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NIOSH HEALTH HAZARD EVALUATION REPORT

HETA 95-0335-2566
Schrock Cabinet Company
Arthur, Illinois

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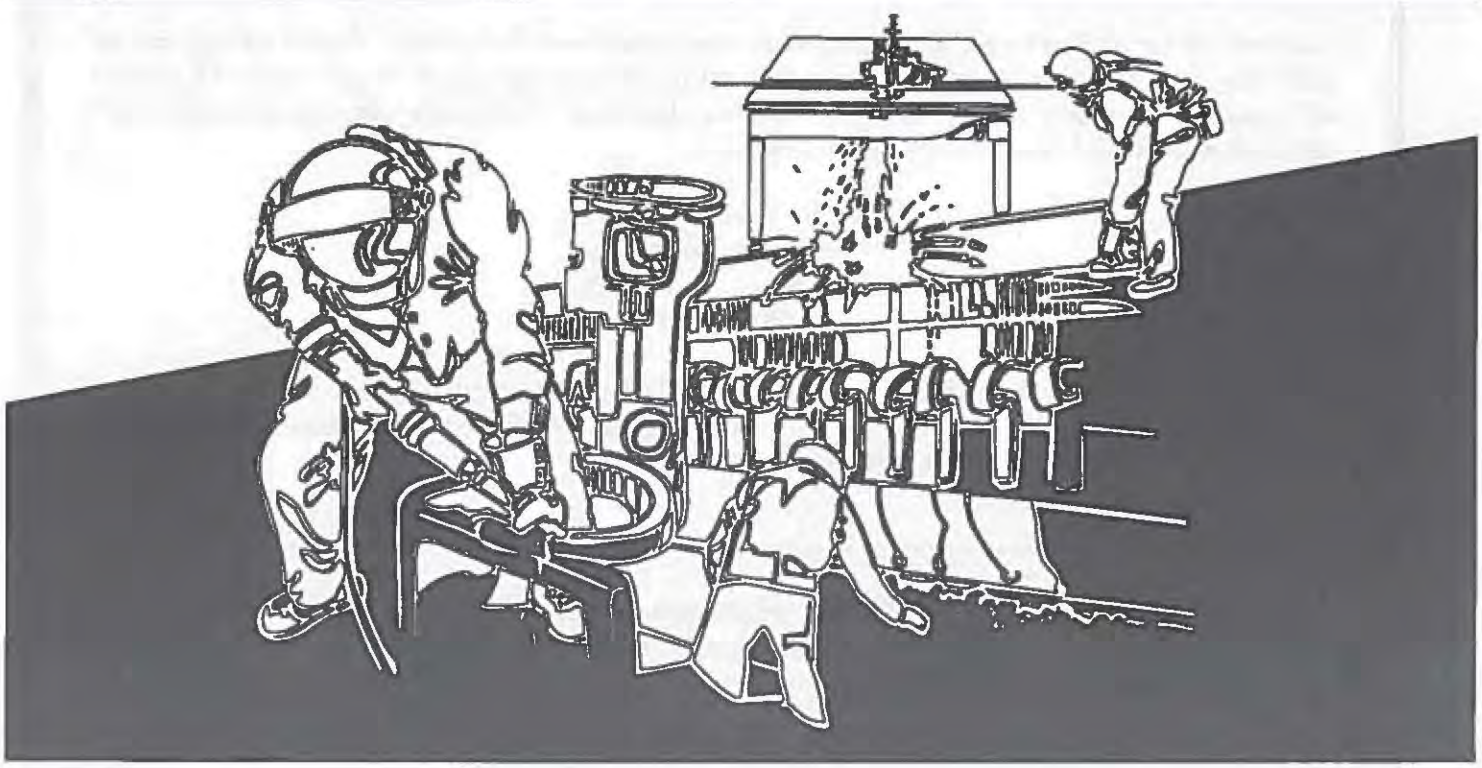

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

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SUMMARY

On September 20-21, 1995, the National Institute for Occupational Safety and Health (NIOSH) responded to a health hazard evaluation request from the management of the Schrock Cabinet Company in Arthur, Illinois, to evaluate potential lifting hazards in the shipping department. The request was prompted by an increase in musculoskeletal disorders among workers in this department in the last two years, and the introduction of a new and heavier line of cabinets. NIOSH investigators reviewed the company's Occupational Safety and Health Administration Log and Summary of Occupational Injuries and Illnesses (OSHA 200), interviewed employees, and administered a symptom questionnaire to all current employees in the shipping department to assess the extent of the musculoskeletal problems. The investigators also observed and videotaped the activities of eight workers performing lifting activities in the loading dock and staging area. Measurements of box sizes, lifting heights and cabinet weights were obtained. Representative lifts were analyzed using the Revised NIOSH Lifting Equation.

The medical evaluation revealed that 26% (5 of 19) of the shipping department employees were reported to have an OSHA recordable musculoskeletal disorder in the first 8 months of 1995 and 79% (15 out of 19) of the employees reported work-related musculoskeletal pain or discomfort in the past year. The lifting analyses showed that more than half of lifts executed by trailer loaders exceed the NIOSH Recommended Weight Limit (RWL), and that some exceed the RWL by more than three times. Using a multi-task analysis approach and various assumptions about the job, composite lifting indices ranging from 3.9 to 8.2 were calculated for the trailer loading job. Based on this analysis, it is possible that this job will place even a highly select group of workers at substantial risk for low back injury.

Based on the data obtained during this Health Hazard Evaluation, NIOSH investigators conclude that work in the shipping department imposes a high level of physical demand, which may increase the risk of work-related musculoskeletal injury. The medical survey found a high prevalence of self-reported work-related back pain or discomfort in the year prior to the survey, confirmed by the OSHA Illness and Injury Logs. Efforts should be made to reduce these demands by redesigning the job. Recommendations for changes in work organization, more frequent rotation, and additional worker training are also provided in this report.

KEYWORDS: SIC 2434 (Wood Kitchen Cabinets), ergonomics, musculoskeletal disorders, repetitive lifting, trailer loading, lower back pain.

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INTRODUCTION

On September 20-21, 1995, representatives from the National Institute for Occupational Safety and Health (NIOSH) visited the Schrock Cabinet Company in Arthur, Illinois, in response to a management request for a health hazard evaluation (HHE). The request was prompted by concerns about potential hazards due to repetitive lifting by workers employed in the shipping department. Specifically, the company reported an increase in the number of musculoskeletal disorders in the last two years. Furthermore, the company had recently introduced a new and heavier line of cabinets to its product mix, prompting concerns from the shipping department employees. During an opening conference, NIOSH staff met with management and worker representatives to discuss the HHE objectives:

1. Determining the prevalence of musculoskeletal complaints associated with the material handling activities of workers in the shipping department.

2. Assessing potential lifting hazards due to manual material handling activities in the shipping department.

3. Developing recommendations for reducing or eliminating the physical stresses associated with manual material handling activities in the shipping department.

BACKGROUND

Plant and Job Description

Schrock Cabinet Company, a subsidiary of White Consolidated, Inc., is a manufacturer of handcrafted wooden cabinets located in Arthur, Illinois. The company employs 600 people; 460 of these are employed in the cabinet making shop. The plant operates in two shifts and is non-unionized.

The focus of this investigation was limited to workers employed in the shipping department. At the time of this study, 19 workers (10 on day shift, 9 on night shift) were employed in this department. Almost all of these workers are employed as "trailer loaders." As the title implies, these workers are responsible for loading cabinets into one of 22 trailers for distribution. In addition, one worker on each shift is employed as a "truck driver." Although truck drivers were not observed extensively during this investigation, they do perform some loading tasks at loading docks located elsewhere in the plant.

Trailers are loaded manually, without mechanical assist devices. In addition to moving cabinets into trailers, trailer loaders manage a 9300-foot^2 staging area located behind the loading dock. The staging area serves as a temporary storage area for cabinets waiting to be shipped. The company uses a "just-in-time" (JIT) inventory system whereby cabinets are made as needed and shipped immediately afterward. When this system breaks down, parts of an order are stored in the staging area until the entire order (also known as a "drop") is completed and can be loaded together on the trailer. The two shifts are organized somewhat differently with regard to how this work is carried out. The day shift uses a team approach, whereby loaders work in groups of 2 or 3 to load individual trailers in order of their scheduled departure. The night shift uses a more individual approach, whereby each loader is assigned to a number of different trailers (usually 5) for which he alone is responsible. On both shifts, there is some daily rotation; i.e., workers who load trailers one day may work in the staging area the next. The only worker who does not rotate is the truck driver.

Cabinets arrive in the staging and shipping areas individually packed in cardboard boxes, via conveyor belt. Cabinets range in weight from less than 10 lbs. to more than 200 lbs. (exclusive of packing materials), depending on their size and construction. The average weight of Schrock's top-selling cabinets (those that comprise 67% of sales) is approximately 47 lbs. When all the cabinets in an order (or drop) are assembled, the cabinets are released to the shipping area via conveyor belt. A drop may contain as many as 50-60 cabinets; a full-size trailer (3200-foot^2) typically holds between 6 and 9 drops. To maximize space usage, loaders are encouraged to "pack tightly," i.e., to stack cabinets to the ceiling of the trailer, leaving as little space between boxes as possible. It is important for loaders to keep cabinets in the same drop together in the trailer. As cabinets are moved onto trailers, they are checked off against a "pick ticket," i.e., a list of cabinets contained in the drop. During loading sequences, lift rates range from 2 to 3 lifts/minute. Between drops, loaders usually get short breaks from lifting, usually to provide information to a computer that schedules the next drop to be delivered to the shipping dock. Although work load can vary, loaders (overall) move an average of 1800 cabinets daily. Most trailers are completely loaded in 2 days. Trailers which are missing components after 2 days are moved to a separate set of docks, where loading is completed by the truck driver. There is little or no overtime work in the shipping department. Loaders perform virtually all lifts unassisted. In 1992, a training program was instituted to provide workers training in proper lifting techniques. Loaders are also provided with back belts, which are widely used. In July 1995, Schrock introduced a new line of cabinets known as the Gallery line. Although similar to cabinets in the Schrock cabinet line, Gallery cabinets feature metal-reinforced drawer boxes, which increase the overall weight of the cabinet by up to 100%. As of September 1995, Gallery cabinets comprised less than 10% of the company's sales.

Safety Committee

A safety committee was formed by the company in April of 1995. The company's contract "Medical Administrator," who is an emergency medical technician (EMT) by training, is in charge of the safety committee. The committee includes 8 volunteers: 5 employees from the cabinet making shop and 3 employees from the office area. During the single meeting the committee has held since it was formed and the time of our evaluation, all members received 8 hours of safety training from an outside consultant. The training materials included some information related to ergonomics. This is the only training related to ergonomics the safety committee members and the Medical Administrator received.

METHODS

Medical Evaluation Methods

The medical evaluation included: (1) a review of the Occupational Safety and Health Administration Log and Summary of Occupational Injuries and Illnesses (OSHA 200) from 1992-1995, (2) discussions with the contract Medical Administrator, who is the health care provider at the plant and the person who is responsible for maintaining the OSHA 200 logs; and (3) a self-administered symptom questionnaire that was distributed in small groups to all 19 employees in the shipping department. The questionnaire inquired about age, gender, job tenure and whether the employee had any work-related musculoskeletal pain or discomfort in the past year. Employees experiencing pain or discomfort were asked whether the problem interfered with their ability to do their job, caused them to miss days of work or be placed on restricted work duty. Employees were also asked to identify the location of pain or discomfort (i.e., shoulder, neck, upper extremities, back, or lower extremities.)

Ergonomic Evaluation Methods

During the site visit, NIOSH investigators observed the activities of employees working in the staging and shipping areas. To capture information about lifting postures and the frequency of manual lifts, work activities were recorded on videotape. NIOSH researchers also measured the sizes of different boxes and the heights of various lifts. Because of difficulties in making the measurement inside a trailer, the horizontal distance between the center of the box and the midpoint of the worker's ankles was measured (for various box sizes) in the staging area. Information about box sizes and cabinet weights was provided to NIOSH by the Schrock health and safety representative. This information was subsequently used as input to the revised NIOSH Lifting Equation. The NIOSH equation is a tool for assessing the physical demands of two-handed lifting tasks (Waters et al., 1993). A full description of the NIOSH Lifting Equation is provided in Appendix A. In brief, the equation provides a Recommended Weight Limit (RWL) and a Lifting Index (LI) for a lifting task, given certain lifting conditions. The RWL is the weight that can be handled safely by almost all healthy workers in similar circumstances; the LI is the ratio of the actual load lifted to the RWL. Lifting tasks with an LI $\leq$ 1.0 likely pose little risk of low back injury for the majority of workers. Tasks with an LI > 1.0 may place an increasing number of individuals at risk of low back injury. Many researchers believe that tasks with an LI > 3.0 pose a risk of back injury for most workers (Waters et al., 1993).

RESULTS/DISCUSSION

Medical

OSHA 200 logs revealed no recorded musculoskeletal disorders in the shipping department for 1992 and 1993. Four (1 back, 1 neck, 1 wrist, 1 knee) musculoskeletal disorders were recorded in 1994, resulting in a total of 56 restricted duty days and 32 lost work days. Five (3 back, 1 neck, 1 arm) musculoskeletal disorders were recorded on the OSHA 200 logs from January 1 - August 31, 1995. These disorders resulted in a total of 13 restricted duty days and 12 lost work days. According to the Medical Administrator, the direct medical costs for treating work-related musculoskeletal disorders in the shipping department for the period March 3, 1994 - May 18, 1995 totaled $23,000.00.

All 19 employees assigned to the shipping department completed the questionnaire. All workers were male, between the ages of 21 and 46 years (mean age = 32 years). All but one had been employed in their current job for more than a year, and 11 of the 19 had been employed in their current job for more than 5 years.

Seventy-nine percent (15 of 19) of shipping department employees reported work-related musculoskeletal pain or discomfort during the past year. There were 9 reports of work-related back pain or discomfort, 8 neck, 7 shoulder, 6 upper extremity (elbow/forearm, hand/wrist, or fingers), and 6 lower extremity (hip, knee, or ankle/foot).

Five employees who reported work-related musculoskeletal pain or discomfort in the past year also reported that their problem interfered with their ability to do their job. Four employees reported missing days of work in the past year due to work-related musculoskeletal pain. Two employees stated that they had been assigned to restricted or light duty work in the last year because of work-related musculoskeletal problems.

Ergonomic

Table 1 displays the results of an evaluation of 15 lifts using the revised NIOSH Lifting Equation. Lifts were selected for analysis using sales data provided by Schrock. The 15 cabinets were chosen to represent the variety of cabinets handled by workers in the staging and shipping areas during an average work day. Lifting indices (LIs) were computed for the same cabinets in both the Schrock and Gallery cabinet lines. Assumptions regarding the way these cabinets are handled were derived from observations of lifts involving the same or similarly-sized cabinets. For this analysis, researchers assumed that each lift was performed less than once every 5 minutes for periods of less than an hour, that each lift covered a distance of 12 inches, and that coupling was poor. As shown, the LI for individual lifts ranged from 0.7 to 6.0. More than half of lifts examined had an LI > 1.0, indicating that the lift could increase the risk of back injury to some portion of the working population.

Because the energy demands of repetitive lifting are significantly higher than that for a single lift, a multi-task analysis approach was also applied to the trailer loading job. Based on observations of workers in the shipping area, an overall lifting frequency of 3 lifts/minute was assumed. A composite lifting index (CLI) for the overall job was computed from the single-task, frequency independent lifting indices (FILIs) for each of the 15 cabinets. Assuming that loaders lift only Schrock line cabinets for durations of less than one hour, a CLI of 3.9 was computed for the job. Table 1 shows that as workers lift for longer durations, or as the percentage of Gallery cabinets increases, the CLI for the job also increases. For example, if workers spend more than 2 hours continuously handling Gallery cabinets, the CLI for the job increases to 8.2.

The CLIs calculated for the trailer loading job should be viewed as conservative assessments of the lifting demands of this job for several reasons. First, cabinets included in our sample were somewhat lighter (mean = 44 lbs.) than the average Schrock cabinet, and no cabinet weighed more than 119 lbs. Company records indicate that some Gallery cabinets weigh more than 200 lbs.; it is likely that even a one-time lift of this magnitude would substantially increase the risk of back injury to these workers. Furthermore, many lifts cover distances greater than 12 inches; in several instances, loaders were observed lifting objects overhead to heights of 80 inches or more (distances of at least 50 inches). Therefore, it is likely that our sample calculations using the Lifting Equation underestimate the risk of back injury associated with this job.

Nonetheless, the results of this investigation indicate that nearly all workers in the shipping department are at elevated risk of work-related injury when performing lifting activities, even for short time periods. This risk increases as (1) the lifting duration increases, (2) the opportunity for rest is reduced, and/or (3) cabinet weight increases. For example, if Gallery cabinet sales were to rise substantially, and shipping department workload and practices remain the same, the company could expect an additional increase in reports of low back pain and musculoskeletal injury among workers in this department.

Although lifting is believed to be the major contributor to the potential for back injury, another hazard unique to the truck driver's work deserves mention. The truck driver is responsible for retrieving cabinets from the assembly area to complete orders which are awaiting shipping. To achieve this, the truck driver pushes a cart loaded with cabinets up an incline to the area where the nearly-filled trucks are located. The truck driver said that powered means of moving the cabinets (i.e., fork lifts or pallet jacks) were not available for this task.

CONCLUSIONS AND RECOMMENDATIONS

Even under ideal conditions, the maximum recommended weight for manual lifting tasks is 51 lbs (Waters et al., 1993). Approximately 40% of cabinets produced by the Schrock Cabinet Company exceed this weight, and because cabinets are inherently large and bulky, optimal lifting conditions cannot be achieved. *Therefore, workers in the shipping department will likely be at increased risk of back injury as long as cabinets are handled manually, without assistance.*

The preferred method of controlling overexertion hazards is to provide engineering controls, i.e., to redesign tools, workstations, and jobs to eliminate hazardous work conditions. Administrative controls or policies designed to limit workers' exposures to hazardous conditions can be used temporarily until engineering controls can be implemented. In addition, training is recommended to allow employees to participate in the process of identifying hazards and making job modifications.

Engineering Controls

Recommendations that would eliminate or significantly reduce manual lifting requirements in the shipping department include the following:

1. **Consider implementing an automatic truck loading (slug loading) system.** Automatic truck loading (ATL) technology has been in existence for about 20 years. It is a system of quickly and efficiently loading trailers that is often used in conjunction with JIT inventory processes. With ATL, a pre-assembled load is automatically moved into a trailer as a unit, instead of one package at a time. Using ATL, workers could build the load outside the trailer using pneumatic, vacuum or mechanical handling equipment, and move the unit into the truck when complete. Implementing this type of system would require additional space inside the shipping area (for building loads outside the trailer) and a method for moving the necessary lifting equipment between different trailers/docks. Although some ATL systems necessitate use of a dedicated trailer fleet (because the load mechanism becomes an integral part of the trailer bed), other types of loading systems are dock-mounted and can service any conventional trailer.

2. **Consider implementing an automated palletizing system.** Using automated palletizing equipment has two potential benefits. First, machines are used to stack materials on the pallets, eliminating manual

handling. Second, software is available for determining the optimum method of stacking items on a pallet to maximize space usage. Loaders would no longer be responsible for trying to figure out how to make a load fit on the truck. Once palletized, loads could be moved into the trailers using forklifts, pallet jacks, or ATL equipment. This alternative would require the company to purchase pallets and forklifts; also, this option may slightly reduce the amount of shipping space available inside the trailer (since the pallets will take up some room). However, if some loads are transferred to slip sheets before loading occurs, the number of pallets needed and the loss of shipping space will be minimized. The existing system of conveyors would also require modification to allow forklifts access to the lifting docks.

3. **Consider implementing assistive devices for lifting in the staging area.** The staging area is not subject to the same constraints that limit the utility of assistive equipment in the shipping area; i.e., the staging area is smaller and there are no overhead space limitations, which may permit installation of stationary lifting devices. Therefore, implementing a pneumatic, vacuum or mechanical lifting system may be feasible. Devices with articulated handles (to permit high stacking) are currently available from a number of manufacturers. Installation of an overhead bridge crane (to allow lateral movement of the system) may be necessary.

4. **Provide the truck driver with a powered means of moving cabinets within the plant.** Because there is no conveyor for transporting cabinets to the loading docks used by the truck driver, a powered means of moving cabinets (i.e., fork truck or pallet jack) should be provided to reduce potential hazards associated with pushing or pulling heavy loads.

Administrative Controls

The effectiveness of administrative changes in work practices for controlling musculoskeletal disorders is dependent on management commitment and employee acceptance. Regular monitoring and reinforcement is necessary to ensure that control policies and procedures are not circumvented in the name of convenience, schedule, or production. An advantage of administrative controls is that they can be implemented quickly and easily without capital expense. However, because administrative controls do not eliminate the hazard, they should be considered temporary solutions for controlling exposure until engineering controls can be implemented. Administrative control recommendations include the following:

1. **Encourage two-man lifting**. Although workers on the day shift already work in teams, the current procedure has evolved into one where one worker marks cabinets off the pick ticket and the other does the majority of the lifting. Although workers rotate between these roles on a daily basis, the end result is a situation where one worker is subjected to heavy physical demands for an entire eight hour workday, while the other performs paperwork and virtually no lifting. Encouraging workers to work in pairs when lifting heavier boxes would balance the demand between the workers, and hopefully reduce the risk of overexertion injury for both. Modifying larger boxes to include handles or cutouts would enable each worker to grasp one side of the box as the lift is performed. Experimentation may be necessary to determine the proper placement of hand holds on the various types of boxes.

2. **Consider more frequent rotation schemes.** Although analyses using the NIOSH lifting equation show that decreasing the lifting duration only slightly reduces the risk of low back injury, there may be some benefit (from the standpoint of preventing systemic and local muscle fatigue) in rotating workers from lifting tasks to lighter work assignments on a more frequent basis (e.g., hourly).

3. **Limit the need for staging.** One area where improvements will result in reductions in material handling is in the management of inventory and the sequencing of assembly operations. Currently, the company is undertaking efforts to implement a just-in-time (JIT) production system, whereby cabinets will proceed directly to a truck after leaving the assembly area. The present status of the JIT system is such that only 30% of cabinets go directly to the loading docks; 70% of cabinets are removed from the conveyors and stacked in the staging area due to production or sequencing problems. As a result, cabinets are lifted and/or lowered multiple times in staging before they are sent to shipping and loaded into a truck. By increasing the percentage of cabinets which are ready for immediate shipping, manual lifting in the staging area will be greatly reduced.

4. **Ship certain components in separate boxes.** The heavier cabinet components should be packaged and shipped in separate boxes. NIOSH lifting indices less than 1.0 cannot be achieved if box weights exceed 51 lbs. One way to reduce load weights would be to ship cabinet components (tops, shelves, etc.) in boxes separate from the cabinet frame. Limited assembly of these cabinets will be required upon arrival at their destination.

Back Belts

In August of 1992, NIOSH formed a Working Group to review the scientific literature addressing the use of back belts to reduce work-related back injuries in healthy, previously uninjured workers. At the completion of this review, the working group concluded that, because of limitations of the studies that have analyzed the workplace use of back belts, there is insufficient evidence to either support or refute the effectiveness of back belts in injury reduction. **As a result NIOSH does not recommend the use of back belts to prevent injuries among workers who have never been injured.** "Back belts do not mitigate the hazards to workers posed by repeated lifting, pushing, pulling, twisting or bending." (NIOSH, 1994) The most effective means of minimizing hazards is to redesign jobs and workstations to ensure that workers can perform required activities without exceeding their physical capabilities and capacities. Employers should not make back belt use mandatory, and they should not be used <u>instead of</u> appropriate engineering and administrative controls.

Safety Committee

Effective control of worker safety and health requires management commitment and employee involvement. Although Schrock has been successful in developing an employee safety committee, the following recommendations are offered to improve the efficacy of the committee:

1. Appoint a management representative to the safety committee, as a way of ensuring that adequate authority and resources are made available to the committee to fulfill its objectives.

Safety Committee

Effective control of worker safety and health requires management commitment and employee involvement. Although Schrock has been successful in developing an employee safety committee, the following recommendations are offered to improve the efficacy of the committee:

1. Appoint a management representative to the safety committee, as a way of ensuring that adequate authority and resources are made available to the committee to fulfill its objectives.

2. The committee should develop procedures and mechanisms to evaluate safety goals and monitor progress. These goals and objectives should be organized into a written safety program that is endorsed by management and communicated to all employees. Safety committee meetings should be held on a regular basis, to evaluate progress, assign responsibilities, and identify potential problem areas.

3. Provide additional training in ergonomics for the members of the safety committee to complement the limited training that has already taken place. If all safety committee members cannot receive more comprehensive training, the Medical Administrator should receive additional training since he is responsible for the committee.

4. Provide periodic training to all employees in the shipping department regardless of membership on the safety committee. This training should include information on the signs and symptoms of work-related musculoskeletal disorders, their prevention, and the proper use of control methods.

REFERENCES

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TABLE 1
Evaluation of sample lifting tasks using NIOSH Lifting Equation.
Analyses assume poor coupling and no asymmetry.
SCHROCK CABINET COMPANY
ARTHUR, ILLINOIS
HETA 95-0335

Description (Box #, Product ID)	Weight (lbs)		Ho (in)	Vo (in)	D (in)	FIRWL (lbs)	FILI	
	Schrock	Gallery					Schrock	Gallery
#4, W3030	43	60	17	30	12	26.3	1.6	2.3
#23, W1230	23	31	17	47	12	22.9	1.0	1.4
#30, W2430	35	50	15	30	12	29.8	1.2	1.7
#18, W3018	24	36	12	30	12	37.0	0.7	1.0
#12, DW30	49	73	15	30	12	29.8	1.6	2.5
#8, SB36	64	77	24	35	12	18.0	3.6	4.3
#4, W3630	55	69	17	30	12	26.3	2.1	2.6
#18, W1830	28	41	12	30	12	37.0	0.8	1.1
#7, B30	65	90	17	36	12	25.2	2.6	3.6
#30, W2730	40	55	15	30	12	29.8	1.4	1.9
#6, B24	55	77	15	34	12	29.0	1.9	2.7
#33, B18	45	66	15	34	12	29.0	1.6	2.3
#30, W2130	32	45	15	30	12	29.8	1.1	1.5
#32, B12	37	55	15	36	12	28.6	1.3	1.9
#14, BLS26	68	119	22	35	12	19.7	3.5	6.0
CLI (duration < 1 hr., lifting frequency = 3/minute)							3.9	6.4
CLI (duration = 1 to 2 hrs., lifting frequency = 3/minute)							4.0	6.8
CLI (duration = 2 to 8 hrs., lifting frequency = 3/minute)							4.6	8.2

Ho = Horizontal Location
Vo = Vertical Location
D = Vertical Travel Distance
FIRWL = Frequency-Independent Recommended Weight Limit
FILI = Frequency-Independent Lifting Index

APPENDIX A

1. THE REVISED LIFTING EQUATION

This section provides the technical information for using the revised lifting equation to evaluate a variety of two-handed manual lifting tasks. Definitions, restrictions/limitations, and data requirements for the revised lifting equation are also provided.

1.1 Definition of Terms

1.1.1 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:

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

A detailed description of the individual components of the equation are provided in Section 1.3 on pages 12-13.

1.1.2. 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.

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

1.1.2. 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 Location (H)	Distance of the hands away from the mid-point between the ankles, in inches or centimeters (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 1.
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) of 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 worker's 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 Position	Describes the position of the body when the hands are directly in front of the 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 either 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., handle, 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.

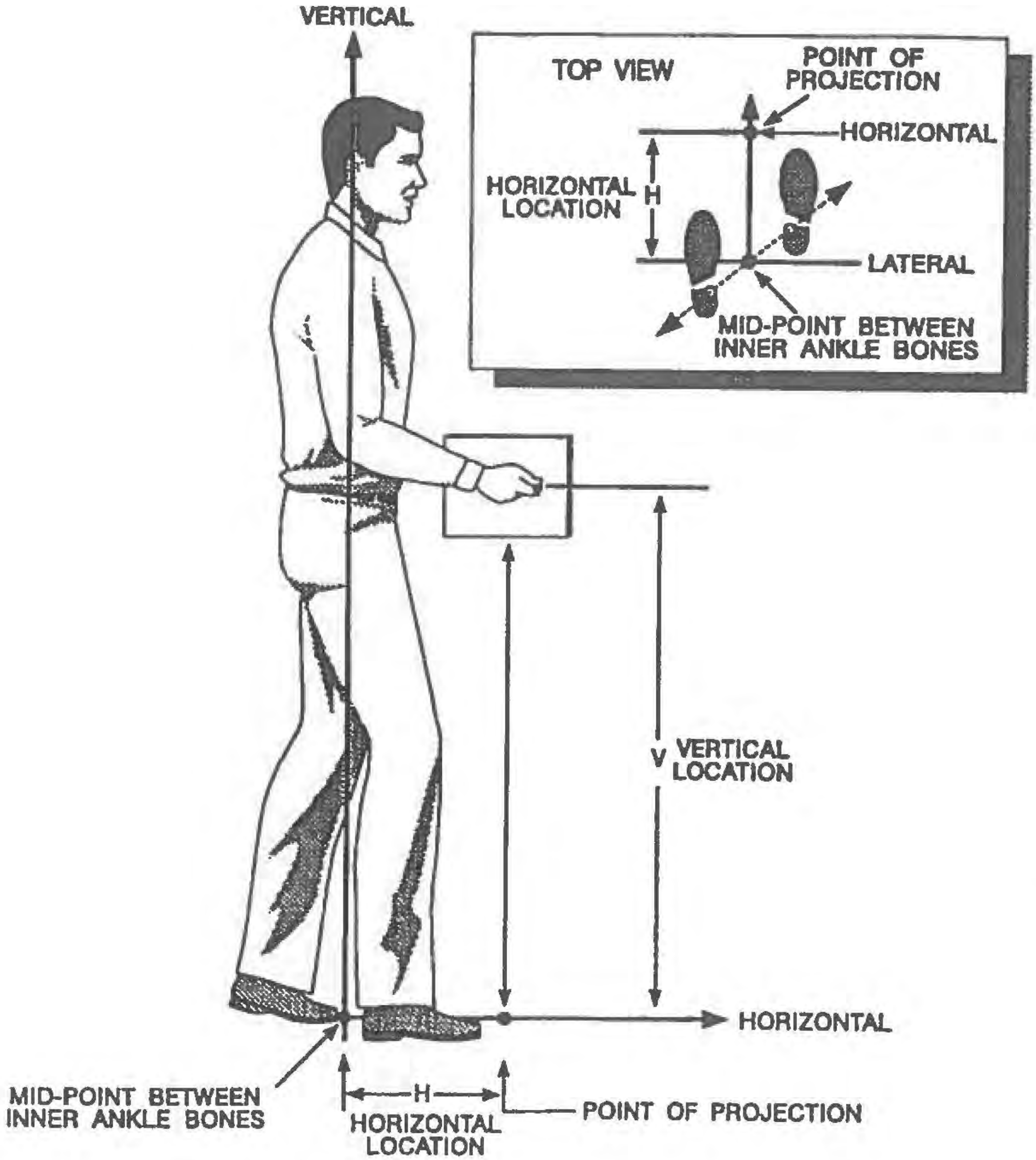

Figure 1 Graphic Representation of Hand Location

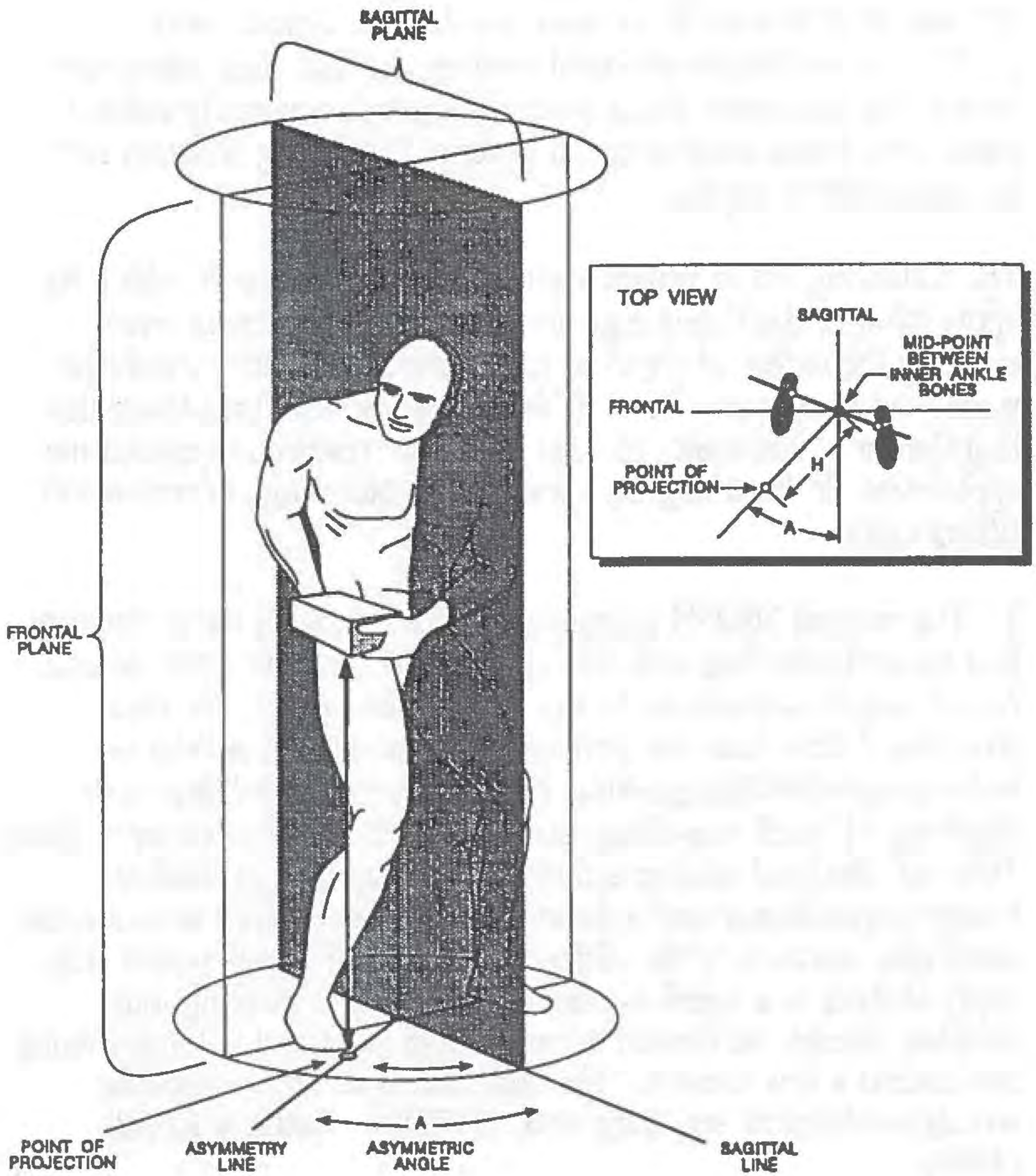

Figure 2 Graphic Representation of Angle of Asymmetry (A)

1.2. 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 assumptions 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 identifies a set of work conditions in which the application of the lifting equation could either under- 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 of 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 task 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 19° to 26°C [66° to 79°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 equation, 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 some 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 Ciriello (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

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[3] The research staff of the Bureau of Mines have published numerous studies on lifting while kneeling and in restricted workspaces (See Gallagher *et al.*, 1988; Gallagher and Unger, 1990; and, Gallagher, 1991).

[4] Although lifting speed is difficult to judge, a high speed lift would be equivalent to a speed of about 30 inches/second. For comparison purposes, a lift from the floor to a table-top that is completed in less than about 1 second would be considered high speed.

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 the floor to a table is as hazardous as lowering the same 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 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)

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 the 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.

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- Lifting/lowering in an unfavorable environment (i.e., temperature significantly outside 66-79° F (19-26° C) range; relative humidity outside 35-50% range)

For those lifting tasks in which the application 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.

1.3. 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:

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

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