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Prevention Through Design: A Commercial Fishing Vessel Case Study

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Author Note: Deborah founded ErgoFit Consulting in 2001 after earning her Master's degree in Occupational Therapy at the University of Puget Sound and working for three years in Industrial Rehabilitation. She also has over 25 years of fitness training experience and enjoys being a national Continuing Education Provider for personal trainers. Deborah is long time member and current Administrator / Facilitator of the Pacific Northwest Ergo Roundtable, as well as active member and past President of the Puget Sound Human Factors & Ergonomics Society. She has spoken at many note-worthy conferences including the National Applied Ergonomics Conference, National ASSE Professional Development Conferences, Oregon Governor's Safety & Health Conference, VPP Association for Construction Synergy Conference, the World Of Concrete conference, and several national Firefighter Safety, Fitness, & Health conferences. In addition, Deborah created office ergonomics Web TV shows for Whitney & Wyatt, has been featured on CBS radio, Better Homes & Gardens, EWeek, ivillage, The Ergonomics Report, Ergonomics Today, and more. Gregory Mohs is a Safety Manager at Coastal Villages Region Fund/Coastal Premier Seafoods.

Abstract: A commercial fishing organization was experiencing higher rates of musculoskeletal injuries to their employees, particularly in their fish meal processing area on their trawler fleet vessels. Their job consists of three personnel working 12-16-hour shifts, with two men working at a time while the third sleeps. The two men on-duty rotate every 3 hours between lifting and stacking 77 lb. fish meal bags from floor level to above shoulder or overhead and a bagging/sealing position which also involves lifting fish meal. This is the only job these workers perform for up to 12 days out at sea. They stack 5800 – 6000 bags in 10-12 days. Each fish meal bag is lifted five times prior to off-loading processes; two times during off-loading processes. Our analysis found that lifting of fish meal bags was determined to be a hazardous task based on the combination of lifting conditions. The Intervention included interviewing an Employee, Safety Manager, and Operations Manager in addition to conducting an ergonomic assessment. The author recommended design changes, engineering controls, and administrative controls. Recommendations were shared with Operations manager, Safety Manager, Chief Engineer, Factory Manager and a custom-build conveyor contractor. Some of the recommendations were quickly implemented to eliminate 4 of the 5 lifts per bag prior to the next fishing season, eliminating a total of 1,848,000 lbs. of manual lifting. Results showed that the affected operators reported significant benefits after using the re-designed process during a season at sea.

Keywords: commercial fishing ergonomics, design in safety, engineering controls, prevention through design

1. Prevention Through Design: A Commercial Fishing Vessel Case Study

Prevention Through Design (PtD) is an initiative being advised through the United States' CDC National Institute for Occupational Safety and Health program. The website states "The mission of the Prevention through Design National initiative is to prevent or reduce occupational injuries, illnesses, and fatalities through the inclusion of prevention considerations in all designs that impact workers." The website defines PtD as "PtD encompasses all of the efforts to anticipate and design out hazards to workers in facilities, work methods and operations, processes, equipment, tools, products, new technologies, and the organization of work. The focus of PtD is on workers who execute the designs or have to work with the products of the design. The initiative has been developed to support designing out hazards, the most reliable and effective type of prevention."

Prevention through Design is a best practice that eliminates or reduces occupational health and safety hazards during the design process and prevents work-related injuries, while maximizing efficiency and improving profitability associated with various job tasks, job processes, and facilities.

A commercial fishing organization was experiencing higher rates of musculoskeletal injuries to their employees, particularly in their fish meal processing area on their trawler fleet vessels.

The author was told by the EHS Manager that there had been five employees who sustained injuries working in the Fish Meal production area on one of their commercial trawler vessels in 2014 - 2016, resulting in a direct cost of $390,000 todate, not including their most recent injury. This cost included four of the injuries, maintenance (a daily pay rate until employee is medically cleared – a maritime law), medical treatment, and rehabilitation; but some of the claims were not closed so costs were expected to rise. They asked for an ergonomic assessment and recommendations to reduce the likelihood and/or severity of musculoskeletal injuries. The boat was scheduled to return from the Bering Sea in Alaska the beginning of September.

2. Method

Due to the perishable nature of the fish, fish meal processing occurs immediately after harvest while out on the open ocean. Because all of the processing was already complete once the vessel returned to the dock, no direct measurements or observations could be taken of the active fish meal processing operations. Due to this constraint, the author instead conducted preliminary interviews with the EHS Manager to better understand the job requirements, and conducted preliminary research by watching YouTube videos recommended by the EHS Manager and reading papers and case studies discovered through a Google Search using keywords such as “trawler ergonomics”, “commercial fishing vessel ergonomics”, “fish meal processing”.

The preliminary interviews with the EHS Manager revealed that the Fish Meal production area is staffed with a three-person crew working twelve to sixteen-hour shifts, seven days per week. The fish meal bags weigh 77 pounds and measure 32” x 16” x ~7“. Two crew members alternate every 2-3 hours between bagging/sealing the fish meal bags and stacking them. The stacking task consists of carrying each fish meal bag from a conveyor (on employee’s shoulder) to a stacking spot ranging from below knee level to above shoulder height (~68” H). (Figure 1). The third crew member sleeps Each fish meal bag is lifted seven times: four times in the fish meal bag production process (bagging/sealing), once to stack and, twice to off-load. The first five lifts of each fish meal bag total 385 lbs. worth of manual lifting per. Roughly 6,000 bags are processed during a 10-12 day trip, equaling 2,310,000 lbs. of manual lifting. Future plans will allow an additional 3,000 to 4,000 fish meals bags to be produced.

During the on-site assessment, the author had access to the empty fish meal production and storage areas in the trawler vessel. She also had access to the Chief Engineer, Factory Manager, Fish Meal Technician/Supervisor, one Fish Meal Processor/Laborer, and the EHS Manager. These personnel explained the production and stacking processes step by step, including some simulated demonstrations. Photographs and dimensional measurements were also taken.

During bagging/sealing, the fishmeal is released from a hopper to fill a bag at the bag filling station (Figure 2). Then the open bag is lifted onto a scale. Next it is lifted over and pushed through a 24” W x 29” H hatch with a 4” H threshold (Figure 3). This lift requires the operator to pinch the gathered bag material at the top with a very awkward lifting posture. The bag is then sewn shut (Figure 4). Afterward, the operator is required to lower the bag to the floor and flatten the bag for storage by stepping on it. The bag is then lifted from floor level and carried to a 20” H powered conveyor. The complete bagging/sealing production process requires each 77 pound fish meal bag to be lifted four times by one crew member.

In the lower storage room during stacking, the fish meal bags are lifted from a manual height-adjustable conveyor (via a chain fall) as shown in Figure 5 (shown at 69” height), allowing them to be placed directly on the shoulder one at a time, and then carried to their stacking location where they are lowered onto the stack. Operators are not required to lower the bags below knee level and are able to use gravity to assist the movement. This lowering/stacking maneuver is considered the fifth lift in the production process.

In the upper storage room during stacking, the fish meal bags are lifted from a conveyor at about 49” height (Figure 6), requiring taller employees to lift from a squat position in order to unload the fish meal bag directly to the shoulder and then carry to its stacking spot.

The ACGIH TLV for Lifting was used to analyze the fish meal bag lifting. This assessment tool recommends workplace lifting conditions under which it is believed nearly all workers may be repeatedly exposed, day after day, without developing work-related low back and shoulder disorders associated with repetitive lifting tasks. The “Frequent, Long Duration Lifting” chart was used (Figure 7). The ACGIH TLV for Lifting is designed for an 8-hour shift and for objects with fair-to-good handholds. The recommended weight limits range between 20 – 30 lbs. varying by region of the body in the near zone. Because operators are lifting 77 lb. fishmeal bags with poor handholds for 12-16 hour shifts the recommended limits are even much lower than these indicated in the chart. The bags are lifted/lowered, in some instances, to 3” below shoulder and above, which is an area with no known safe limit for repetitive lifting at this duration.

Figure 1. Fish meal bags get stacked in a staircase fashion from the floor to roughly 68” H.

Figure 2. Bag Filling Station. Table below filler (left) 22” H; scale on lower surface (right) is ~20”H, not pictured

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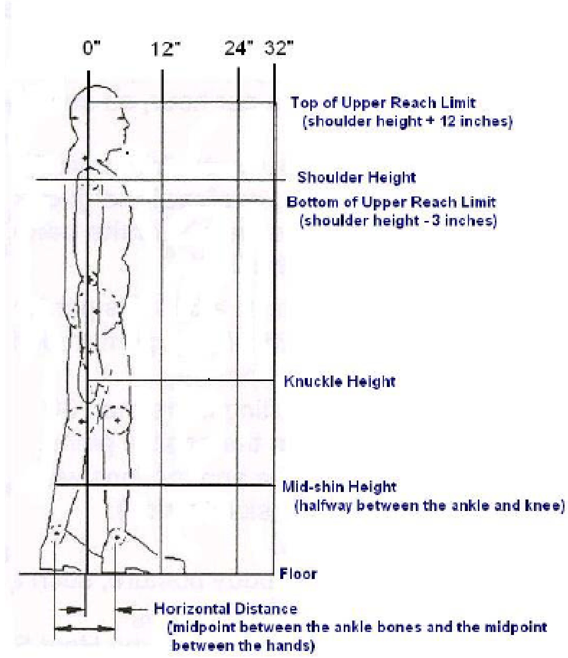
Figure 3. 12” H door threshold creates a tripping hazard; hatch threshold is ~4” H and is ~24” x 29”

Figure 4. Sewer counterbalanced by a spring which is set too low and therefore requires a manual lift each time. Powered conveyor (front left) is 20” H.

Figure 5. Powered conveyor in lower storage area has some height adjustability for different employee statures. Shown here at 69” H for comfortable shoulder loading for this employee.

Figure 6. Powered conveyor in upper storage area requires squatting to unload due to the inability to adjust the height of the conveyor higher without having the fish meal bags slip down the conveyor belt. Shown here at ~ 49” H.



Vertical Height of Hands	Horizontal Distance of Hands from Body[A]		
	Close: < 12 inches (30 cm)	Intermediate: 12-24 inches (30-60 cm)	Extended:[B] 25-32 inches (60-80 cm)
Reach Limit:[C]	25 lbs (11 kg)	No known safe limit for repetitive lifting[D]	No known safe limit for repetitive lifting[D]
Shoulder Area: 12" above to 3" below shoulder	25 lbs (11 kg)	No known safe limit for repetitive lifting[D]	No known safe limit for repetitive lifting[D]
Torso Area: Below shoulder to knuckle height[E]	30 lbs (14 kg)	20 lbs (9 kg)	10 lbs (5 kg)
Knee Area: Knuckle to middle of shin height[E]	20 lbs (9 kg)	15 lbs (7 kg)	5 lbs (2 kg)
Ankle Area: Middle of shin height to floor	No known safe limit for repetitive lifting[D]	No known safe limit for repetitive lifting[D]	No known safe limit for repetitive lifting[D]

Footnotes for Table 3:

A. Distance from midpoint between inner ankle bones and the load
B. Lifting tasks should not start or end at the horizontal reach distance more then 32 inches from the midpoint between the inner ankle bones (See Figure 1)
C. Routine lifting tasks should not start or end at heights that are greater than 12 inches above the shoulder or more than 71 inches above floor level (see Figure 1)
D. Routine lifting tasks should not be performed for shaded table entries marked "No known safe limit for repetitive lifting." While the available evidence does not permit identification of safe weight limits in the shaded regions, professional judgment may be used to determine if infrequently lifts of light weight may be safe.
E. Anatomical landmark for knuckle height assumes the worker is standing erect with arms hanging at the sides.

Figure 7. ACGIH TLV Frequent, Long Duration Lifting chart

3. Results

The majority of recommended improvements directly addressed the bagging/sealing area, which account for four of the five fish meal bag lifts before off-loading. The fifth lift occurs during stacking. Two additional lifts occur during off-loading, which is not addressed in this paper.

The author recommended the handheld sewer be installed directly over the scale on a properly calibrated tool balancer in order to eliminate another fish meal bag lift (formerly to the floor for sealing), the lifting of the sewer itself, and to reduce inefficiencies. This was implemented (Figure 8). The author recommended a metal ramp/chute be installed between the bag filling surface and the scale. This was not implemented because there was insufficient time in the shipyard before the next sailing. Instead, an adjustable stand was provided under the scale to make it level, which allows the bag to be slid from the filling surface to the scale. (Figure7). Future modifications are planned for the month after the writing of this paper, and a ramp/chute may be installed.

The author recommended the scale be lowered to a height that would allow each newly filled bag to be slid onto the scale rather than lifted, and would place the employee's hands at about waist height (~33" H) for sealing. This was not implemented, so the sealing elbow is at about chest height ('winged' to the side) (Figure 9). The current height was chosen so the roller conveyor height matches up with the powered conveyor height, in order to avoid a manual lift or push. This will be re-visited while the vessel is back in the shipyard. The author recommended removing the 12" H door threshold to eliminate the tripping hazard and free up and speed up movement within the work area. This was implemented (Figure 10). Furthermore, after investigating, the company discovered they could remove the entire door & hatch wall, which they completed (Figure 10).

The company was already planning to install an automated bag squeezer. This was implemented, embedded into the existing powered conveyor (Figure 11). It presented a new challenge with the new process because the bag needed to be flat on its side in a particular orientation to fit through the squeezer. This resulted in the author recommending fabrication of a push-lever bar, which the company did successfully implement (Figure 12). The author recommended installing a powered conveyor to move the fish meal bags directly from the scale through the hatch to the automated bag squeezer (which might involve modifying the hatch opening dimensions) and adding a conveyor knuckle to connect to the existing powered conveyor. This would increase production and eliminate the awkward lift up and over the 4" H hatch threshold. Installing a pop-up roller ball transfer section was recommended for the bag squeezer area if it could tolerate the force. Instead of a powered conveyor, they installed a roller conveyor adjacent to the scale, but the fish meal bags are too soft and get caught so the employees have modified by using a piece of rigid plastic (UHMW plastic) under each bag; then the employee rolls the fish meal bag along the rollers at a comfortable height while walking next to it. (Figure13).

The upper storage powered conveyor was recommended to be raised to a height that would eliminate squatting in order to position the fish meal bag onto an employee's shoulder, yet still allow some height adjustability. This was implemented (Figure14). The author recommended consideration of using smaller ~66 pound bags like other companies. This has not been implemented because of customer preference. The author recommended one-hour rotations between bagging/sealing and stacking instead of every two-three hours. A strict two-hour rotation was implemented and well received.

Once the recommended changes had been implemented, an employee survey was conducted with the six affected operators, after a full season of use. A 4-point Likert scale was used for employees to rate their level of agreement with statements about the design changes: strongly disagree, somewhat disagree, somewhat agree, strongly agree, with corresponding scores of 1, 2, 3, or 4. The results were very positive as seen in Table 1. 92% of respondents somewhat or strongly agreed that "Having the bag sewer on a tool balancer has helped reduce my discomfort or fatigue". 92% of respondents somewhat or strongly agreed that "having the bag sewer on a tool balancer has helped reduce my discomfort or fatigue." 100% of respondents somewhat or strongly agreed that "The removal of the door has helped reduce my discomfort or fatigue." 96% of respondents somewhat or strongly agreed that "the roller added between the bag sewer to the powered conveyor has helped reduce my discomfort or fatigue." 100% of respondents somewhat or strongly agreed that "the automated bag squeezer has helped reduce my discomfort or fatigue." 95% of respondents somewhat or strongly agreed that "the modified angle of the powered bagged-fishmeal conveyor to the upper room has helped reduce my discomfort or fatigue". The supervisor was the only respondent to answer he strongly agreed that "the 1-hour rotation between bagger/sewer and stacker has helped reduce my discomfort or fatigue."

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Figure 8. Sewer suspended on tool balancer. No ramp between bag filler table and scale surface; bag is dragged.

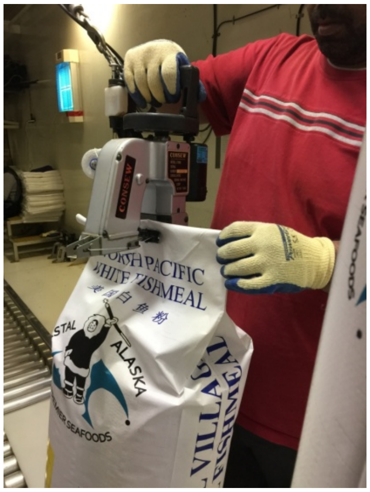

Figure 9. Sewer machine too high and too far to the left (from employee perspective), causing high risk shoulder posture.

Figure 10. Entire wall opened up to allow easier, faster movement.

Figure 11. Automated bag squeezer on existing powered conveyor to the lower storage level.

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Figure 12. Push-lever bar to transition the fish meal bag from upright to side-lying in the correct orientation to feed into the bag squeezer.

Figure 13. Rigid plastic used under each bag to ease sliding.

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Figure 14. Powered conveyor in upper storage area set at height that avoid a squat lift and allows bag to easily be positioned on employee's shoulder.

Table 1. Post-Design Field Testing Survey

Post-Design Field Testing Survey Item	Number of people who answered	Score	Rating
The new bag filler stand that lets me slide the bag to the scale has helped reduce my discomfort or fatigue	**6**	22 out of 24	92% Somewhat or Strongly Agreed
Having the bag sewer on a tool balancer has helped reduce my discomfort or fatigue	**6**	22 out of 24	92% Somewhat or Strongly Agreed
The removal of the door has helped reduce my discomfort or fatigue	**6**	24 out of 24	100% Strongly Agreed
The roller added between the bag sewer to the powered conveyor has helped reduce my discomfort or fatigue	**6**	23 out of 24	96% Somewhat or Strongly Agreed
The automated bag squeezer has helped reduce my discomfort or fatigue	**6**	24 out of 24	100% Strongly Agreed
The modified angle of the powered bagged-fishmeal conveyor to the upper room has helped reduce my discomfort or fatigue	**5**	19 out of 20	95% Somewhat or Strongly Agreed
The 1-hour rotation between bagger/sewer and stacker has helped reduce my discomfort or fatigue	**1**	4 out of 4	100% Strongly Agreed

4. DISCUSSION

During the fish meal bag production and stacking process, five lifts were required per fish meal bag produced, requiring a total of 385 lbs. of manual lifting per bag. With 6,000 fish meal bags being produced during a 10-12 day trip, that was equivalent to 2,310,000 lbs. of manual lifting. The ergonomic re-design of a commercial fishing vessel's fish meal production area resulted in four of five manual lifts being eliminated per 77-lb. fish meal bag produced, eliminating a total of 1,848,000 lbs of manual lifting. The affected operators, rotating between the tasks of bagging/sealing and stacking, reported significant benefits after using the re-designed process during a season at sea.

For the entire fish meal bag production process, 80% of the manual lifting was eliminated using a Prevention Through Design philosophy using ergonomics as the solution to prevent musculoskeletal discomfort and injuries as well as to improve efficiencies and moral. Although a 77 lb. lift is still considered a high risk when performed for the durations required for this task, it was eliminated for the bagging/sealing area. The 2-hour rotation into the bagging/sealing area, therefore, now provides rest and recovery after working in the stacking area for 2 hours. This reduces the lifting demands from continuous for 12-16 hours, down to a total duration of 6 – 8 hours over the course of a shift. Remediation recommendations are still being explored for the stacking position, and further refinements for the bagging/sealing area will likely be implemented before the next season. Efficiency measurements were not taken for that first season. This would have been a meaningful metric and it is recommended for the next season and for other ergonomic design projects.