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Foss Manufacturing Company, Inc.
Hampton, New Hampshire

Thomas Waters, Ph.D., C.P.E.
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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Thomas Waters of the Applied Psychology and Ergonomics Branch Division of Biomedical and Behavioral Science and Laurie Piacitelli of the Industrywide Studies Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Libby Cole, Ph.D. and Frank Stern, M.S. Desktop publishing performed by Pat Lovell. Review and preparation for printing by Penny Arthur.

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SUMMARY

On March 3–5, 1997, representatives from the National Institute for Occupational Safety and Health (NIOSH) visited the Foss non–woven textile manufacturing plant in Hampton, New Hampshire, in response to a company request for a health hazard evaluation. The request was prompted by the company's concerns about potential hazards of repetitive lifting, pushing, pulling, carrying, and other physical stressors for the manufacturing process workers. There were three objectives of this evaluation:

(1) Document the presence of exposure to physical stressors associated with manual material handling (MMH) activities that are known to increase the risk of work–related musculoskeletal disorders (WRMSDs).

(2) Determine the prevalence of WRMSDs associated with MMH activities of manufacturing process workers.

(3) Develop recommendations for reducing the physical demands of the jobs, thereby reducing the risk of injury associated with MMH at the manufacturing facility.

During the visit, the NIOSH team (1) collected information at the Foss work site to assess the physical characteristics of each of the potentially hazardous jobs, and (2) administered a questionnaire to workers who perform the selected jobs to determine the workers' perception of physical workload, work organization, and symptoms of musculoskeletal disorders.

Our ergonomic evaluation found that a number of workers at Foss are exposed to unnecessary bending and lifting that can be reduced by better design of the workplace. In some cases, there is excessive lifting of heavy and /or awkward loads. In other cases, there is excessive bending due to the placement of the load for packaging. These unnecessary physical demands can be reduced by changing the way the work is performed or by providing assistance for lifting and lift tables for some operations. Manual material handling workers at Foss, however, reported background rates of low back pain (LBP). Moreover, Foss workers indicated that they had a positive work environment, and they reported higher levels of control over their work, increased job satisfaction and social support from supervisors and coworkers than reported by other manual material handling workers studied by NIOSH.

Keywords: SIC: 2297 non-woven textiles, ergonomics, and lifting

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Introduction

On March 3–5, 1997, representatives from the National Institute for Occupational Safety and Health (NIOSH) visited the Foss non–woven textile manufacturing plant in Hampton, New Hampshire, in response to a company request for a health hazard evaluation. The request was prompted by the company's concerns about potential hazards of repetitive lifting, pushing, pulling, carrying, and other physical stressors for the manufacturing process workers.

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Background

Plant and Job Description

The Foss plant in Hampton, New Hampshire, manufactures a variety of non–woven textile fabrics and products, ranging from commercial size rolls of coated and uncoated fabrics to small packages of craft fabrics. The plant operates 24 hours a day, seven days a week with four 12 –hour rotating shifts. The plant is divided into three main areas, the fiber line, the fabric lines, and the retail area. In the fiber line, large bales of fiber material (approximately 1000 lb. bales) are produced using a fiber extrusion process. In the fabric line area, the bales of fiber are taken to the production lines, where the fiber is fed into fabric machines that produce various size rolls of non–woven fabrics (typically 50–300 lb. rolls). In the retail area, the rolls of fabric are inspected, cut, rewound, bolted, and wrapped for retail distribution.

Fiber Line

The primary material handling jobs in the fiber line area include the spinnerette technician and the baler/floater job.

Fabric Lines

There are approximately 12 fabric lines, as well as additional lines for inspecting, coating, and embossing the fabric in a finishing process. The primary material handling jobs in the fabric line include the fabric line operators and assistants, the saturation and coating line assistants and compounders, and material handlers.

Retail Area

The primary material handling jobs include panel cutters, bolters, inspection line operators and assistants, and material handlers in shipping and receiving.

Workforce

Foss employs approximately 400 workers in jobs requiring various amounts of manual material handling. A number of these jobs are entry level jobs requiring significant amounts of manual lifting, with moderate to high rates of turnover among personnel.

Methods

Questionnaire

On March 3–5, 1997, workers employed in the jobs listed in Table 1 were given a questionnaire and asked to complete it during work hours. A group of workers who were not employed in jobs requiring manual material handling, were also asked to complete the questionnaire to serve as a comparison group. The questionnaire was voluntary, and the company allowed the worker to meet with the NIOSH team in the safety room to complete the questionnaire. The questionnaire (Appendix A) included items about perceived physical workload of the respondent's job and symptoms of musculoskeletal disorders in the previous year. Questions were also included concerning the overall workload and the workers' perceived control over their workload. A more complete description of these indicators is provided below:

Assessment of Perceived Workload

The Borg scale was used to elicit an overall assessment of the perceived physical workload. This scale consists of a 15-point numerical list, anchored by adjectives describing increasing levels of physical effort (Question 24, Appendix A). The Borg scale was initially developed through laboratory experiments using exercise bicycles and has subsequently been used at the work site to assess the perceived physical effort of persons performing manual tasks. Studies have shown a good correlation between perceived workload and objective measures of physiologic workload such as heart rate (Borg 1982, Borg 1990).

Assessment of Reported Discomfort

Exposure to lifting has been found to increase the risk of developing low back injuries. To assess the prevalence of low back pain, workers were asked if they had experienced low back pain every day for a week or more during the last 12 months. (Question 27, Appendix A). Several investigations have used questionnaires to determine the prevalence of musculoskeletal disorders among working populations. A particularly descriptive method for determining the location and severity of complaints is the use of a body parts map diagram (Question 37, Appendix A). A number of studies have documented the relationships between complaints of discomfort and inadequate ergonomic work conditions. These body map diagrams are useful in identifying which parts of the body are under the greatest stress. (Corlett-Bishop 1976, Kuorinka et al. 1987, Silverstein et al. 1986, Viikari-Juntura 1983). A five point scale was used with the verbal anchors describing levels of discomfort ranging from none at all to worst imaginable. For this study, a worker was considered to have significant discomfort if he/she reported discomfort at a level of 2 or greater in one of the areas of the body shown in Appendix A, question 37.

Assessment of Injuries and Missed Workdays

Workers were asked about injuries at work and lost workdays due to those injuries. Although these cases probably represent the more severe problems, they provide another indicator of the magnitude of the problem.

Employees Perception of Work Organization

A series of work organization questions from the NIOSH generic Job Stress Questionnaire (Hurrell and McLaney 1998) was included to determine workers' perception of their job (Questions 50, 54, 55, 57, 58, and 59, Appendix A). There is increasing evidence from epidemiologic studies that psychosocial factors related to the job and work environment play a role in symptoms of ill health and work related musculoskeletal disorders (Bongers 1993, Bernard 1997).

Questionnaires containing these same questions have been administered by NIOSH to 200 workers employed in a variety of manual material handling jobs, thus providing a comparison group of workers who perform similar jobs involving manual material handling. (Waters, submitted for Publication)

Ergonomic Assessment

Due to the variability of some of the jobs, a multi−faceted approach was used to document the physical demands of the material handling activities. Based on discussions with the company, jobs F0−1 through F0−14 (Table 1) were prioritized for analysis. Jobs FO−15 through F0−18 were not analyzed. The revised NIOSH lifting equation was used to evaluate exposure to lifting for jobs FO−1 to FO−7. Jobs F0−8 through F0−14 involved excessive variability and could not be analyzed with the revised NIOSH lifting equation. For these jobs, a variety of other methods were used, including biomechanical modeling to estimate joint loading and strength requirements, a psychophysical approach for estimating pushing and pulling demands, and a postural analysis program for estimating the extent of awkward postures. For all 14 jobs, workers were videotaped while working and the workers were interviewed. The purpose of the interview was to determine the range of activities and the relative proportion of the time spent on each activity.

Revised NIOSH Lifting Equation

The Revised NIOSH Lifting Equation (NLE) (Waters et al., 1994), which is described in Appendix B, is a tool for assessing the physical demands of two−handed manual lifting tasks. Input data include measurements of the location of the load relative to the worker, the lifting frequency, duration, and other task−related factors. The principal results from the NLE are the The University of Michigan 3D Static Strength Prediction Program (3D SSPP) is a computerized model for estimating the joint loads and required muscle forces for a wide range of manual handling activities, such as lifting, pushing, and pulling (Chaffin and Andersson 1991). The program takes into consideration the anthropometry and posture of the worker, and the forces at the hands necessary to accomplish the task. For this analysis, the 3D SSPP model was used to estimate the joint loads and required muscle forces for a number of pushing and pulling tasks. Input for the biomechanical model includes 24 data elements, Recommended Weight Limit (RWL) and the Lifting Index (LI). The RWL is that amount of weight that nearly all healthy workers should be able to lift safely for a specified lift. The LI, which is defined as the ratio of actual weight lifted to the recommended weight limit (i.e., LI=L/RWL), provides an index of the level of physical stress for a job. As the LI increases, the level of physical stress increases and the risk of injury increases. According to the authors of the NLE, it is likely that lifting tasks with a Lifting Index > 1.0 pose an increased risk for lifting−related low back pain for some fraction of the workforce and that many workers will be at elevated risk if the Lifting Index exceeds 3.0 (Waters et al., 1993).

Procedure

Seven jobs were analyzed with the NLE. The seven jobs included, (F0−1) spinerette technician, (F0−2) bolter, (F0−3) inspection line (decorative), (F0−4) panel cutter, (F0−5) inspection line (quality), (F0−6) saturation line compounder, and (F0−7) coating line operator. During the site visit, each of the seven jobs were videotaped, the weights of the lifted objects were measured or determined from the daily production logs, and the work pattern was determined. The other input data for the NLE (i.e., horizontal and vertical location of the load, vertical displacement, asymmetric angle, and coupling) were determined directly from the videotape or from a laboratory simulation.

Biomechanical Modeling

including three anthropometric measures (gender, height, and weight), eight upper limb angles, four lower limb angles, three trunk angles, and six hand force measures. Output from the model includes the L5/S1 disc compression force, joint−specific estimates of the percent population capable, estimated back ligament strain, joint moments, joint−specific muscle strength requirements of the job compared to population−distributed baseline strength capabilities, and the required coefficient of ground friction. It should be noted that static biomechanical models typically underestimate the actual forces developed during a dynamic activity.

If the activity is performed in a slow smooth manner, however, the error is considered negligible. Examples of the Human Graphic Model for two of the jobs analyzed are shown in Figures 1& 2.

Procedure

The magnitude of pushing or pulling force and the working postures were measured for several tasks required by the Blending Line Assistant, Spinnerette Technician, Fiber Line Baler/Floater, and a few miscellaneous tasks. These data were then used as input into the 3D SSPP model to determine the biomechanical loads associated with these tasks.

Psychophysical Measures

Psychophysical criteria provide weight limits for pushing and pulling that are based on the worker's perception of the integration of the biomechanical and physiological demands of a job. Psychophysical databases of maximum acceptable weight limits for lifting have been developed from laboratory studies of workers' strength and capacity for a wide range of task conditions. In these studies, workers' maximum acceptable pushing and pulling force for specified combinations of task characteristics are defined as the amount of force a person determines they can push or pull repetitively, working as hard as they can without straining themselves, or without becoming unusually tired, weakened, overheated, or out of breath. Typically, data are collected from a series of standard tasks that are then used to generate normalized distributions of maximum forces that are acceptable to 10, 25, 50, 75, and 90% of the male and female population. Researchers have shown that back injuries increased for lifting tasks rated acceptable by less than 75% to 90% of the workers (Snook 1978, Herrin et al., 1986).

Procedure

The magnitude of pushing or pulling force was measured for several tasks required by the Blending Line Assistant, Spinnerette Technician, Fiber Line Baler/Floater, and a few miscellaneous tasks. These forces were then compared to published baseline pushing and pulling capacity data (Snook and Ciriello 1991).

Postural Analysis

The Ovako Working Posture Analysis System (OWAS) is a computerized technique for determining the postural requirements for the back, arms, legs, and trunk during a physically demanding activity (Karhu et al., 1977). For this method, the analyst reviews a videotape of a worker performing the work process and intermittently rates the posture at fixed time intervals. This technique is especially useful in documenting the relative time spent in bent or awkward postures, a known risk factor for low back disorders.

Procedure

The OWAS method was used to assess the postural requirements for various phases of the job performed by the fabric line assistant. One of the tasks required in this job is to wrap the rolls of fabric in plastic and heat shrink the plastic wrap in preparation for shipment. The amount of bending required by the worker is dependent upon whether the rolls are moved from the fabric machine to a table for wrapping or placed on the floor. For this study, the OWAS method was used to assess three fabric lines, the A, F, and G lines. Two different approaches were used. For the G Line, an entire cycle of 18.33 minutes was evaluated at a sample rate of one sample every 10 seconds. For the A and F Lines, only the wrapping phase of the cycle was evaluated, but the sampling rate was increased to one sample every 2 seconds.

RESULTS AND DISCUSSION

Questionnaire

Of the 124 production workers in the selected study jobs, 120 were working at the time of the survey, and all but 2 of the workers present completed a questionnaire. Also, two of the four workers who were on leave returned questionnaires by mail, resulting in a response rate of 97%. In addition, 36 workers identified as unexposed to manual material handling completed the questionnaire. Workers in the unexposed group were excluded from the study, however, if they reported heavy pushing or pulling more than 10 times per day, lifting 25 pounds or more 10 times per day or more, or lifting 50 pounds even once per day. Workers performing jobs in the unexposed group, however, could have been exposed to lifting on previous jobs. After exclusions for reported lifting, and one exclusion for temporary employment, the unexposed group was composed of 19 workers primarily employed in technical and supervisory jobs. Questionnaire results were analyzed both by individual job and by exposure status. For this report, however, the results are presented primarily by exposure status and gender rather than by individual job due to the small number of exposed workers in many of the jobs evaluated.

Demographics

Table 2 shows the demographics of the exposed and unexposed workers. The exposed workers were predominantly male (82%). All but one of the unexposed workers was male, so only male material handlers were compared to the unexposed group. The unexposed workers tended to be older and to have worked at Foss longer than the male and female production workers. Seventy-two percent of the production workers had been employed at Foss greater than a year, and 59% had been working in their current job at Foss at least a year.

Reported Symptoms and Missed Workdays

As shown in Table 3, 14% of both the male and female MMH workers at Foss reported low back pain that lasted a week or more during the last 12 months (Question 27, Appendix A). In comparison, 22% of the unexposed group reported low back pain lasting a week or more during the last 12 months. Thirty-five percent of the 200 manual material handling workers previously evaluated by NIOSH reported low back pain lasting a week or more during the last 12 months. (Waters, submitted for publication). A 1988 Health Interview Survey asked workers the same question about back pain lasting a week or more in the last 12 months (Guo et al., 1995). This survey provides us with some community-based data for comparison. In the 1988 survey, 17.6% of respondents reported having back pain lasting a week or more in the last 12 months. In the current study, the unexposed group reported the highest rate of low back pain - 22%, which was greater than the 17.6% reported in the health interview survey of workers across the United States, while the male and female MMH workers at Foss reported a lower rate (14%) of low back pain. Low back pain is common in the general population and is associated with both occupational and non-work related factors. The higher rate of low back pain in the comparison group may be due to previous work history or non-work related factors such as age, cigarette smoking status, physical fitness level, anthropometric (body characteristic) measures, strength, medical history, or structural abnormalities.

Four MMH workers and one unexposed worker reported that they had missed work due to back pain during the previous 12 months, and two of the workers reported they had been on light or restricted work due to low back pain.

Table 3 also shows the rate of musculoskeletal discomfort lasting a week of more during the past 12 months as reported on the body parts map diagram (Question 37, Appendix A). Workers had higher rates for "back discomfort" (20% & 18%) than for "back pain" (14% for both male and female). Male manual material handlers (MMH's) reported discomfort most frequently for the back (20%), knee (17%), and shoulder (16%). Female workers reported discomfort most frequently for the hands (27%), back (18%), and shoulder (14%).

Borg Scale

Male production workers reported an average Borg score of 13.4 (somewhat hard physical effort) which was significantly higher than the average Borg score of 12.1 for female production workers (p<.007). As expected, the unexposed workers reported a much lower level of perceived physical work load with an average score of 9.5. Compared to workers who do manual material handling (MMH) at other sites previously evaluated by NIOSH, the perception of the physical workload was significantly less for the male workers at Foss (13.4 versus 14.4, p<.005), which may have been due in part to age, the Foss workers were younger (mean of 36 years versus 42 years) than the male MMH workers at previous sites. There was no significant difference between the female MMH at Foss and the comparison MMH workers.

Work Organization

Average scores were computed for the questions regarding work organization for male and female MMH workers at Foss and compared to the scores of 200 manual material handlers at four companies previously studied by NIOSH. Female workers at Foss reported significantly less job demand and were also younger than the female MMH comparison group. However, the male workers reported similar job demands. Foss workers felt they had significantly greater control over their work and reported a significantly higher level of job satisfaction. They also reported significantly greater social support from supervisors and co–workers, while social support from others outside of work was similar to the manual material handlers comparison group. All of the differences were statistically significant at the p=0.05 level or better. These positive results can be due to a number of factors but suggest that efforts made by Foss to provide a good working environment, such as shift flexibility, and continuing education opportunities, have been successful.

Ergonomic Assessment

Revised NIOSH Lifting Equation

Seven jobs were selected for analysis using the NLE. As mentioned previously, the seven jobs included, (F0–1) spinerette technician, (F0–2) bolter, (F0–3) inspection line (decorative), (F0–4) panel cutter, (F0–5) inspection line (quality), (F0–6) saturation line compounder, and (F0–7) coating line operator. The two inspection line jobs (FO–3& F0–5) were found to have too much variability to be analyzed with the NLE. The results of the analysis for five jobs are shown in Table 5. The LI values for these jobs ranged from 0.9 to 3.6. The two jobs with LI's above 2, spinerette technician and coating line compounder, should have the highest priority for redesign. (See Table 5)

Due to small sample size, workers in the five jobs assigned a lifting index were divided into two groups: (1) lifting index ≤ 1, and (2) lifting index greater than 1.0 We did not see an increase in reports of low back pain with an increase in lifting demands at Foss. As shown in Table 4 , the rate of low back pain for the two exposure groups were 20% and 18%. The "healthy worker effect"may account for the lack of increased low back reports in the workers with jobs with lifting indexes greater than 1. It is well known that there is considerable selection of workers into and out of manual lifting jobs. Selection of stronger and younger workers into jobs with high physical demands is quite common, even when a specific worker selection program is absent. Moreover, there is also the potential for a survivor effect, in which certain individuals with high tolerance for physical loads due to heavy manual lifting can continue to work in jobs with high physical demands, whereas workers with lower tolerances may have to leave the job. Both of these effects can bias risk estimates of low back pain towards the null, especially for those jobs with high physical demands.

Biomechanical Modeling

The results of the biomechanical analysis of selected tasks required by the Blending Line Assistant, Spinnerette Technician, Fiber Line Baler/Floater, and a few miscellaneous tasks are shown in Table 6. Three of the tasks (2,4,5) required excessive internal muscular forces at the hip and two of the tasks (4,5) created large disc compression forces on the low back. Strength requirements of the tasks should not exceed the strength capacity of the average worker (50% capable) and disc compression force should be well below 770 lbs.

Psychophysical Measures

The results of the comparison of the population–distributed pushing capacity database (Snook and Ciriello 1991) and the magnitude of pushing or pulling force measured for several tasks required by the Blending Line Assistant, Spinnerette Technician, Fiber Line Baler/Floater, and a few miscellaneous tasks are shown in Table 7. The level of acceptability is typically assumed to be 75% of the exposed workforce. Forces for four of the five tasks (1, 2, 4, & 5) exceeded the 75%, 50%, and 25% acceptable force.

Postural Analysis

The results of the OWAS analysis that was used to assess the postural requirements for various phases of the job performed by the fabric line assistants for Lines G, A, and F are shown in Tables 8 to 11. Wrapping and packaging rolls near the floor required significant amounts of bending and squatting. Examination of Table 8 reveals that a significant fraction of the cycle time on Fabric Line G is spent performing the Vacuum Shrinking Operation. Moreover, review of Table 11 shows that 62.2% of the shrink wrapping phase on Line F was spent in a bent posture. Although there are no specific recommended limits for percent of work time spent in flexed postures, excessive bending has been shown to be related to increased risk of low back pain (Snook 1978, Kelsey 1984, Bigos 1986, Punnet 1991, Marras 1993).

Miscellaneous Observations

Shift work

There are number of shifts at Foss; however most workers work one of four 12–hour rotating shifts. Previous research has shown that extended work shifts (i.e., shifts of more than eight–hour duration) may be associated with lower levels of physical and mental health, and may be related to poor living habits, alcohol intake and higher risk of cardiovascular disease (Rosa 1997). However, the findings of studies on the effect of condensed working hours (e.g., 12–hour shifts) on health and work efficiency are inconsistent. There is also a concern about the increased risk of accidents due to extended work shifts. It has been shown, for example, that the majority of accidents are caused by human error; and sleepiness, fatigue and perception ability are essential factors affecting the probability of an error (Smith et al., 1994). In shift work, the night shift is typically characterized by higher injury rates, presumably due to increased sleepiness. It should be noted, however, that there are some positive aspects of 12–hour shifts. For example, it has been suggested that 12–hour shifts provide increased value of free time, enhanced work motivation and morale, reduced stress, reduced staff turnover, and decreased time for shift changes.

A common recommendation among work shift specialists is that the work pattern should be developed through a successful and enthusiastic participatory process within the company. There must be cooperation between the employer, the employees, and the safety and health department. Active review of the work shift plan is essential to maintain safe and healthy working conditions. Condensed work shifts may become problematic when other physical stressors exceed acceptable levels. Additional information regarding shift work can be obtained from the NIOSH document "Plain Language About Shiftwork"(Rosa 1997).

Heat stress

High heat and humidity can significantly increase the effect of physical loading on the human body (Kodak 1986). When environmental heat and humidity exceed ambient values, physiological capacity and muscular capacity is decreased. Heart rate and respiration is increased. Additional breaks are needed and an ample supply of cool water is necessary. Work in the upper mezzanine, such as the coating line and saturation compounders, should be monitored regularly to ensure that workers are not exposed to significant health risks due to high heat and humidity.

Space restrictions

Many of the ergonomic problems observed at Foss are indirectly attributable to space limitations. Although efficient use of floor space is essential to high productivity, it can create significant ergonomic problems for the workers. For example, in the area where the large rolls of fabric are stored and moved, space constraints sometimes make it difficult to use a motorized truck to move the large A-frames. The force required to move these A- frames manually, however, creates large spinal and muscle forces that can cause overexertion injuries or back pain.

CONCLUSIONS

The objective of the ergonomic job analysis is to fit the job to the worker so that one can work without excessive physical stress, fatigue, or harm to one's health. Our analyses indicated that workers are exposed to unnecessary bending and lifting that can be reduced by better design of the workplace. In some cases, there is excessive lifting of heavy and /or awkward loads. In other cases, there is excessive bending due to the placement of the load for packaging. These unnecessary physical demands can be reduced by changing the way the work is performed or by providing assistance for lifting and lift tables for some operations. Reducing the physical demands of the job will also reduce the risk of injury to the musculoskeletal system.

This investigation included a number of assessments of the physical characteristics of specific job tasks performed by workers at Foss. Since the data were collected during a portion of only three days, it is difficult to know whether our assessment is representative of the usual workload. In some of these evaluations we focused on job tasks which were considered to be most hazardous. As a result, some of our analyses are not necessarily representative of all job tasks. Rather, we intended to describe ergonomic hazards. Because the job tasks are repetitive, short sampling periods should yield data representative of usual job tasks. The conclusions of this investigation are supported by the consistency of the results of the different exposure assessments.

RECOMMENDATIONS

Fabric Lines

Feeder operation

This operation occurs at each of the fabric lines. In order to eliminate trunk flexion and heavy lifting by the workers when they bend over to pick up a bundle of fiber, one or more mobile lift tables could be placed at the end of each feeder line to hold the bales as they are moved into position. As shown in figures 3 and 4, the tables would be retracted to the lowest position when the bale is first opened, then raised as the fiber was removed from the bale. When the bale is almost empty, the table would be in the highest position.

Wrapping Operation

This operation also occurs at each of the fabric lines. The rolls are doffed onto the floor for wrapping at some lines and wrapped while on a weighing table at other lines. The amount of bending can be reduced dramatically by eliminating the wrapping operation near the floor. This can be accomplished by wrapping the rolls on the table, as currently performed at some of the fabric lines.

Lifting Mandrels

This operation occurs at many of the fabric lines. On some lines, a mandrel is lifted into position for the winding operation; but in others, a mandrel is not needed. To reduce the stress associated with lifting the mandrel, all lines should be redesigned, to the extent feasible, to eliminate the need for a mandrel.

The NIOSH team did not empirically evaluate the needle board replacement operation due to the variability of the activity. Nevertheless, the lifting requirements of this operation are excessive and place a significant load on the worker. Moreover, many of the boards must be lifted into place with the workers in extremely awkward postures. This operation should be further evaluated and redesigned to the extent feasible. One possibility would be to design a mobile cart that would allow the boards to be adjusted to the right height and then slid into position on the machine without lifting being required.

Lifting Rolls

At some of the lines, the rolls are lifted onto end to begin the wrapping operation. Some of these rolls weigh in excess of 100 lbs. The location of the lift and the weight distributions make these lifts extremely hazardous. To the extent feasible, lifts of this type should be avoided. Better packaging design would eliminate much of the lifting required at many of the lines.

Coating Line Windup

Lifting Rolls

Lifting activities in this job are variable. The sizes and weights of the rolls and the rate at which they come off the line vary considerably. During two different observation periods, workers were required to push and lift rolls of fabric that had been removed from the rewind machine. The amount of lifting was excessive; the speaker cover rolls were especially difficult to handle. The NIOSH team was told that this line was currently being evaluated and was being redesigned. High heat and humidity may present a significant problem if the line is moved into the upper level of the plant. This should be evaluated fully before implementation of the proposed redesign.

The lifting index for this work activity was 3.6, which is considered to be hazardous. In order to

Replacing Needle Boards

Pushing/Pulling Rolls

Pushing and pulling of rolls along the floor was observed on two occasions during the site visit. The pushing and pulling force was not measured, but the rolls weighed between 65 and 100 lbs. These forces, in combination with awkward postures, can create unacceptably high forces on the musculoskeletal system, especially the low back. Material handling devices may be used to reduce the bending, pushing, and pulling. Unfortunately, space constraints may severely limit the use of most conventional material handling devices in this area. If the area surrounding the rewind machine was enlarged, improved material handling systems could be incorporated into the workstation, thereby reducing the need to bend and lift when packaging and transferring the rolls of fabric

Lifting Mandrels

As with many of the fabric lines, workers must lift the mandrels each time a new roll is begun. To the extent feasible, the winding machines without mandrels should be used.

Wrapping Rolls near the Floor

During the observation period, the NIOSH team observed workers packaging rolls of coated fabric. To reduce the physical demands due to excessive trunk flexion during the packaging operation (i.e., wrap and heat shrink), a lift table should be used to hold the rolls after they are removed from the machine. This would allow the worker to work at about waist level, keeping the body in an upright posture during the work activity.

Spinnerette Technician

Lifting Jets from the Floor

reduce the lifting index for this job, we recommend that the jets be lifted and lowered using a lift device, such as a hoist or manipulator arm. The device should be flexible enough to allow full range of motion and rapid lifting and lowering. Some obstacles to implementation of a control involve the skill required to lift the jets without bumping the side of the jet receptacle. Therefore, a revised tool will be needed to hook onto the jets while they are in the receptacle.

Bolter

Stacking Bolts on Pallets

The results of our analysis indicate that the job of bolter is not excessively demanding, with a lifting index for the job of only 0.9, a value considered acceptable for nearly all workers. However, we found that the workers were required to lift the bolts to a height of 85–88 inches, an excessive height. Therefore, we recommend that the job be redesigned so that the workers are not required to lift the bolts higher than about 70 inches. This could be accomplished by reducing the maximum height of the pallets to 70 inches, or alternately, limiting the height to one–half the current height and then designing a method for stacking the two pallets prior to wrapping with plastic wrap. Care should be taken to avoid excessive reaching with the new design, however.

Lifting the Mandrel and Roll to the Bolter Machine

During the roll change phase of the job, the worker is required to lift the mandrel and roll of fabric from the floor to the machine with one hand. This job creates significant forces on the spine that could result in low back pain. Although some of the force is offset by the use of the non–lifting hand as a brace on the machine, the risk of injury to the worker could be reduced if the lift was eliminated.

Fiber Line Baler/Floater

Baling Operation

Lifting the rolls of fabric from the rewind machine to the floor and from the floor to the storage cart

Only about 38% of the male population has the hip strength needed to pull the cart and bale along the track. This operation could be automated so that the baler operator did not need to push the cart.

Moving Fiber Carts

This activity is required when the electric tow truck is not available. The internal back forces and strength requirements are high. Therefore, we suggest that this activity be avoided to the extent feasible. A smaller electric towing machine could be provided to assist the worker when the larger towing truck is not available.

Embossing Line

Replacing Rolls at the Beginning of the Line

This is a physically demanding job because of the heavy lifting and fast pace. Moving heavy rolls of fabric into position requires substantial strength and creates large internal forces on the back. The physical demands could be reduced by redesigning the way the rolls are mounted on the machine. The transfer task should be designed so that the worker does not have to move or lift the heavy rolls of fabric.

Moving Rolls off the Machine and Packaging

This activity is less physically demanding on the worker than tasks at the beginning of the line, but this worker is exposed to excessive bending due to the location of the roll near the floor during the packaging phase of the operation (See recommendations for fabric line above).

Inspection Lines

could create excessive physical demands for some workers. To reduce these excessive physical demands, the workstation could be redesigned so that the worker does not need to lift the rolls after they are removed from the rewind machine. One approach would be to install a roller table or conveyor near the end of the rewind machine so that the rolls could be transferred to the wrapping area and to the storage cart without lifting.

Storage Area

A larger storage area would allow all A–frames to be moved with the motorized truck, thereby reducing the risk of an overexertion musculoskeletal injury.

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Table 1
List of Jobs included in the Study
Foss Manufacturing

Job Title	Primary MMH Activities	Analysis Categories
FO–1 Spinerette Technician	Lift spinerette jets from the injection machine, push/pull racks of jets from oven, move jets during cleaning	Lifting, pushing, and pulling
FO–2 Bolter	Move rolls of fabric, make bolts, stack bolts	Lifting, repetitive arm movements
FO–3 Inspection Line Decorative	Make rolls of fabric, inspect fabric, move and stack rolls of fabric	Lifting and awkward posture
FO–4 Panel Cutter	Box small packages of fabric, stack boxes on pallets	Lifting
FO–5 Inspection Line Quality	Make rolls of fabric, inspect fabric, move and stack rolls of fabric	Lifting, pushing, and pulling
FO–6 Saturation Line Compounder	Mix saturation compound, lift bags of powder, move drums of liquid, move hoses	Lifting, pushing, and pulling
FO–7 Coating Line Compounder	Mix coating compound, lift bags of powder, move drums of liquid, move hoses	Lifting, pushing, and pulling
FO–8 Fabric Line Oper/Asst.	Opens bales, feeder operation, replace Needle boards, doff rolls, wrap rolls, move rolls	Lifting, repetitive bending, pushing and pulling
FO–9 Fiber Line Baler/Floater	Makes bales of fiber, moves bales of fiber, moves fiber carts	Pushing, pulling, and awkward posture
FO–10 Blending Line Baler	Opens bales, makes bales of fiber, blends fiber, feeder operation, moves bales of fiber	Lifting, pushing, and pulling
FO–11 Saturation Line Windup	Pushes, pulls, wraps, and stacks rolls of fabric	Pushing, pulling, awkward postures
FO–12 Coating Line Windup	Moves rolls of fabric, moves small A–Frames	Lifting, pushing, pulling, and awkward postures
FO–13 Perkins Line	Make and move rolls of fabric, wrap rolls of fabric	Lifting, pushing, pulling, and awkward postures
FO–14 Embossing Line	Make and move rolls of fabric, wrap rolls of fabric	Lifting, pushing, pulling, and awkward postures
FO–15 Lectra	Not analyzed	
FO–16 Coating Line Windup	Not analyzed	
FO–17 Pickers	Not analyzed	
FO–18 Inspection Line Auto	Not analyzed	

Table 2
Demographics of Study Population
Foss Manufacturing

	Unexposed Males (N=18)	Manual Material Handlers Male (N=99)	Manual Material Handlers Female (N=22)
Average Age (range)	43 (34–60)	36 (18 – 68)	41 (19 – 55)
Average Years at Company	13.9 (<1 – 31)	5.2 (< 1– 24)	5.1 (<1– 17.5)
Average Years on Current Job	4.2 (<1 – 19)	2.5 (<1 – 14)	3.4 (<1– 12.2)

Table 3
Rate of Reported Musculoskeletal Symptoms
Foss Manufacturing

Body Part	**Unexposed Males** (N=18)	**Manual Material Handlers – Males** (N=99)	**Manual Material Handlers – Females** (N=22)
Back Pain‡	22%	14%	14%
Musculoskeletal Discomfort †			
Back	27%	20%	18%
Shoulder	11%	16%	14%
Hand	5%	13%	27%
Elbow	5%	3%	4%
Hip	0	2%	4%
Knee	5%	17%	4%
Foot	5%	11%	4%

‡Back pain lasting a week or more during the last 12 months, (Question 27, Appendix A)
†Reported discomfort rated as 2 or greater on a 0 – 5 scale,(Question 37, Appendix A)

Table 4
Reported Back Pain by Lifting Index Category
Foss Manufacturing

	Lifting Index ≤ 1.0	Lifting Index > 1.0
Number of workers	15	11
Back Pain in last 12 months	20%	18%

Table 5
Summary Results of NIOSH Lifting Equation Evaluation
Foss Manufacturing

JOB #	**LOAD (lbs)**	**LIFTING EQUATION COMPONENTS**							**RESULTS**	
		LC	**HM**	**VM**	**DM**	**CM**	**AM**	**FM**	**RWL (lbs)**	**LI**
FO–1	94	51	0.77	0.84	0.90	0.90	0.97	1.00	25.9	3.6
FO–2	38.7	51	0.71	0.89	1.00	1.00	1.00	0.95	30.6	0.9
FO–4	26	51	0.71	0.98	1.00	0.95	0.94	0.95	26	1.0
FO–6	50	51	0.67	0.96	1.00	0.90	1.00	0.93	27.5	1.8
FO–7	50	51	0.56	0.99	1.00	0.90	1.00	0.95	24.2	2.1

Where,
LC = Load Constant (51 lbs)
HM = Horizontal Multiplier
VM = Vertical Multiplier
DM = Distance Multiplier
CM = Coupling Multiplier
AM = Asymmetric Multiplier
FM = Frequency Multiplier
RWL = Recommended Weight Limit
LI = Lifting Index
(For detailed descriptions of terms, see Waters et al., 1994 and Appendix B).

Table 6
Summary Results of Biomechanical Modeling with 3D SSPP
Foss Manufacturing

Task	Load	Disc Comp. ‡	% Capable		Sagittal Shear Force	Torsion
			Hip	Torso		
1. Push Bale from Baler Blending Line	100 lbs / lh	369 lbs	96	99	36 N	62 N
2. Pull Bale and Cart Blending Line	50 lb/ lh 50 lb/ rh	460 lbs	6	99	113 N	2 N
3. Pull Open Baler Door Blending Line	29 lb/ rh	213 lbs	87	99	368 N	11 N
4. Pull Bale and Cart Fiber Line	55 lbs / lh 55 lbs / rt	601 lbs	38	93	645 N	0 N
5. Pull Metal Fiber Can Fiber Line	70 lbs / lh 70 lbs / rh	665 lbs	24	88	752 N	0 N

‡Disc compression force should be well below 770 lbs
lbs pounds
lh/rt left hand/ right hand
N newton

Table 7
Summary Results for Comparison of Pushing/Pulling Forces to Psychophysical Database
Foss Manufacturing

Initial Applied Force (pounds)					
Task	Applied Force	75% Male‡	50% Male‡	25% Male‡	Vertical Height (inches)
1. Push Bale from Baler Blending Line	100 lbs	79 lbs	99 lbs	121 lbs	37 in
2. Pull Bale and Cart Blending Line	100 lbs	73 lbs	86 lbs	99 lbs	37 in
3. Pulling Open Baler Door Blending Line	29 lbs	53 lbs	62 lbs	73 lbs	57 in
4. Pull Bale and Cart Fiber Line	110 lbs	73 lbs	86 lbs	99 lbs	37 in
5. Pull Metal Fiber Can Fiber Line	140 lbs	73 lbs	90 lbs	112 lbs	25 in
Sustained Applied Force (pounds)					
Task	Applied Force	75% Male‡	50% Male ‡	25% Male ‡	Vertical Height
1. Push Bale from Baler Blending Line	100 lbs	57 lbs	75 lbs	90 lbs	37 in
2. Pull Bale and Cart Blending Line	100 lbs	57 lbs	70 lbs	83 lbs	37 in
3. Pull Open Baler Door Blending Line	29 lbs	44 lbs	53 lbs	64 lbs	57 in
4. Pull Bale and Cart Fiber Line	75 lbs	57 lbs	70 lbs	83 lbs	37 in
5. Pull Fiber Cart Fiber Line	97.7 lbs	57.2 lbs	74.8 lbs	90.2 lbs	25 in

‡ Maximum initial & sustained forces for 2.1 meter push, 1 per 30 minutes. From Tables 6 & 7, Snook and Ciriello, 1991. Pushing and pulling forces should not exceed the 75% force levels

Table 8
Summary Results of OWAS Postural Analysis,
Fabric Line G
Foss Manufacturing

Work phase	Frequency	Percentage of Cycle
0 Doffing Roll	1	0.91
1 Handle Mandrel	5	4.5
2 Cut/Begin Roll	9	8.2
3 Prepare for Packaging	12	10.9
4 Feeder Operation	7	6.4
5 Administrative	29	26.4
6 Vacuum Shrink Operation	39	35.4
7 Open Bale	0	0.00
8 Move Bale/Roll	8	7.3
Total	110	100.00

Cycle time was 18.33 min. Sampling rate was 1/10 seconds.

Table 9
Summary Results of OWAS Risk Category Analysis,
Fabric Line G
Foss Manufacturing

Work phase	Category 1	Category 2	Category 3
0 Doffing Roll	0.0	100.0	0.0
1 Handle Mandrel	60.0	40.0	0.0
2 Cut/Begin Roll	55.6	44.4	0.0
3 Prepare for Packaging	91.7	8.3	0.0
4 Feeder Operation	28.6	71.4	0.0
5 Administrative	100.0	0.0	0.0
6 Vacuum Shrink Operation	76.9	23.1	0.0
7 Open Bale	N/A	N/A	N/A
8 Move Bale/Roll	87.5	0.0	12.5
Total	79.1	20.0	0.9

As the numerical value of the risk category increases, the risk of musculoskeletal disorders due to bent and twisted postures also increases. Categories 3 and 4 are undesirable.

Table 10
Summary Results of OWAS Postural Analysis,
Fabric Line A
Foss Manufacturing

Part of Body	Posture	Percentage of Activity
Back	Straight	96.7 %
	Bent	3.3 %
	Twisted	0.0 %
	Bent and Twisted	0.0 %
Arms	2 below shoulder	91.7 %
	1 above shoulder	8.3 %
	2 above shoulder	0.0 %

Table 11
Summary Results of OWAS Postural Analysis,
Fabric Line F
Foss Manufacturing

Part of Body	Posture	Percentage of Activity
Back	Straight	37.8 %
	Bent	62.2 %
	Twisted	0.0 %
	Bent and twisted	0.0 %
Arms	2 below shoulder	100.0 %
	1 above shoulder	0.0 %
	2 above shoulder	0.0 %

Figure 1
Graphic Human Model for Biomechanical Analysis
of Bale Pushing Task (Blending Line)
Foss Manufacturing

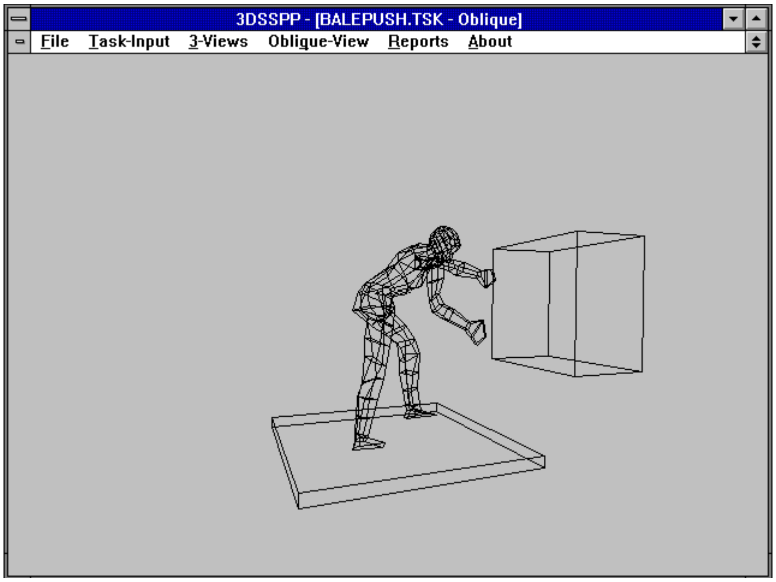
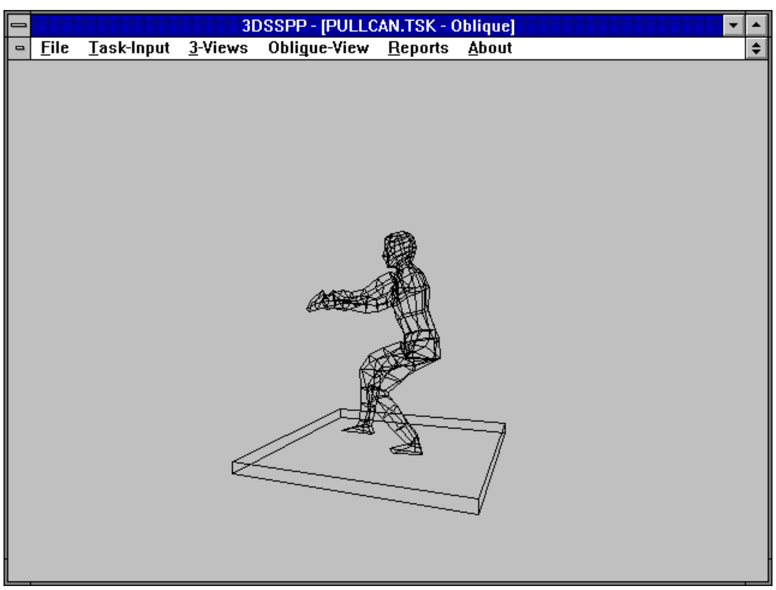
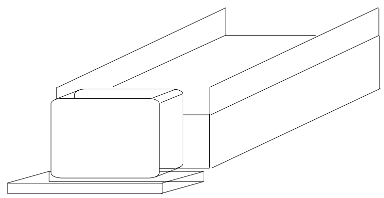
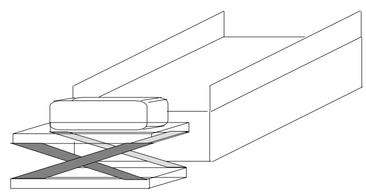


Figure 2.
Graphic Human Model for Biomechanical Analysis
of Pulling Bale and Cart (Fiber Line)
Foss Manufacturing



Figures 3 and 4
Lift Table for Feeder Operation
Foss Manufacturing





Appendix B
NIOSH Lifting Equation Calculations

A. Calculation for Recommended Weight Limit

RWL = LC * HM * VM * DM * AM * FM * CM
(* indicates multiplication.)

Recommended Weight Limit

Component	METRIC	U.S. CUSTOMARY
LC = Load Constant	23 kg	51 lbs
HM = Horizontal Multiplier	(25/H)	(10/H)
VM = Vertical Multiplier	(1-(.003|V-75|))	(1-(.0075|V-30|))
DM = Distance Multiplier	(.82+(4.5/D))	(.82+(1.8/D))
AM = Asymmetric Multiplier	(1-(.0032A))	(1-(.0032A))
FM = Frequency Multiplier	(from Table 1)	
CM = Coupling Multiplier	(from Table 2)	

Where:

H =Horizontal location of hands from midpoint between the ankles. Measure at the origin and the destination of the lift (cm or in).

V =Vertical location of the hands from the floor. Measure at the origin and destination of the lift (cm or in).

D =Vertical travel distance between the origin and the destination of the lift (cm or in).

A =Angle of asymmetry - angular displacement of the load from the sagittal plane. Measure at the origin and destination of the lift (degrees).

F =Average frequency rate of lifting measured in lifts/min.
Duration is defined to be: $\leq$ 1 hour; $\leq$ 2 hours; or $\leq$ 8 hours assuming appropriate recovery allowances (See Table X).

Appendix B
Table 1
Frequency Multiplier (FM)
NIOSH Lifting Equation

Frequency Lifts/min	Work Duration					
	≤ 1 Hour		≤ 2 Hours		≤ 8 Hours	
	V < 75	V ≥ 75	V < 75	V ≥ 75	V < 75	V ≥ 75
0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

†Values of V are in cm; 75 cm = 30 in.

Appendix B
Table 2
Coupling Multiplier
NIOSH Lifting Equation

Couplings	V< 75 cm (30 in)	V $\geq$ 75 cm (30 in)
	Coupling Multipliers	
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90