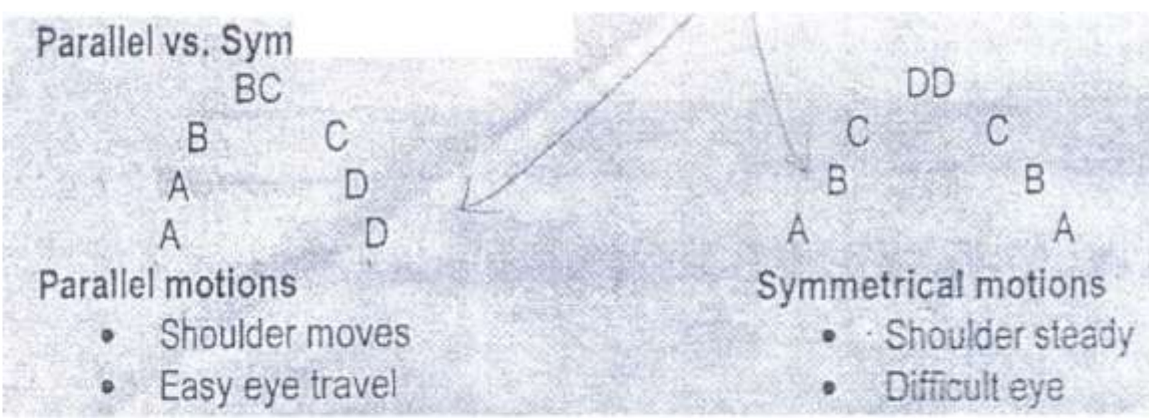


Fig: Parallel vs Symmetrical motions

<u>Guideline 10</u>

Use Rowing Motions for 2-Hand Motions

- * Alternation causes movement of the shoulder and twisting of the torso.
- * Alternation causes higher heart rate.
- * Rowing motions are more efficient and provide greater power

<u>Guideline 11</u>

Pivot Motions about the Elbow

*Motion time is minimized with motion about the elbow.

*Cross-body movements are more accurate than those about the elbow.

*Physiological cost is lower for movements about the elbow.

<u>Guideline 12</u>

Use the Preferred Hand

*The dominant hand is:

- 10% faster for reach-type motions
- More accurate than the non-dominant
- More exposed to cumulative trauma
- 5% to 10% stronger

*Work should arrive from the operator's preferred side and leave from the no preferred side.

<u>Guideline 13</u>

Keep Arm Motions in the Normal Work Area

*Avoid long benches.

*Use swingarms and lazy Susans.

* For high use, keep it close.

*Remember the arm pivots on the shoulder, not the nose.

* The shoulder is very sensitive to small changes in workplace layout.

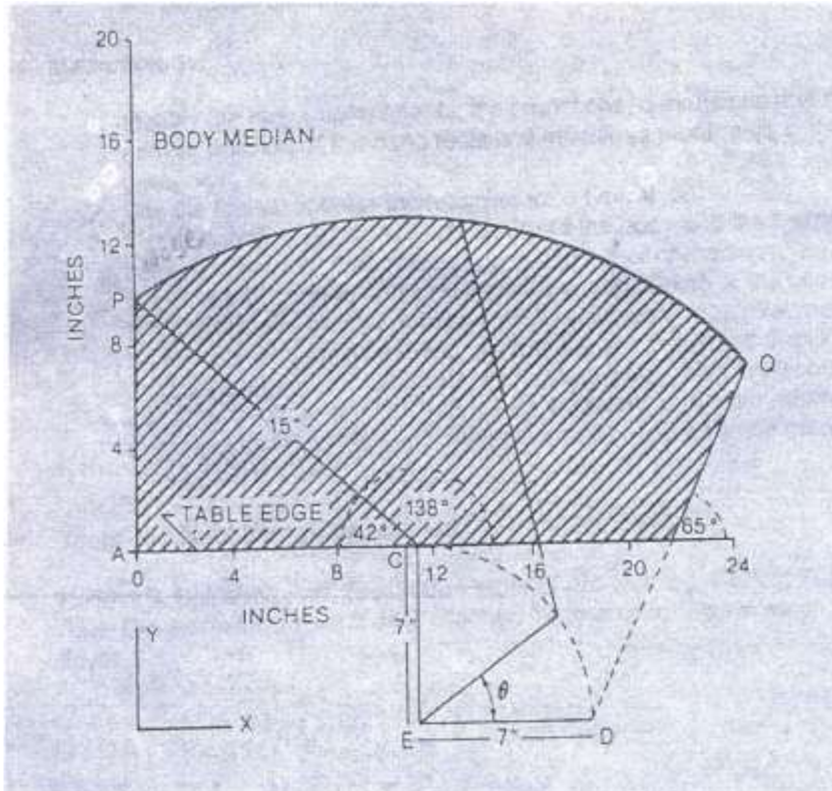


Fig: Windshield Wiper" pattern

Guideline 14

Let the Small Person Reach; Let the Large Person Fit

* Design so most of the user population can use the design.
* Jobs must be designed for both sexes.
* Multipurpose use of equipment functions is becoming more common.
* Civilian industrial population data are not the same as military data.
* International populations be a consideration.
* The proportion to exclude depends on the seriousness of designing people out and the cost of including more people.

Ways to Exclude Few

* One size fits all
* Multiple sizes
* Adjustability

Assigned Workstations

Group 1: A call center operator

Group 2: A student's workstation

Group 3: An office workstation

Group 4: Private car driver's seat

Group 5: Doctor's chamber

Group 6: Wall painter's workstation

Group 7: Watch mechanic's workstation

Group 8: Cobbler's workstation

<u>Experiment No: 6</u>

<u>Experiment Name:</u> Preperation of Hazard Evaluation Worksheet (task based) for a Workstation

<u>Introduction:</u>

A hazard analysis is one of the most important elements of the safety management program. A hazard analysis is an organized and systematic effort to identify and analyze the significance of potential hazards in work place. This analysis provides information that will assist employers and employees in making decisions for improving safety and reducing the consequences of unwanted or unplanned hazardous situation. The hazard analysis should focuses on equipment, instrumentation, utilities, human actions (routine and no routine), and external factors that might impact the process. These considerations assist in determining the hazards and potential failure points or failure modes in a process.

<u>Objective:</u>

Objective of this experiment is to identify hazards and evaluating risks in structured and systematic way in order to prioritize decisions to reduce risks to a tolerable level.

<u>Methodology:</u>

1. Identify potential hazards in the workplace using the hazard evaluation checklist.
2. Evaluating risk by using risk calculator.
3. Decide corrective actions.
4. Preparing the task-based Hazard Evaluation Worksheet.

<u>Theory:</u>

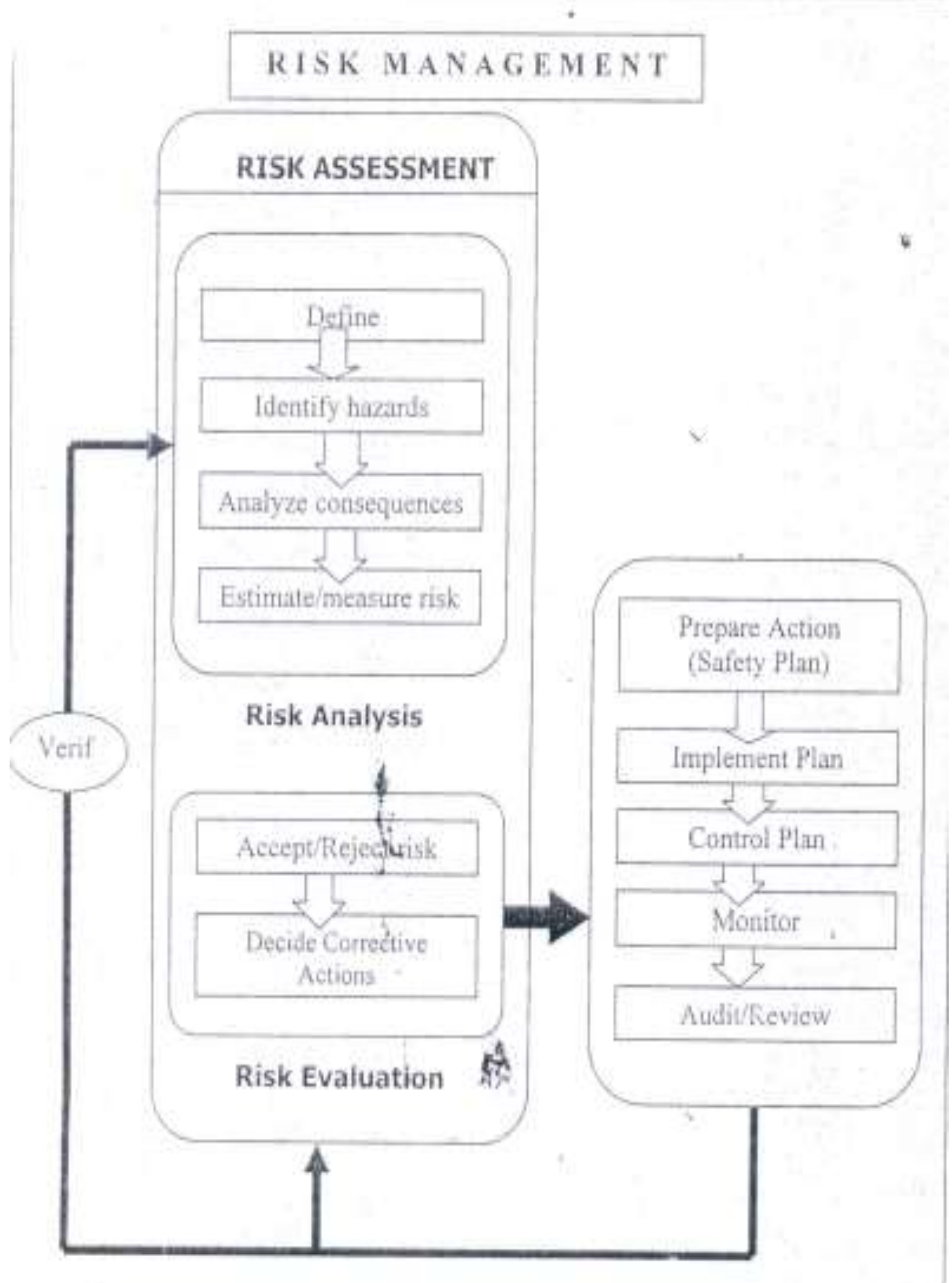
Risk: Chance (Probabilty) of exposure to a hazard combined with the consequences of such exposure.
Hazard: Source or potential source.
Harm: Injury or damage to health, damage to environment, economic loss etc.
Risk: Probability of Exposure * Severity, i.e. F (likelihood* consequences)

Risk Matrix

Likelihood ↑

<table>
<tr><td>Likely</td><td rowspan="2">B</td><td rowspan="2">A</td><td rowspan="3">A</td><td rowspan="4">A</td></tr>
<tr><td>Probable</td></tr>
<tr><td>Possible</td><td rowspan="3">C</td><td rowspan="2">B</td></tr>
<tr><td>Improbable</td><td rowspan="2">B</td></tr>
<tr><td>Remote</td><td>C</td><td>B</td></tr>
<tr><td></td><td>Minor</td><td>Major</td><td>Severe</td><td>Fatal</td></tr>
</table>

Consequences (Severity) →


RISK MANAGEMENT
RISK ASSESSMENT
Define
Identify hazards
Analyze consequences
Estimate/measure risk
Risk Analysis
Accept/Reject risk
Decide Corrective Actions
Risk Evaluation
Verif
Prepare Action (Safety Plan)
Implement Plan
Control Plan
Monitor
Audit/Review

Hazards Identification Checklist. (Sheet 1 of 2)

TYPE OF HAZARD	SOURCE	WHO IS EXPOSED and WHEN
1. Mechanical Hazards		
1.1 Crushing		
1.2 Shearing		
1.3 Cutting/Severing		
1.4 Entanglement		
1.5 Drawing-in/Trapping		
1.6 Impact		
1.7 Stabbing/Puncture		
1.8 Friction/Abrasion		
1.9 High pressure fluid injection		
1.10 Slips/Trips/Falls		
1.11 Falling object		
1.12 Other mechanical hazards		
2. Electrical Hazards		
2.1 Direct contact		
2.2 Indirect contact		
2.3 Electrostatic phenomena		
2.4 Short circuit/overload		
2.5 Source of ignition		
2.6 Other electrical hazards		
3. Radiation Hazards		
3.1 Lasers		
3.2 Electro-magnetic effects		
3.3 Ionising/Non-ionising radiation		
3.4 Other radiation hazards		

TYPE OF HAZARD	SOURCE	WHO IS EXPOSED and WHEN
4. Hazardous Substances (THINK COSHH)		
4.1 Toxic fluids		
4.2 Toxic gas/mist/fumes/dust		
4.3 Flammable fluids		
4.4 Flammable gas/mist/fumes/dust		
4.5 Explosive substances		
4.6 Biological substances		
4.7 Other hazardous substances		
5. Work Activity Hazards		
5.1 Highly repetitive actions		
5.2 Stressful posture		
5.3 Lifting/Handling heavy items		
5.4 Mental overload/Stress		
5.5 Visual fatigue		
5.6 Poor workplace design		
5.7 Other workplace hazards		
6. Work Environment Hazards		
6.1 Localised hot surfaces		
6.2 Localised cold surfaces		
6.3 Significant noise		
6.4 Significant vibration		
6.5 Poor lighting		
6.6 Hot/Cold ambient temperature		
6.7 Other environment hazards		
Use this completed list to produce your Risk Assessment.		

Estimation/Measurement of Risks

Risk may be described in qualitative, semi-qualitativ or quantitative terms:

- Qualitative risk- no figures, judgement is used to estimate risk level
- Semi- quantitative risk- risks may be ranked on a sci·llgaiatlve scale or using .
- Quantitative risk - risk may be described sa frequency or probability in absolute terms.

The risk matrix gives a clear definition of risk. If it was estimated that the chance of the operator exposed to explosion hazard is remote, but the exposure will result in a fatality, the matrix shows this risk level as 'B '. ·

If on the other hand it was estimated that the chance of oil leaking out of a machine which would result in a person slipping is likely. This is expected to result in minor injury which is ranked by the matrix also as risk level 'B'. Therefore risk is not judged by the consequences alone.

Evaluation of Risks

One of the most important steps in risk assessment is to evaluate risks, which are to determine whether the level of risk is tolerable - or unacceptably high and would warrant some urgent attention.

Evaluation 'of risks will depend on the method used for estimating the risk. Risk evaluation could be carried out qualitatively, semi quantitative or quantitative.

- Qualitative risk- judgement is used , difficult to prioritize.

- Semi-quantitative risk - decide which area of the risk matrix.

- Quantitative risk - use the HSE criteria for tolerability of risk if a fatal accident can result from exposure to the hazards.

The Risk Matrix can be a tool to estimate and evaluate risks on a semi guantitative basis. The criteria used for risk evaluation is as follows:

- Risk level 'A' would be regarded as 'Intolerable'. Relevant activity cannot be justified on any grounds.
- Risk level 'B' is a region of uncertainty. Risk assessment is needed to ensure that risks in this region are As Low As Reasonably Practicable or '**ALARP'.**

- Risk level 'C' is broadly tolerable. No further action is necessary.

The Risk Calculator

There arc several drawbacks with the criterion described so far for the estimation and evaluation of risks, as they either focus attention on potential fatal accidents or they miss out a vital component in measuring risk. Thi s is the proportion of time person(s) are exposed to the hazard.

One of the main differences between this risk calculator and other risk matrices, is that the calculator takes into account the frequency and duration of exposure of hazards. The risk calculator is primarily based on a Normogram introduced in the British Standard BS 5304: 1988 (machinery safety) .
·
The basic elements in calculating the order of magnitude of risk are:

- The **chance** which hazard is likely to occur ('probability level') -- this ranges from frequent or 1 in 10, to extremely remote, 1 in1 million. The probabilities are used to describe the Order of magnitude of what is meant by probable, remote, ...etc.
- The **frequency and duration of exposure** to hazard -- this is measured on a scale ranging form very rare or less than 1%, to continuous exposure 100% of the time.
- The **consequences** or potential severity of injury/damage, measured on a scale ranging from category (I) minor loss/first aid, to category (VI) multiple fatalities/total loss ......etc.

By connecting th e appropriate points on each scale and using the tie line in ·the middle of the calculator, it is possible to determine the level of risk involved. The risk leve l is divided into four general categories.

- High risk (A) - which indicates that the level of risk is unacceptable and cannot be justified on any grounds.
- Moderate risk (B)- which indicates that the level of risk should be reduced to a level as low as reasonably practicable 'ALARP', and
- Low risk (C) - which indicates that the level of risk is broadly acceptable and no further precautions should be necessary.

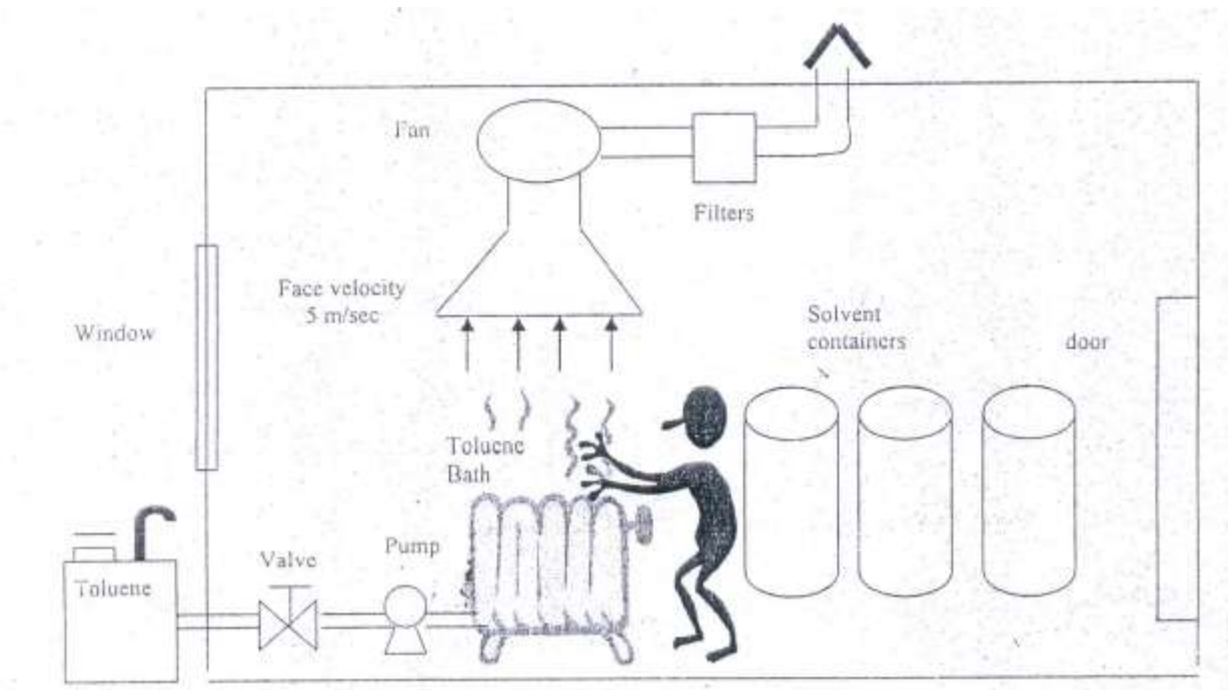
Analysis of the Consequences

Consequences

	I	II	III	IV	V	VI
Personnel	Insignificant	minor	major	severe	fatality	Multi-fatalities
Economic	<£1000	<£10,000	<£100,000	<£1million	<£1million	Total loss
Environment	minor	Short term	major	severe	widspread	catastrophe

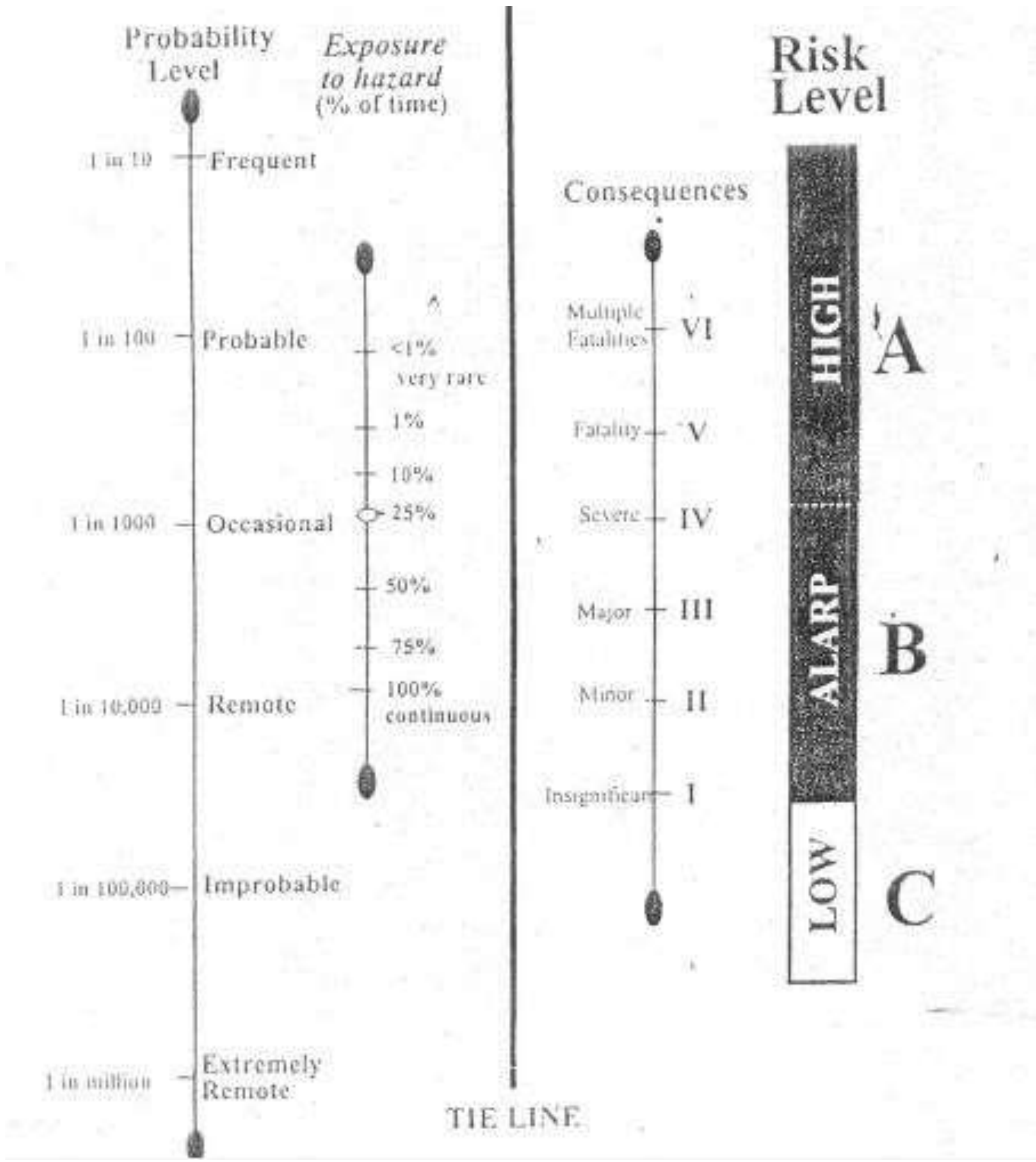
Catagory	Description	Examples
I	insignificant	Bruising, light abrasion etc
II	Minor	‘first aid’(normally reversible)
III	Major	Lossof consciousness, burns etc. (3 days off work
IV	Severe	Serious injury/damage to health (norn1ally reversible)
V	Fatality	Permanent disability, loss of sight, amputation, respiratory damage etc (not reversible)
VI	Multi-fatalities	To in: ude delayed effects, catastrophic

Risk Assessment Case Studies



Example of hazard identification and analysis work sheet (task based)

Machine /process/activity Metal cleaning shop		Hazard Analysis Study Reference		Sheet ……2…… of …..5……	
ACTIVITY TYPE	**Hazardous Events Error/Failure**	**POSSIBLE CAUSES**	**CONSEQUENCES**	**RISK LEVEL**	**CONTROL MEASURES/ACTION REQUIRED**
Filling cleaning tank with Toluene	Overfilling tank	Operator does not switch pump off	Increased toxic and flammable concentration	B	Action: consider high level alarm and pump trip
		Pump fails to stop (electrical fault)	Same as above	A/B	Action: same as above as well as emergency stop
Switch tank heater ON	toluene overheated	Thermostat fails	Major fire	A	Action: consider temperature indicator and alarm + procedure
	toluene not heated	Thermocouple fails	Valves not cleaned	B/C	Same as above
Dipping metallic components inside cleaning tank	Operator fails in tank	Loss of ability	fatality	A	Action: review tank height and consider mechanical handling
	Too many valves put in basket	Cut down cleaning time	Valves fall into tank/upper limb disorder	B	Action: review basket design + consider mechanical handling
		Tank topped up with other chemical	Possible reaction	B	Action: remove chemical drums from the workplace
	Toluene may be contaminated	Delivery of toluene already contaminated	Possible high level of benzene, water, etc.	B/C	Action: insure supplier compile with ISO 9000+sample
		Lack of maintenance	Explosion to high concentrations	B	Action: introduce planned preventive maintenance PPM
	Tank may leak	Impact by mobile equipment	Same as above	B	Action: remove all sources of impact



Probability Level
Exposure to hazard (% of time)
Risk Level
1 in 10
Frequent
1 in 100
Probable
1 in 1000
Occasional
1 in 10,000
Remote
1 in 100,000
Improbable
1 in million
Extremely Remote
<1% very rare
1%
10%
25%
50%
75%
100% continuous
TIE LINE
Consequences
Multiple Fatalities
VI
Fatality
V
Severe
IV
Major
III
Minor
II
Insignificant
I
HIGH
A
ALARP
B
LOW
C

Experiment No: 7

Experiment Name: Determination of Light Level in different workplaces

Introduction:

The majority of industrial tasks depend for their effeciency on adequate vision, therefore lighting plays an important part in determining the efficiency with which tasks are carried out. The amount of light required for the performance of a visual task is influenced by four factors which are independent. These are:

I. The size of the object
II. The contrast between the object and its immediate surround
III. The reflectivity of the immediate surround
IV. Time allowed for seeing.

The amount of which is required for the task cannot be determined until all these factors have been established.

Objective: In this experiment, students have to determine the illumination level of a number of workstations.. They are also required to critically analyze the findings and comment for improvements (if any).

Apparatus:

1. Light Meter

Procedure:

1. Measure the light intensity of the workplace assigned.
2. Identify whether existing lighting system is adequate or not for the specific workplace.
3. Comment for improvements (if any).

Light Meter:

The instrument is easy to use with pocket size and light weight, providing accurate display light level in terms of Foot Candles (FC) or LUX over wide range.

Fig: Light Meter

1. LCD Display
2. Power / function/ range switch: Turn power ON/ OFF and select measurement function and ranges.
3. Photo Detector
4. Max Hold: To hold maximum reading.
5. Data Hold: To hold the reading.
6. Function button: Select measurement functions of Lux or Fc

Operation:

1. Turn the power switch to select range to desired lux/fc range.
2. Hold the “Photo Detector” to light source in a horizontal position.
3. Read the illunination nominal from the LCD display.
4. To hold a measurement , press the “Hold” button, the reading will freeze in the display until the button is pressed again.
5. If the input signal is too strong, the instrument will display one “1” only , then a hoigher range should be selected.
6. For measurements made on the Lux 20000 or 50000 range, the displayed reading must be multiplied by 10 and 100 respectively.

Table: Range Display Multiplier

Range	Units	Multiplier
200	Fc	Direct reading
2,000	Fc & Lux	Direct reading
20,000	Lux	Reading * 10
50,000	Lux	Reading * 100

Example: If a measurement on the 20,000 Lux range displays 500, then the actual measured value is 500 * 10=5000

The table below is guidance for recommended light level in different work spaces:

Activity	Illumination *(lux, lumen/m²)*
Public areas with dark surroundings	20 - 50
Simple orientation for short visits	50 - 100
Working areas where visual tasks are only occasionally performed	100 - 150
Warehouses, Homes, Theaters, Archives	150
Easy Office Work, Classes	250
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500
Supermarkets, Mechanical Workshops, Office Landscapes	750
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000
Detailed Drawing Work, Very Detailed Mechanical Works	1500 - 2000
Performance of visual tasks of low contrast and very small size for prolonged periods of time	2000 - 5000
Performance of very prolonged and exacting visual tasks	5000 - 10000
Performance of very special visual tasks of extremely low contrast and small size	10000 - 20000

Assigned Workplaces

1. Machine Shop (Lathe, Milling)
2. Machine Shop (Drilling, Grinding)
3. Welding Shop
4. Measurement Lab
5. Drawing Lab
6. Computer Lab
7. Classroom
8. Departmental Office Room
9. Library

Experiment No: 8

Experiment Name: Performing time study in workplace

Introduction:

Work measurement is concerned with determining the length of time it should take to complete the job. Time standard provides an indication of expected output. It reflects the amount of time it should take an average worker to do a given job working under typical condition. It is a study of the operational steps or production procedure and the time consumed by them for the purpose of devising methods of increasing efficiency or productivity of workers. This work-study aims at improving the existing and proposed ways of doing work and establishing standard times for work performance. Improving the ways in which the work is done (methods) improves productivity, work study and industrial engineering techniques and training are the areas which improve the work methods, which in term enhances the productivity.

Time study was formally introduced by Frederick Taylor in nineteenth century. It is the most widely used method of work measurement; especially appropriate for short, repetitive tasks.

Objective: In this experiment, students have to determine standard work time for workers in their assigned workplaces. They are also required to critically analyze the findings and comment for further produtivity improvements (if any).

Apparatus:

1. Stop Watch

Procedure:

1. Obtain and record all the job information.
2. Define the task to be studied and inform the worker(s) who will be studied.
3. Break down the operation into elements.

4. Determine the number of cycles to be observed.
5. Check that the job is being performed efficiently before setting the time standard.
6. Measure the time of the each job element using stop watch.
7. Assess the effective working speed of the operator and rate the performance.
8. Determine the allowances to be made.
9. Compute the standard time.
10. Test and review standards wherever necessary.

Standard Time

Standard time is the amount of time a qualified worker should spend to complete a specified task, working at sustainable rate, using given methods, tools and equipment, raw material and workplace arrangement.

Time study is used to develop a time standard based on observations of one worker taken over a number of cycles. However, it is very difficult to select the right person who should perform the job. Hence, average of a few properly trained workers' performed time are taken as the standard. The standard time is then applied to the work of all others in the organization who perform the same job.

Development of a time standard involves computation of 3 times:

I. Observed time (OT)
II. Normal time (NT)
III. Standard time (ST)

I. Observed Time (OT): Simply the average of the recorded times.

$$OT = \frac{\sum x_i}{n}$$

$\sum x_i =$ sum of recorded time

n = number of observations

II. Normal Time (NT): It is the observed time adjusted for worker performance.

Computed by multiplying the observed time by a performance rating of the concerned worker.

$$NT = OT * PR$$

If ratings are made on an element-by-element basis,

$$NT = \sum (OT_i * PR_i)$$

OT_i – average time for element i

PR_i – performance rating for element i

Performance Rating *:* Assessing the effective speed of working of the operator relative to the observer's concept of the rate corresponding to standard rating.

Time studies should be made on a number of qualified workers; and that very fast or very slow workers should be avoided.

III. Standard Time (ST): It is the normal time required for a job plus an allowance time.

$$ST = NT * AF$$

AF= Allowance factor

Allowances: Many jobs require spending of human effort and some allowance must therefore be made for recovery from fatigue and for relaxation.

Allowance must be made to allow a worker for different delays:

- Personal – drink, restroom
- Unavoidable – machine adjustment
- Material shortage
- Worker fatigue (physical / mental)

Allowance can be based on

- Job time (allowance for total job produced) $AF_{job} = 1 + A$
- Time worked (allowance for total work period) $AF_{day} = \frac{1}{1 - A}$

Assignment:

1. A direct time study was taken on a manual work element. The regular cycle consisted of four elements a, b, c and d.

Work element	**a**	**b**	**c**	**d**
Observed time (min)	0.56	0.25	0.50	1.10
Performance rating	100%	80%	110%	100%

Determine Standard time for the cycle, using allowance factor of 15%.

2. Find out the standard time using the following data:
Average time for machine elements = 6 min
Average time for manual elements = 4 min
Performance rating = 110%
Allowances = 10%

3. Assuming that the total observed time for an operation of assembling an electric switch is 1.00 min. If the rating is 120%, find normal time. If an allowance of 10% is allowed for the operation, determine the standard time.

4. In attempt to increase productivity and reduce cost, a company is planning to install an incentive pay plan in its manufacturing plant. In developing standards for one operation, time study analysts observed a worker for a 30 minute period. During that time the worker completed 42 parts. The analysts rated the worker as producing at 130 percent. The base wage rate for a worker is $5 per hour and an incentive of $ 2 for each extra unit produced. The firm has established 15% as a fatigue and personal time allowance.

i. What is the standard time for the task?

ii. If the worker produced 500 units during an eight hour day, what wages would be the worker have earned?