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HAZARD EVALUATION AND TECHNICAL ASSISTANCE REPORT
HETA 88-237-L1960
ELJER PLUMBINGWARE
FORD CITY, PENNSYLVANIA
APRIL 1989

Hazard Evaluations and Technical Assistance Branch
Division of Surveillance, Hazard Evaluations and Field Studies
National Institute for Occupational Safety and Health
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TECHNICAL ASSISTANCE REPORT

SITE ..... Eljer Plumbingware, Ford City, PA
INVESTIGATORS .. Roger Jensen, Division of Safety Research, and Linda Frederick, Division of Behavioral and Biomedical Science, National Institute for Occupational Safety and Health
INVESTIGATION .. HETA Number 88237
PROBLEM ..... Back Injuries
HAZARD ..... Manual Materials Handling

I. SUMMARY

A site visit was conducted at the Eljer Plumbingware manufacturing facilities in Ford City, Pennsylvania on July 13-14, 1988 by two investigators with the National Institute for Occupational Safety and Health (NIOSH). The concern was with back injuries associated with lifting heavy products. This report presents the findings of the site visit, and provides recommendations for reducing stresses associated with lifting.

Tasks found to exceed the Maximum Permissible Limit (MPL) were found in the two areas investigated: casting line and sprayer. In casting, the tasks which exceeded the MPL were: 1) one person transferring toilet bowls from the pouring line to the highest or lowest stillage shelves, and 2) one person moving bowls from the highest stillage shelf to the turntable. One lifting task at the sprayer loading/unloading workstation involved an exposure approximately equal to the MPL. These tasks should receive first priority for finding ways to avoid exposures to these stress levels. Other lifting tasks in the casting area and at the sprayer loading/unloading workstation were less than the MPL, but greater than the level considered acceptable for most workers. These tasks should also be reviewed to find alternative procedures or methods for doing the operation without exposing workers to such high levels of stress.

This report contains three main recommendations. First, in the casting area use two-person lifts for transferring newly cast bowls from the cast line to the stillage shelves, and for moving bowls from the highest shelf to the turntable. In implementing this recommendation, the incentive pay system should be reviewed, and modified if necessary, to assure that workers have the same opportunities for earnings when using two-person lifts as they do with one-person lifts. Second, at the sprayer operation assess the feasibility of the three alternative procedures mentioned in this report for loading toilet bowls from the monorail cart to the sprayer conveyor. Third, make sure that all workers who do manual load handling have received a comprehensive training program on back care and load handling procedures, and those who work in the casting area or at the sprayer have received training on the specific procedures for transferring the toilet bowls in these respective areas.

II. BACKGROUND

A site visit was conducted at the Eljer Plumbingware manufacturing facilities in Ford City, Pennsylvania on July 13-14, 1988. It was conducted by two investigators with the National Institute for Occupational Safety and Health (NIOSH). The request for NIOSH ergonomic technical assistance was made by the plant Safety Director, Mr. David Byers. The request was prompted by an OSHA inspection that found high back injury rates at the facility relative to the rates at other manufacturing plants in the same industrial classification (SIC 3261, Plumbing Fixtures, Vitreous China). This industry as a whole had the tenth highest OSHA reportable incidence rate in the U.S. for the year 1986 (Bureau of Labor Statistics, 1988).

The work areas where the most back injuries had been occurring were identified from discussions with the Safety Director. This was followed by a walk-through survey which provided the NIOSH investigators an opportunity to observe numerous operations, including those the Safety Director identified as involving the most back injuries. It was apparent that a few jobs were the most stressful on the workers' back. These jobs were investigated more completely during the one and one-half day survey at the facility.

For those tasks identified as being the most physically demanding, NIOSH investigators observed the work and obtained essential data using photographs, videotape recordings, and tape measurements of critical dimensions. Some of the tasks were subsequently evaluated using the criteria in the NIOSH Work Practices Guide for Manual Lifting (NIOSH, 1981). This analysis resulted in the determination of the acceptable lifting loads for these tasks.

III. WORKSITE

There are two plants at the Ford City site. The new plant manufactures the standard, moderately priced products. An older plant produces higher priced, deluxe products. The products are toilets, lavatories, and urinals. The jobs evaluated during the site visit were located in the new plant and involved the manufacture of toilets. From the perspective of worker involvement, the steps in the production process are listed in the following. The steps with the jobs investigated were steps 4-6, 8, and 9.

1. A line of molds are set in place.
2. A mixture of clay, sand, and silica is poured into the molds.
3. After allowing time for solidification, the molds are removed.
4. The solidified product is picked up by one or two workers and moved to the stillage area where it is placed on one of four shelves for further drying.

5. After further drying a worker picks up the molded product (greenware) from the drying shelf and carries it to a turntable on a fixed table where excess clay is wiped off.
6. The product is then picked up again by the same worker and carried a short distance where it is set on a three-tiered monorail rack suspended from a ceiling-mounted rail system.
7. The monorail rack is manually pushed to a queue for the sprayer process.
8. At the sprayer loading/unloading workstation, a worker lifts the product from the monorail rack, rotates his body 180 degrees, and places it on a special holder affixed to a conveyor. The conveyor transports the product through the sprayer and eventually back to the workstation.
9. The worker at the loading/unloading workstation picks up the sprayed product, rotates his body 180 degrees, and sets it on a shelf of a monorail rack.
10. The monorail rack is manually pushed to a queue for the kiln drying process known as "firing".
11. After firing and a period of cooling the products are inspected. Those that pass inspection are stored on the monorail racks for a variable period of time. Those that fail inspection are either scrapped or sent to the rework area for repair and refire.
12. Products are transported by monorail to another line for a series of finishing operations that involve frequent manual handling.
13. At the end of the finishing line the products are moved on a roller conveyor to the packaging area where each is manually loaded into a cardboard container and stacked onto a pallet. Subsequent handling is by lift truck to a storage area and eventually to shipping.

Prior to kiln drying the products weigh the most due their moisture content. This makes the manual lifting tasks more stressful on the lower backs of the workers. Consequently, the investigation focused on the product lifting tasks that occurred prior to kiln drying -- specifically those involved in steps 4, 5, 6, 8, and 9.

IV. CRITERIA

To evaluate the stressfulness of manual materials handling tasks, it is helpful to utilize an objective and quantitative approach for measuring the stressfulness of a task, and to have available valid criteria with which to compare the measured values. For lifting tasks, the best available set of methods and criteria is described in the NIOSH Work Practices Guide for Manual Lifting (NIOSH, 1981). This document is referred to in the remainder of this report as the "NIOSH Guide".

The NIOSH Guide provides a formula for quantifying the relative stressfulness of a lifting task on the lower backs of workers based on the dimensions of the task layout and lifting frequency. The NIOSH Guide

also includes a basis for categorizing the tasks into one of three categories: (1) acceptable lifting conditions, (2) conditions that need administrative or engineering controls, or (3) hazardous lifting conditions requiring engineering controls. The line separating category 1 from category 2 is the Action Limit (AL). The line separating category 2 from category 3 is the Maximum Permissible Limit (MPL). If the lifting task is found to be less than the AL, it is considered a nominal risk to most industrial workers, i.e., 99% of male workers and 75% of female workers can perform the task without feeling overstressed. If the lifting task is above the AL and below the MPL, it is considered unacceptable without some type of administrative or engineering controls. If the task is above the MPL, it is considered an unacceptable situation which requires intervention through engineering controls to redesign the lifting task (or the identification of another method for accomplishing the task) to avoid exposing the workers to such hazardous lifting conditions. Lifting work that exceeds the MPL can be performed by only 25% of male workers and 1% of female workers.

Five variables are used to apply the NIOSH Guide. These variables are defined below.

H: Horizontal location of the load from the worker when the lifting begins, measured horizontally from the midpoint of a line connecting the ankles to the point where the hands hold the load.

V: Vertical location of the load at the beginning of the lift.

D: Vertical travel distance of the load from pick-up to set-down. If less than 10 inches, the Guide indicates that a value of 10 should be used.

F: Average frequency of lifting per minute. For less than one lift per minute set F = 0.

F_{max}: Maximum lifting frequency that can be sustained. Values are found in Table 8.2 of the NIOSH Guide. For work sessions lasting less than one hour, the values for standing and stooped postures are 18 and 15 lifts per minute respectively.

V. METHODS

For the lifting tasks analyzed, values for H, V and D were obtained from the photographs, videotapes, and physical measurements made during the site visit. The Action Limit (AL) was calculated from the formula in the

NIOSH Guide and the MPL was determined by multiplying the AL by 3. For convenience and clarity, the AL formula may be presented as the product of five values.

$$AL = I \times J \times K \times L \times M$$

where,

$I = 90$ lb.	(weight of load most people can lift safely if conditions are ideal)
$J = 6/H$	(coefficient accounting for distance of the load from the body)
$K = 1 - 0.01\ \lvert V - 30 \rvert$	(coefficient accounting for vertical position of load when picked up)
$L = 0.7 + 3/D$	(coefficient accounting for vertical distance lifted or lowered)
$M = 1 - F/F_{max}$	(coefficient accounting for frequency of lifting relative to maximum frequency most workers find acceptable)

For those situations in which a worker performed several lifts of different characteristics within the observation period, overall values for AL and MPL were determined. The procedure for this computation is explained in the NIOSH Guide as Example 4, pages 137 to 142. It involves determining average values for H, V, and D; and total frequency of lifts per minute for F. In the computation of the average value of D, the actual measured distance is used, even if the distance is less than 10 inches.

VI. FINDINGS

Casting Operation

In the casting operation, results of the analyses are applicable to those manual tasks that appeared to be most stressful. These tasks were:

* transfer greenware to shelves for drying (step 4),
* transfer greenware from stillage to turntable (step 5), and
* transfer greenware from turntable to monorail (step 6).

Findings regarding each task are described in the following text.

Transfer Greenware to Shelves (step 4)

The operation observed during the site visit was the casting of toilet bowls. After pouring the clay mixture into the mold and allowing a period for drying, the molds are removed. Then the fragile greenware is manually picked up by one or two workers for transfer to one of four

shelves (known as stillage). There are eight basic options to consider: one or two workers and four shelves.

Values for dimensions and frequencies are shown in Table I. For F_{max} the values were obtained from Table 8.2 in the NIOSH Guide. Application of the NIOSH Guide to the eight lift options resulted in the values for AL and MPL shown in Table I. Distances have been rounded to the nearest inch, and the AL and MPL values have been rounded to the nearest whole pound. Note that for the two-worker lifts the value of H is smaller because their grip point is closer to their body than it is when lifting individually. Also, the AL computed from the formula was doubled because two workers can be expected to lift approximately twice the load a single worker can safely lift.

Table I
Determination of Acceptable Load for Lifting Greenware for Transfer to Stillage Shelving for Drying.

	Distances (inches)			Frequencies (lifts/min.)		Loads (pounds)	
Lift Description	V	H	D	F	Fmax	AL	MPL
One Worker to:							
Highest Shelf	42	13	30	6	18	19	58
Third Shelf	42	13	8*	6	18	26	78
Second Shelf	42	13	13	6	18	22	67
Lowest Shelf	42	13	34	6	15	17	52
Two Workers to:							
Highest Shelf	42	8	30	6	18	64	191
Third Shelf	42	8	8*	6	18	73	223
Second Shelf	42	8	13	6	18	74	222
Lowest Shelf	42	8	34	6	15	56	113

* The lift analyzed was 8 inches, but the value of D was set at the minimum value of 10 for calculation of AL and MPL per instructions in the NIOSH Guide.

As indicated in Table I, the AL depends on which of the eight situations is being considered. For a one-person lift, the AL ranges from 17 to 26 pounds, and the MPL from 52 to 78 pounds. For a two-person lift, the AL ranges from 56 to 74 pounds, and the MPL from 113 to 223 pounds. At this stage in the production process the toilet bowls weigh about 60 to 65 pounds. This weight compares with the AL and MPL values as follows.

* If one worker performs the lift: the AL is exceeded regardless of which shelf it is being moved to, and the MPL is exceeded for the lowest shelf and the highest shelf.

* If two workers perform the lift: the AL is exceeded in transfers to the lowest shelf and possible to the highest shelf, but the MPL is not exceeded for any of the four transfers.

In all the single-worker transfers the exposure to biomechanical stresses from lifting is greater than the acceptable level. This indicates that the lifting requirements are unacceptable without some type of administrative and/or engineering control. The Safety Director indicated that the standard work method is to have two workers make the transfer to the highest shelf; although during the site visit it was apparent that this procedure is not always followed. The NIOSH investigators did not find out if transfers to the lowest shelf are supposed to be performed by two workers. According to the criteria in the NIOSH Guide, no individual worker should be expected to lift loads weighing as much as the recently cast toilet bowls to either the highest or lowest shelf under the conditions observed. Having two workers perform these lifts together would avoid the problem of either being exposed above the MPL.

It occurred to the investigators after the site visit that the incentive pay system might provide a financial inducement to perform these lifts individually, rather than as a team of two workers. The incentive pay system should, therefore, be reevaluated by the plant industrial engineering staff to assure that workers have the same opportunities for earnings when using two-person lifts as they do with one-person lifts.

Transfer from Stillage to Turntable (step 5)

After the greenware has been in stillage the required time, a worker picks it up, carries it to the end of the stillage area, and sets it down on a turntable for inspection and smoothing of rough spots. The pick up may be from any of the four shelves. The procedure is to move several toilet bowls from shelves at one height as a batch operation. Consequently, the computations of AL and MPL were performed separately for the lowest, second, third, and highest shelf respectively.

The values for input variables are shown in Table II. The value for horizontal distance of load was estimated from the size of the toilet bowl. The values for F_{max} were found in the NIOSH Guide, which

specifies 18 lifts per minute if the worker is standing, and 15 lifts per minute if the worker is in a stooped posture. For the lowest shelf the worker was considered to be in a stooped posture. Dimensions have been rounded to nearest inch, and the AL and MPL values have been rounded to the nearest whole pound.

Table II
Determination of Acceptable Load for Lifting Greenware for Transfer from Stillage Shelving to Turntable.

	Distances (inches)			Frequencies (lifts/min.)		Loads (pounds)	
Lift Description	V	H	D	F	Fmax	AL	MPL
Highest Shelf	72	16	29	1	18	15	44
Third Shelf	50	16	8*	1	18	25	76
Second Shelf	28	16	14	1	18	29	86
Lowest Shelf	8	16	35	1	15	19	58

* The lift analyzed was 8 inches, but the value of D was set at the minimum value of 10 for calculating the AL and MPL per instructions in the NIOSH Guide.

The data in Table II indicate that the AL and MPL depend on which shelf the product sits when the worker picks it up. The highest shelf has the lowest MPL, indicating that anything weighing more than 44 pounds is excessive for one worker to lift. At this point in the production process the toilet bowls weigh about 50 to 60 pounds, depending on the model. Thus, transfers from the highest shelf to the turntable should not be performed by a single worker. Transfers from the second and third shelves are between the AL and MPL. Transfers from the lowest shelf definitely exceed the AL, and are very close to the MPL of 58 pounds. At this stage in the production process some toilet bowls models may exceed 58 pounds, whereas others may weigh less.

Transfer from Turntable to Monorail (step 6)

After completing the operation on the turntable, the worker picks up the toilet bowl (Figure 1), carries it about two steps to the monorail cart, and gently sets it on one shelf of the cart. Since there are three shelves on the cart, there are three different manual transfers.

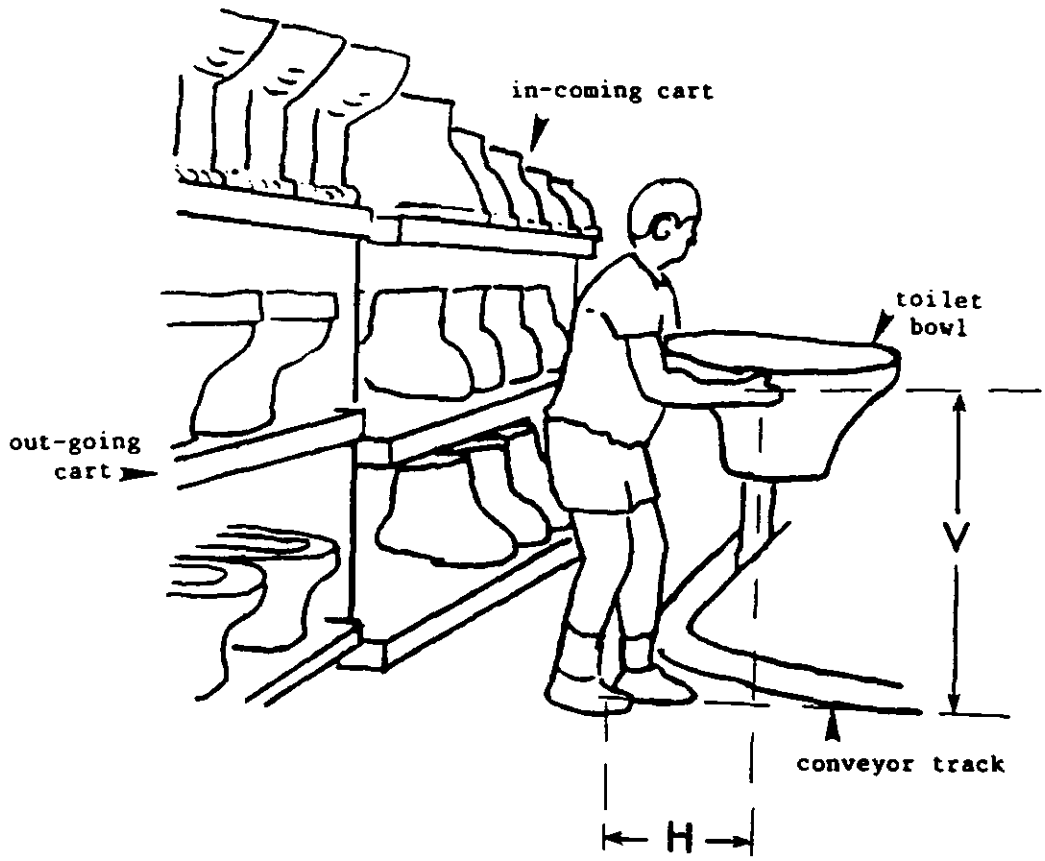

Figure 1. Worker lifting ware from turntable.

The characteristics of the three transfers are listed in Table III. Also shown as the last row on Table III is the overall AL and MPL based on average values for H, V, and D, and total frequency of lifts per minute for F. In the computation of the average value of D, the actual measured distance of 3 inches was used for the middle shelf.

Table III
Determination of Acceptable Load for Lifting Greenware
from the Turntable to the Monorail Cart.

	Distances (inches)			Frequencies (lifts/min.)		Loads (pounds)	
Lift Description	V	H	D	F	Fmax	AL	MPL
Turntable to:							
top shelf	43	16	30	1	18	22	66
middle shelf	43	16	3*	1	18	28	83
bottom shelf	43	16	23	1	15	23	68
Overall Analysis	43	16	19	3	18	21	63

* The lift analyzed was 3 inch, but the value for D was set at the minimum value of 10 for calculating the AL and MPL per instructions in the NIOSH Guide.

The AL values range from 22 to 28 pounds. The MPL values range from 66 to 83 pounds. The overall analysis found an AL of 21 pounds and an MPL of 63 pounds.

The weight of the toilet bowls fall above the AL and below the MPL whether using the individual transfer values or the overall values. According to the NIOSH Guide, this lifting task is unacceptable without some type of administrative controls or engineering changes to reduce the stress level.

Sprayer Loading and Unloading

After the casting operation is completed, the toilet bowls are transported on monorail carts to the sprayer operation. At the sprayer loading/unloading workstation, each bowl is removed from the cart and placed on a special form attached to a conveyer. The conveyor moves the toilet bowls to the sprayer and eventually back to the same workstation.

The worker at the sprayer loading/unloading workstation performs a machine paced job that requires alternately loading a bowl from an

in-coming cart to the conveyer, then unloading another bowl from the conveyor to an out-going cart. Three workers take turns doing this job. Each performs it for 24 minutes, then rotates to a workstation with less stress on his back. During this 24 minutes the worker will load and unload two pairs of carts. The conveyor speed is set so that three bowls will be moved to the conveyor and three will be removed from the conveyor every 72 seconds.

Each of these six moves involves somewhat different stresses on the worker. The moves are from the top, middle, or lower shelf of the in-coming cart to the conveyor, and from the conveyor to either the top, middle, or lower shelf of an out-going cart. Figure 2 shows a worker picking up a toilet bowl at the conveyor in order to move it to the middle shelf of the out-going cart.

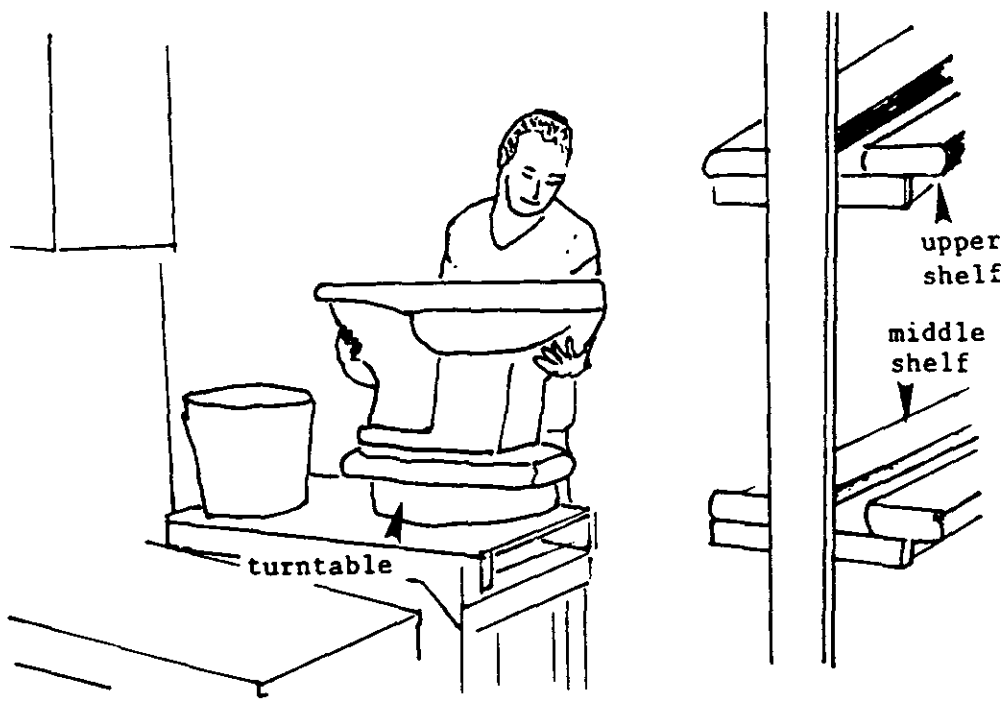

Figure 2. Worker starting to lift toilet bowl off sprayer conveyor.

Each specific lift is performed once per 72 seconds, or at a frequency of 0.83 times per minute. Table IV lists these F values as 0.8, but according to the NIOSH Guide, if frequency is less than one lift per minute, the value of F should be set at zero. Thus, in computing the AL and MPL, F was set at zero for each of the six lifts. Table IV also shows the calculated values of AL and MPL for each of the six moves. According to the safety director the heaviest model is the extended rim model, which weighs about 45 pounds at this stage in production. From Table IV it can be seen that for the move from the top shelf of the in-coming cart to the conveyor, the MPL is 45 pounds. Thus, for this lift the weight of the extended rim model is approximately equal to the MPL. Other models weigh less and are, therefore, below the MPL.

Table IV
Determination of Acceptable Load for Lifting at the Sprayer Loading/unloading Workstation.

	Distances (inches)			Frequencies (lifts/min.)		Loads (pounds)	
Lift Description	V	H	D	F	Fmax	AL	MPL
To conveyor:							
from top shelf	65	19	26	0.8**	18	15	45
from middle shelf	42	18	3*	0.8**	18	26	79
from bottom shelf	15	15	24	0.8**	15	25	76
From conveyor:							
to top shelf	39	19	26	0.8**	18	21	64
to middle shelf	39	19	3*	0.8**	18	26	79
to bottom shelf	39	20	24	0.8**	15	20	61
Overall Analysis	40	18	18	5	18	17	50

* The lift analyzed was 3 inch, but the value for D was set at the minimum value of 10 for calculating the AL per instructions in the NIOSH Guide.

** The frequency was 0.83 lifts per minute, but the value for F was set at zero for calculating the AL per instructions in the NIOSH Guide.

An overall value of AL was also computed. The value of F for this overall analysis was 5 lifts per minute (6 per 72 seconds). For F_{max} the value applicable to standing work, 18 per minute, was used. The computed values for overall AL and MPL were 17 and 50 pounds, respectively. The weight of product at this point in the process puts the overall exposure for the extended rim model between the AL (17 pounds) and the MPL (50 pounds).

VII. RECOMMENDATIONS

The following recommendations for improving workplace safety are provided based on the results of the site visit conducted by the NIOSH investigators.

Those tasks that require lifting loads which exceed the MPL should receive the highest priority for attention. According to the data in this report, the potential for exceeding the MPL was found in two areas.

CASTING AREA. The specific tasks that could exceed the MPL would be a single worker transferring: 1) a newly cast toilet bowl from the cast line to either the highest or the lowest stillage shelf (step 4); and 2) bowls from the highest stillage shelf to the turntable (step 5). It is recommended that: (a) the work methods be examined to make sure that the standard operating procedure is to have two workers make these transfers as a team; (b) the incentive pay system be reviewed, and modified if necessary, to assure that workers have the same opportunities for earnings when using two-person lifts as they do with one-person lifts; and (c) compliance with the two-person procedure be monitored periodically by management to assure that it is always followed.

SPRAYER. The specific task that may exceed the MPL is the transfer of an extended rim toilet bowl from the top shelf of the in-coming cart to the conveyor (step 8). If the toilet weighs more than 45 pounds, the lift exceeds the MPL. But if it weighs less than 45 pounds, the lift will be below the MPL. Since the load lifted is so close to the MPL, it is recommended that the task be modified. Three alternatives might be considered.

1) One would be to change the job rotation plan so that two workers are available at the sprayer loading workstation. The workers might be able to pick up the toilet bowls from the top shelf as a team.
2) A second possibility to consider is modifying the monorail so the cart can be raised and lowered relative to the worker as the cart moves in its' path parallel to the sprayer conveyor. This option might involve the establishment of three workstations along the conveyor: one where a pair of carts would be at a reduced elevation for loading and unloading the top shelves, a second workstation where the carts would be at a middle elevation for

loading and unloading the middle shelves of a pair of carts, and a third workstation where a pair of carts would be at their highest elevation for loading and unloading the bottom shelves. The three workers who presently work in the sprayer area could be assigned to the three respective workstations, with the pace of loading and unloading being one-third the current pace, i.e., instead of six lifts per 72 seconds they would each do two lifts per 72 seconds. Between lifts they would have time to perform the inspection task presently done at a second workstation on the line. With this approach, instead of an individual working very hard for 24 minutes followed by 48 minutes of lighter work, each worker could work at a moderate pace for an hour or two before a rest break would be needed.

3) The third possibility would be to find a mechanical manipulator to perform this transfer. It is recognized that the very fragile nature of the greenware in the casting area makes it infeasible to use conventional materials handling equipment. However, by the time the product reaches the sprayer it is drier and stronger, and thus, it might be feasible to find a manipulator with a soft and flexible gripping mechanism that could load and/or unload toilet bowls without damage.

Those tasks that require lifting loads which exceed the AL but are less than the MPL should receive the second highest priority for attention. According to the data in this report, such tasks are found in both the casting area and at the sprayer (steps 4, 5, 6, 8, 9). The specific suggestions concerning the more stressful tasks noted in subsection 1 above may be helpful. In addition, it is essential that workers fully understand the basic principles of body mechanics, personal back care, and the importance of:

* using two-person lifts for heavy loads,
* knowing proper techniques for two-person load transfers,
* practicing proper techniques for two-person load transfers in order to develop coordination and timing,
* keeping the center of mass of the load close to the body when lifting,
* avoiding twisting the upper body relative to the lower body,
* using the legs to get close to the load and making use of the body weight and the kinetic energy of the body and load, and
* executing the lift smoothly.

The survey by NIOSH did not include all jobs. Other jobs may also include back-stressing manual load handling. It is the responsibility of the employer to evaluate these other jobs to determine if any lifting tasks are excessive according to appropriate criteria such found in the NIOSH Lifting Guide. Later in 1989 NIOSH plans to complete a revision of the Work Practices Guide to Manual Lifting. It should be useful for evaluating jobs at the two plants. It is suggested that job/task evaluations could be performed by student interns from the Safety Science Department at Indiana University of Pennsylvania. This University is

located not far from the plant and has one of the few university safety programs accredited by the American Society of Safety Engineers. Having students perform these evaluations could be mutually beneficial. Eljer could get free help evaluating lifting jobs, and the students could get experience using the revised work practices guide.

If other jobs do exceed the AL or MPL, some general suggestions regarding workstation design may lead to the identification of alternative procedures for getting the job done without exposing workers to excessive stress. The following list contains ideas for reducing musculoskeletal stresses during lifting tasks.

* Reduce the horizontal distance between the load and the worker.
* Arrange the workstation so that the load to be lifted starts out at knuckle height.
* Keep the load set-down point below shoulder height.
* Reduce lifting frequency.
* Reduce the weight of the load.
* Reduce the duration of the lifting task.
* When loads in containers are lifted, provide containers with handles sized and positioned to enable the lifter to grip it while maintaining a posture and hand/arm positions that are comfortable (see Drury and Deeb, 1986, and Drury and Pizatella, 1983).
* Ensure the working surface is stable, free of debris, and has adequate coefficient of friction for the shoe sole/floor surface interface.

This idea list may be useful for systematically reviewing lifting tasks to see what possibilities might exist for changing the demands on the worker. It should not be viewed as a comprehensive list of all possibilities.

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