Discussion Paper
Manual Materials Handling and Safe Lifting

INTRODUCTION

The total cost of unintentional injuries at work in the US was estimated to be over $175 billion in 2007 (NSC, 2009). Approximately 40% of occupational injuries and illnesses resulting in days away from work were strains and sprains, 24% were associated with overexertion, and 13% with overexertion while lifting (NSC, 2009). In the marine industry, sprains represented approximately 20% of injuries resulting in days away from work (ABS, 2010). It is also estimated that 70 million working days are lost each year in the United Kingdom (UK) due to back pain (Pheasant, 1990).

There are many factors that affect personnel's ability to safely and effectively perform materials handling tasks, including the design of the task, the form of the material handled, the design of the working area, the availability of assisted lifting devices, and the physical/physiological characteristics of the people themselves.

Keys to Acceptable Materials Handling and Lifting. A general approach to designing for materials handling and lifting tasks include the following:

- Avoid manual materials handling altogether, whenever possible
- Redesign the load
- Redesign the lifting/carrying task
- Redesign the working environment
- Introduce assisted lifting devices.

One-versus Two-Person Lifting and Carrying. In general limits on lifting and carrying are as follows:

- Items weighing up to 20 kg (45 lbs) or less may be lifted or carried by one person.
- Items weighing more than 20 kg (45 lbs) and less than 40 kg (90 lbs) should be lifted or carried by two persons, provided the lifting load is distributed equally between the two.

Assisted Lifting. Assisted lifting devices (e.g., padeyes, chain falls, come-alongs, rail cranes, mono-rails, etc.) should be provided for items or devices under the following conditions:

- Load weight in excess of 11kg (25 lbs), for loads which are lowered from or placed in locations greater then 1525 mm (60 in) high
- Load weight in excess of 11kg (25 lbs), which needs to be supported during removal, replacement, or installation
- Load weight in excess of 20 kg (45 lbs), where the load is not distributed evenly or is bulky
- Load weight in excess of 40 kg (90 lbs).

TERMS/DEFINITIONS

Anthropometrics: The measurement of human variability of body dimensions and strength as a function of gender, race, and regional origin.

Assisted Lifting: The use of devices such as cranes, hoists, counter-balancing mechanisms, trolleys, mono-rails, come-alongs, padeyes, or A-frames by personnel to perform materials handling tasks.

Center of mass: the mean location of all the mass in a system (sometimes "center of gravity is used).

Ergonomic: Designed for ease of use, maximum comfort, efficiency, and safety.

Manual Materials Handling: Actions taken by personnel to physically (manually) lift, lower, push, pull, hold, or carry loads.

Personal Protective Equipment: Specialized clothing or equipment worn by employees for protection against health and safety hazards

Psychophysical: pertaining to the mind and its relation to physical manifestations.

Static Lift: The physical act of a person attempting to move a fixed or immovable object with muscle contraction, but no motion of the object to which force is applied. A static lift is also known as an isometric lift.

DISCUSSION

Materials Handling Factors

There are numerous factors that impact the safety and efficiency of materials handling tasks. For this reason, pre-planning of materials handling tasks should be undertaken before lifting, carrying, or moving any load. Key factors include the actual materials handling task, the size and weight of the load, how the load will be lifted (e.g., manually or with assisted lifting devices), how the load will be moved or transported, the working area, personnel capabilities, and safety considerations. Each factor, either alone, or in combination with other factors, can significantly impact materials handling tasks.

Task-Related Factors. Task-related factors, for both manual materials handling and assisted lifting, that should be considered as a part of pre-planning include:

- Vessel and offshore installation layout in terms of porches, hatches, removable plates, crane placement, pathway size, and location for moving loads
- Vessel or installation motions or movement, as well as motions or movement associated with support or supply vessels
- The material's location with regard to access, pathways, hatches, doors, porches, and any obstructions (overhead or on the deck) in the path of movement
- Distance the load needs to be moved, from the origin of the lift to its final destination (e.g. the distance between the point where the object is lifted and the point where the object is placed)
- Type of lifting method (e.g., manually or with assisted lifting devices).

Task-related factors related solely to manual materials handling that should also be considered during pre-planning include:

- Need for support equipment (e.g., carts, trolleys, overhead rail or conveyor systems)
- How personnel will handle the load (e.g., lifting, lowering, carrying, pushing, pulling, and static lifting/loading)
- The duration and frequency of the handling task (e.g., how long and how often will personnel be performing the handling task?)
- The required body postures for lifting and placing (e.g., reaching, bending, and twisting of the torso and flexion of joints such as the wrist, elbow, neck, and knees)
- The distance of the load from the torso of the worker (e.g. the distance between the load and the worker's body)
- Load height at lift origin and termination, as well as carry distance (e.g. the height the object is at when it is initially lifted, and the height at which the object is placed upon completion of carrying the load)
- Effects of gloves and/or other personal protective equipment (e.g. boots, hat)
- Rest/recovery time between lifts.

Load-Related Factors. Load-related factors, for both manual materials handling and assisted lifting that should be considered as a part of pre-planning include:

- Weight, size, and dimensions of the load
- "Bulkiness" of the load and the potential difficulty in securing (e.g., strapping) or manually grasping the load
- Stability or instability of the load (e.g., likelihood of the load to shift, including within a container, during movement)
- Center of mass of the load.

Working-Area Related Factors. Working-area related factors, for both manual materials handling and assisted lifting that should be considered as a part of pre-planning include:

- Vessel and offshore installation layout in terms of space availability for the securing (e.g., strapping) or manually grasping the load
- The material's location with regard to access, pathways, hatches, doors, porches, and any obstructions (overhead or on the deck) in the path of movement
- The design of stairs, ladders, pathways, hatches, and doors
- Extremes of temperature, humidity, and/or air movement
- Area lighting where the loads are secured, grasped, lifted, and placed.

Working-area factors related solely to manual materials handling that should also be considered during pre-planning include:

- Walking/working surfaces (e.g., slippery, unstable, moving, variable, inclined)
- Design and condition of handling aides (e.g., hand trucks, carts, etc.).

Personnel Capacity-Related Factors. The factors related to the personnel involved with or performing the manual or assisted materials handling tasks that should be considered in relationship to the task, the load, and the work area factors during pre-planning include:

- Anthropometrics (e.g., international population differences)
- Strength
- Physical condition (e.g., cardiovascular and muscular endurance)
- Flexibility (range of motion)
- Health habits (e.g., smoking, alcohol consumption)
- History of previous injury or predisposition for injury
- Manual and assisted materials handling knowledge, training, and experience.

Safety Considerations. Safety must be considered for both manual and assisted materials handling. Safety concerns should be examined within the context of the task, load, working area, and the personnel involved with or performing the handling task. Safety considerations include:

- Clearance for equipment through walkways, passages, doorways, etc., and any obstructions (overhead or on the deck) in the path of movement
- Availability of motorized/mechanized equipment to support inspection and handling
- Vehicles and equipment securing (e.g., brakes, chocks, etc.) while loading and unloading
- Surfaces likely to be effected by wind gusts (e.g., sheets of boarding)
- Noise levels (e.g., ambient and impulse)
- Obstruction of vision (e.g., crane operator or other load handling personnel)
- Housekeeping requirements (e.g. is the work area provided with amenities for keeping the area free from clutter or obstructions)
- Load swinging (e.g. Room for the load to move freely while it is being transported)
- Flammable, corrosive, or reactive substances
- Surface characteristics for personnel or placement of temporary assisted lifting equipment (e.g., even surfaces, those that are likely to abrade, puncture, cut or burn)
- Exposure to vibration and shock for personnel or the load
- Personnel slip, trip, and fall hazards
- Consequences associated with dropping the load.

Manual Materials Handling Planning Tools

There are many tools available for the evaluation and design or re-design of manual materials handling tasks. These tools can assist with planning activities by allowing manual materials handling tasks to be prioritized and by determining when assisted lifting may be required. The majority of these tools are based on a North American population, but some do exist for international populations. Table 1, “Material Handling Planning and Analysis Tools,” identifies several tools, their uses and their sources.

TABLE 1
Material Handling Planning and Analysis Tools

Analysis Tool	*Uses*	*Source*
NIOSH Lifting Equation	Analysis of lifting with several constraints on its application	Waters, T., Putz-Anderson, V., and Garg, A. (1994). *Applications Manual for the Revised NIOSH Lifting Equation.* US Department of Health and Human Services (NIOSH) Publication No. 94-110.
Psychophysical Tables	Analysis of lifting, lowering pushing, pulling, carrying	Snook, S. H. and Ciriello, V. M. (1991). *The design of manual handling tasks: Revised tables of maximum acceptable weights and forces. Ergonomics* 34:1197.
Psychophysical Lifting Capacity for Chinese Subjects	Lifting capacity of Chinese subjects, as well as anthropometric considerations	Wu, Swei-Pi. (1999). *Psychophysically determined infrequent lifting capacity of Chinese participants, Ergonomics* 42(7).
Job Stress Index	Analysis of lifting	Mital, A., Nicholson, A., and Ayoub, M. (1993). A Guide to Manual materials Handling, Taylor and Francis, Washington, DC.
Energy Expenditure Model	Analysis of lifting, lowering, and carrying	Garg, A., Chaffin, D., and Herrin, G.: *Prediction of Metabolic Rates for Manual Materials Handling Jobs*, American Industrial Hygiene Journal, 38, 661 – 674 (1978).

Manual Materials Handling Planning

The values in Table 2, “Design Weight Limits for Lifting” and Table 3, “Design Weight Limits for Carrying,” provide recommended maximum values based on the “ideal” lift or carry for manual material handling tasks. The “ideal” lift or carry includes ergonomic consideration of all the factors and considerations listed in “Materials Handling Factors” above. The “ideal” lift is a lift of a box with a stable load and good handholds, with the center of the load, or center of mass, placed 150 mm (6 in) away from the lifter’s body, at elbow height, carried to the final destination, less then 10 m (33 ft) away, over a dry deck, and placed on a surface at elbow height.

Personnel Lifting Limits. The weight limits in Table 2, “Design Weight Limits for Lifting,” should be considered as maximum values in determining the design weight of items requiring one person lifting with two hands. The weight limits may be doubled for two person lifts, provided the load is split equally between the lifters and both lifters have the same handles or handholds. If the weight of the load is not split equally, the weight limit applies to the heavier lift point.

Object Load Size. The weight limits in Table 2, “Design Weight Limits for Lifting,” apply to an object with equally distributed weight and a compact size not exceeding 460 mm (18 in) high, 460 mm (18 in) wide, and 300 mm (12 in) deep (see Figure 1, “Ideal Object Size and Carrying Mode”). This places the center of the load at half the object’s depth, or 150 mm (6 in) away from the body. If the depth of the object being lifted exceeds 300 mm (12 in), see Table 4, “Lifting and Carrying Multipliers” for weight limit adjustments.

Lifting in the Presence of Obstacles. The weight limits in Table 2, “Design Weight Limits for Lifting,” assumes that there are no obstacles between the person lifting and the surface onto which the object is to be placed. If there is an obstacle, such as a lower shelf, see Table 4, “Lifting and Carrying Multipliers” for weight limit adjustments.

Lifting Frequency. The weight limits in Table 2, “Design Weight Limits for Lifting,” are not for repetitive lifts as found in the loading or unloading of supply vessels. If the frequency of lifts exceeds one lift in 5 minutes or 20 lifts per 8 hours, see Table 4, “Lifting and Carrying Multipliers” for weight limit adjustments.

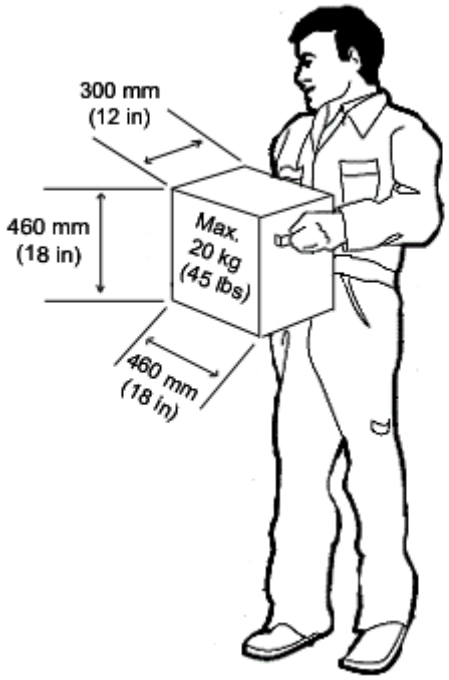
TABLE 2
Design Weight Limits for Lifting*

Handling Function	*Male and Female Handlers*	*All Male Handlers*
Lift an object from the floor and place it on a surface not greater than 1525 mm (60 in) above the floor.	16.8 kg (37 lbs)	20.00 kg (45 lbs)
Lift an object from the floor and place it on a surface not greater than 915 mm (36 in) above the floor.	20.0 kg (45 lbs)	20.0 kg (45 lbs)

* 1 See Section 11, Table 4, “Lifting and Carrying Multipliers” for weight limit adjustments.

2 Weight limits are based on a North American population.

FIGURE 1
Ideal Object Size and Carrying Mode



Personnel Carrying Limits. The weight limits in Table 3, “Design Weight Limits for Carrying,” should be used as the maximum value in determining the design weight of items requiring one person carrying of objects.

The weight limits can be doubled for two person carries, provided the load is uniformly distributed between the carriers. If the weight of the load is not uniformly distributed, the weight limit applies to the heavier lift point.

For carrying activities, it is assumed that the object is first lifted from the floor, carried, and placed on the floor or on another surface not higher than 915 mm (36 in).

Carrying Frequency. The weight limits in Table 3, “Design Weight Limits for Carrying,” are not for repetitive carries. If the frequency of carry exceeds one carry in 5 minutes or 20 carries per 8 hours, see Table 4, “Lifting and Carrying Multipliers” for weight limit adjustments.

Object Carry Size. The weight limits in Table 3, “Design Weight Limits for Carrying,” apply to an object with equally distributed weight and a compact size not exceeding 460 mm (18 in) high, 460 mm (18 in) wide, and 300 mm (12 in) deep (see Figure 1, “Ideal Object Size and Carrying Mode”). This places the handholds at half the depth, or 150 mm (6 in) away from the body. If the load size exceeds these dimensions, see Table 4, “Lifting and Carrying Multipliers” for weight limit adjustments.

TABLE 3
Design Weight Limits for Carrying*

Handling Function	*Male and Female Handlers*	*All Male Handlers*
Carry an object 10 m (33 ft) or less	19.0 kg (42 lbs)	20.0 kg (45 lbs)
Carry an object more than 10 m (33 ft):		
Object carried at side with one hand (tool chest, container with handles, etc.)	9.5 kg (21 lbs)	10 kg (22.5 lbs)
Object with irregular sides (electronic equipment chassis, etc.)	11.4 kg (25 lbs)	14.0 kg (35 lbs)
Object or other item with two hands	14.0 kg (35 lbs)	20.0 kg (45 lbs)

*1 See Table 4, "Lifting and Carrying Multipliers" for weight limit adjustments.

2 Weight limits are based on North American populations.

TABLE 4
Lifting and Carrying Multipliers

Lifting or Carrying Situation	*Multiplier*
Age – For personnel over 50 years old	0.80
Asymmetrical lifting – When a worker must twist the torso 45° or more	0.70
Asian male	0.80
Asian female	0.85
Handholds – In the absence of handles or with poor handholds	0.90
Lifting or carrying frequency – If the frequency of lift or carry exceeds one in 5 minutes or 20 lifts or carries per 8 hours, the weight limits should be reduced by the factor (8.33 × *LF*)/100, where *LF* is the lift frequency in lifts per minute. For example, if the lift frequency is 6 lifts per minute, then the maximum permissible weight is reduced by (8.33 × 6)/100, which equates to .5	(8.33 × *LF*)/100
Lifting or carrying load size	
– If the depth of the object exceeds 61 cm (24 in)	0.66
– If the depth of the object exceeds 91 cm (36 in)	0.50
– If the depth of the object exceeds 122 cm (48 in)	0.33
Limited Headroom – Where personnel must remain "bent" at the waist	0.65

Obstacles – If a lower protruding shelf or other obstacle limits the lifter's approach to the desired surface	0.66
Temperature – For temperatures greater than 32°C (90°F)	0.88

Reducing or Eliminating Manual Materials Handling. As previously mentioned in, "Keys to Acceptable Materials Handling and Lifting," where possible, manual materials handling tasks may be reduced or eliminated by applying any or all of the following strategies:

- Avoid manual materials handling altogether, whenever possible
- Redesign the load
- Redesign the lifting/carrying task
- Redesign the working environment
- Introduce assisted lifting devices.

Assisted lifting aids include devices such as cranes, hoists, counter-balancing mechanisms, trolleys, mono-rails, come-alongs, padeyes, A-frames, etc. Regardless of the choice, in order to use assisted lifting devices, sufficient space is needed either to permanently install a new lifting device or to temporarily place removable equipment in addition to space needed for the load, its manipulation, and personnel assisting with the materials handling task.

Materials Handling Planning for Assisted Lifts

In cases where large (e.g., 40 kg (90 lbs) or greater) loads are anticipated, it is best if a materials handling study is undertaken during the design stage of a vessel or offshore installation in order to determine the following:

- Identify which equipment or items are likely to need removal or replacement
- The dimensions and weights associated with the equipment or items
- The location of the equipment or items within the vessel or installation
- The frequency of materials handling for these
- The assisted lifting methods and devices, including:
  - Single lift, multi-staged lift, lift to a vessel or dock, etc.
  - Whether devices will be permanently installed or moveable
  - The best locations for the permanently installed assisted lifting devices
  - The storage locations for moveable or erectable assisted lifting devices
  - The availability of assisted lifting devices that must be obtained from outside sources
- Transport method within the vessel or offshore installation
- Transport method off the vessel or offshore installation

Materials handling studies should determine all lifting, carrying, moving, and transporting activities related to operations or maintenance in all modes of operation from regular replenishment activities for food stores or supplies to emergency situations. Where such studies are not performed during the design stage, the same types of

factors should be considered within the context of the existing vessel or offshore installation when planning an assisted materials handling task.

SUMMARY

Materials handling studies should determine all lifting, carrying, moving, and transporting activities related to operations or maintenance in all modes of operation from regular replenishment activities for food stores or supplies to emergency situations. Where such studies are not performed during the design stage, the same types of factors should be considered within the context of the existing vessel or offshore installation when planning an assisted materials handling task.

REFERENCE

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