ABSTRACT

EFFECTS OF COLD STRESS ON WORKER PERFORMANCE IN A REFRIGERATED WAREHOUSE

by
Margarita Chernyshov

The effects of cold stress were evaluated on worker performance in a low temperature environment. Level of clothing protection was compared to the functional ability of working on various tasks. Physical as well as mental effects were discussed to develop a basis for the physiological adaptations due to cold stress. The study focused on workers that performed various simple and complex tasks in a refrigerated warehouse with a temperature range 32°-40°F. Surveys were distributed to employees who presently and previously worked in this refrigerated area. The "Picker" and "Feeder" tasks were analyzed as they pertain to this low temperature environment. Workers' productivity was also observed on each work task at 5-minute intervals for the following time periods: 1) Post-shift start, 2) Pre-break, 3) Post-break, and 4) Pre-shift end.

Results from the observations showed a decreasing trend in productivity towards the lunch break compared with the beginning of the shift. Similarly, a downward productivity trend occurred towards the end of the shift compared to when they first came back from lunch break. Suggestions for workplace modifications and environmental controls were provided based on the worker surveys and productivity observations. These recommendations are a model for this and future refrigerated warehouses in terms of improving thermal comfort, safety and production efficiency.

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by
Margarita Chernyshov

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APPROVAL PAGE

THE EFFECTS OF COLD STRESS ON WORKER PERFORMANCE IN A REFRIGERATED WAREHOUSE

Margarita Chernyshov

Dr. One-Jang Jeng, Thesis Advisor — Date
Assistant Professor of Industrial and Manufacturing Engineering and
Director of Occupational Safety and Health Engineering Graduate Program, NJIT

Dr. Arijit Sengupta, Committee Member — Date
Associate Professor of Industrial and Manufacturing Engineering, NJIT

Dr. Norman J. Van Houten, Committee Member — Date
Director of Health and Environmental Safety, NJIT

BIOGRAPHICAL SKETCH

Author: Margarita Chernyshov

Degree: Master of Science in Occupational Safety and Health Engineering

Date: January 2001

Undergraduate and Graduate Education:

- Master of Science in Occupational Safety and Health Engineering
  New Jersey Institute of Technology, Newark, NJ, 2001

- Bachelor of Science in Civil Engineering
  New Jersey Institute of Technology, Newark, NJ, 1997

Major: Occupational Safety and Health Engineering

Presentations:

Margarita Chernyshov,
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To my beloved family…Alex, Ninel, Elvis, Angela and Rob.

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CHAPTER 1

INTRODUCTION

Objective

The objective of this thesis is to evaluate the effects of cold stress on worker performance in a low temperature environment, specifically a refrigerated warehouse.

A workplace survey was conducted in the Order Pick department to assist in gaining valuable information for creating job improvements. The survey was distributed to employees who presently and previously worked in this refrigerated area. The "Picker" and "Feeder" duties in the Order Pick department were analyzed as they pertain to the refrigerated work environment. Productivity observations were also performed on the Picker and Feeder for 5-minute intervals at the following time periods: 1) Post-shift start, 2) Pre-break, 3) Post-break, and 4) Pre-shift end. Physical and mental effects were discussed to develop a basis for any physiological adaptations due to cold stress. The level of clothing protection was compared to the functional ability of working on various tasks. Recommendations based on the surveys and productivity observations were provided for improving workplace thermal comfort and production efficiency.

1.2 Background Information

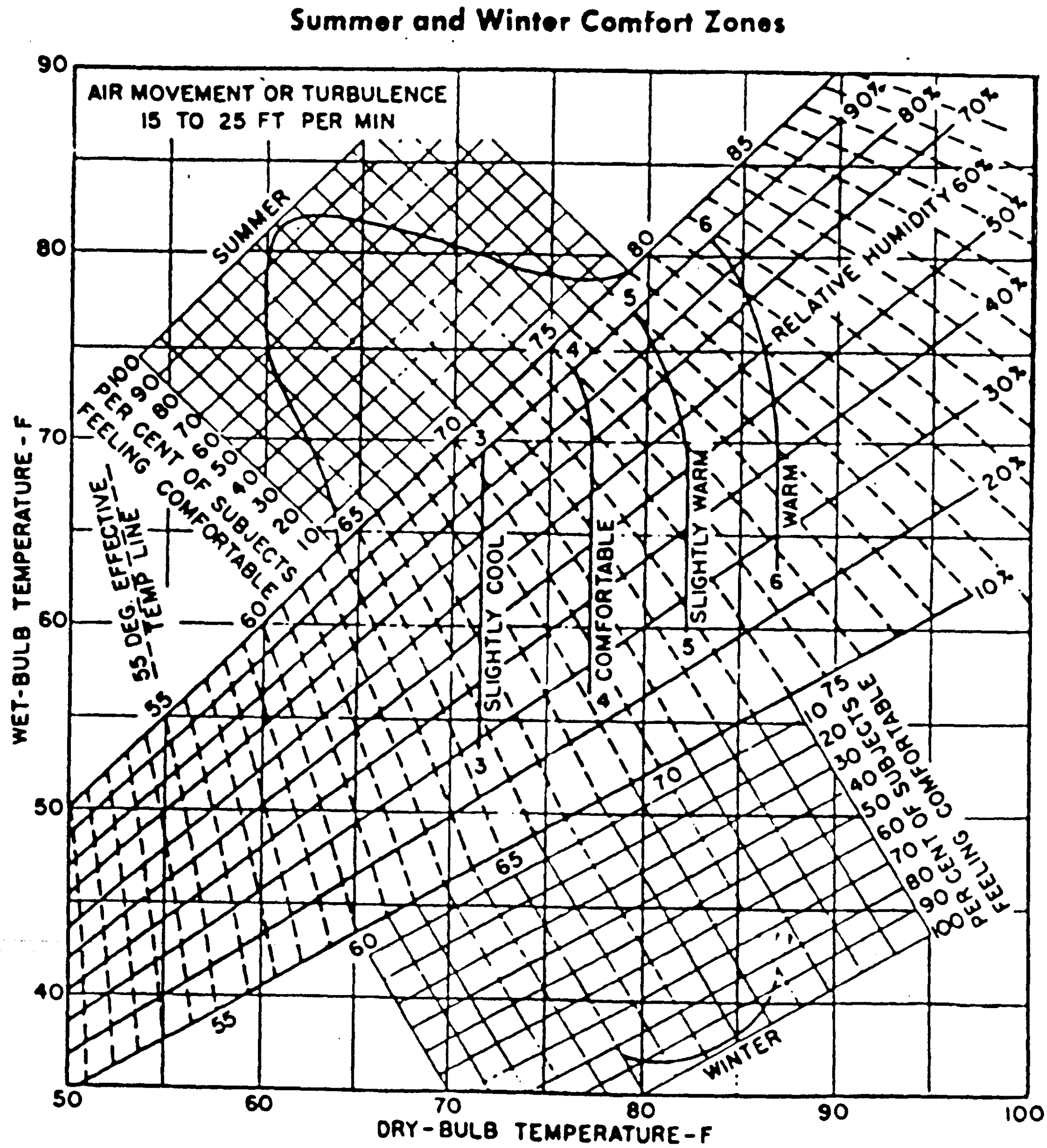
A thermal comfort zone exists that varies for each individual. The temperature range in which the majority of people feel comfortable was named the "comfort zone" by Yaglou, one of the early workers in this field (Yaglou, 1926). The temperature levels within the comfort zone in the UK and USA were found to be in the range 21 - 24°C provided that the relative humidity is between 30 and 70 per cent and that air movement can be no more than 0.2 m/s (Clark and Edholm, 1985). Symptoms of feeling uncomfortable or discomfort are experienced when the temperature begins to exceed or fall below the zone limits. Thermal comfort may be best described as the absence of sensation or discomfort since there are no specific comfort sensory nerves. Table 1.1 shows the Bedford scale and a similar scale that was designed at ASHRAE, (American Society of Heating, Refrigeration and Air-conditioning Engineers, 1974). This scale was used by Bedford (1936) and others to investigate the preferred temperature of people working under different conditions around the world.

Table 1.1 The 'Bedford' scale and ASHRAE scale of warmth (Bedford, 1936).

The Bedford scale	The ASHRAE scale
Much too warm	Hot
Too warm	Warm
Comfortably warm	Slightly warm
Comfortable	Neutral
Comfortably cool	Slightly cool
Too cool	Cool
Much too cool	Cold

Even under optimal conditions studies show that 2.5 percent of the population are too cold and 2.5 percent are too warm. Each individual's comfort level will vary according to time of day, season, diet, hormonal changes, behavior, clothing choices, presence of other job stress, and cultural variables and expectations. Another study gathered on several thousand people using psychophysical data defined the comfort zone (Fanger, 1970). The temperatures they generally considered comfortable are between 19°C and 26°C. Their comfort zone is very close to Clark and Edholm's (1985) results of 21°C to 24°C. Figure 1-1 shows the ASHRAE chart for comfort zones involving sedentary activities provided that humidity isn't too high at the upper limit and air velocity isn't too excessive at the lower limit (Eastman Kodak Company, 1983).

Figure 1-1 ASHRAE chart for comfort zones for sedentary activities. (Based on information in ASHRAE Standard 55-1981)



The core body temperature and wind chill index are two main factors when evaluating cold exposure. The core temperature is a physiological concept to describe internal body temperature. Various methods used to monitor core temperature are not acceptable in the workplace, however an esophageal temperature probe is the preferred instrument. The oral temperature is approximately 1°F over the core temperature. An accurate oral temperature can be registered if the individual does not eat or drink for 15 minutes prior to sampling. Many new advances have surfaced in medical technology. An infrared ear canal sensor, a surface-mounted chest sensor and an edible "pill" transmitter are just some of the new methods used to measure the core temperature (Plog et al., 1996).

The risk of cold injury is determined by the wind chill index. Thermometers capable of measuring temperatures down to at least –40°C (-40°F) determine the ambient temperature (Wald and Stave, 1994). The wind chill index sets the Threshold Limit Values (TLV's) for cold stress in the workplace. Environmental temperatures below 16°C (60.8°F) at the workplace should have adequate thermometry available (American Conference of Government Industrial Hygienists, 1992). Dry bulb temperature should be measured every 4 hours whenever the workplace temperature falls below -1°C (30.2°F) (American Conference of Government Industrial Hygienists, 1992).

Heat stress exposures have adaptive mechanisms such as sweating and acclimation, whereas exposures to cold stress have entirely different physiological adaptations. Some evidence does exist that humans are capable of minor physiologic adaptation and acclimatization or habituation to the cold, however, the ability to acclimatize to heat is much greater (Saunders, 1971). The skin and deep body temperatures, which are both sensed in the hypothalamus, primarily determine our sensations to both heat and cold. The hypothalamus initiates the body's two main defenses against cold, peripheral vasoconstriction and shivering (Wald and Stave, 1994). Table 1-2 shows the cooling power on exposed flesh used as equivalent to measure the wind chill index. It estimates the relative cooling ability using a combination of actual temperature readings and wind speeds.

Table 1-2. Cooling power of wind on exposed flesh expressed as equivalent temperature (Wald and Stave, 1994).

Estimated wind speed (in mph)	**Actual temperature reading (F)**											
	50	**40**	**30**	**20**	**10**	**0**	**-10**	**-20**	**-30**	**-40**	**-50**	**-60**
	Equivalent chill temperature (F)											
Calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-24	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-32	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	39	-53	-67	-82	-96	-110	-121
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-51	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-55	-69	-85	-100	-116	-132	-148
(Wind speeds >40 mph have little additional effect)	LITTLE DANGER				INCREASING DANGER					GREAT DANGER		
	In< 1 hr with dry skin. Maximum danger of false sense of security				Danger from freezing of exposed flesh within 1 minute.					Flesh may freeze within 30 seconds.		
	Trenchfoot and immersion foot may occur at any point on this chart.											

The initial response when the body is being cooled is to conserve heat at the core, primarily the organs. This thermoregulatory reaction reduces blood circulation through the skin by constricting the blood vessels (vasoconstriction). Warm blood is kept away from the body surface making the skin act as an insulating layer. Therefore, the total body heat lost to the environment is decreased. The second physiological response to cold stress exposure is shivering. This type of involuntary muscle contraction results in increased metabolic heat production and can replace heat being lost. The actual metabolic rate may increase two to five times (Reed and Anderson, 1984). Although shivering increases the rate of metabolism it does not completely replace lost body heat. Shivering is associated with an increase in the respiratory and heart rate. However, continued cooling will reduce the core body temperature and decrease the metabolic, respiratory and heart rates. The blood is then shunted from the skin to the body core resulting in cold diuresis and decreased fluid volume (Hamlet, 1988).

The core body temperature is maintained by decreasing heat loss (peripheral vasoconstriction) and increasing heat productivity (shivering). Heat production can be increased by performing physical activity. The sum of heat produced internally plus heat gain and loss from the environment equals the body temperature. The amount of heat the body can store (S) and heat exchange express systemic cold stress by the following equation: $S = M + (R + C) + K + E$ (Plog et al., 1996). In this equation M is Metabolic rate, R designates the radiation factor or radiant heat exchange rate, C is the rate for convective heat exchange, K designates conduction or the conductive heat exchange rate and E refers to the rate of evaporative heat loss.

The body can lose heat from radiation, conduction, convection and evaporation (Wald and Stave, 1994). Heat loss in the cold most often occurs in cold water immersion or low air temperature exposure while wearing wet clothing. The thermal balance of the body is affected by the presence of two types of injuries: systemic (non-freezing) cold injury and local (freezing) cold injury. Hypothermia is a non-freezing cold injury that also includes chilblains, pernio and trench/ immersion foot. Frostnip and frostbite are examples of freezing cold injuries that result in localized tissue damage.

Hypothermia occurs when the body is not able to produce the heat to replace the amount lost to the environment. A lowering of the core body temperature below 35°C (95°F) will result in hypothermia. This systemic cold injury may also be initiated by air temperatures of 18.3°C (65°F) (Wald and Stave, 1994). Hypothermia is generally associated with a long-term exposure to the cold, environment, wind, physical exertion and becoming wet. Cold-related problems may also include accidental injury, sunburn, snow blindness, carbon monoxide poisoning and urticaria.

Frostnip is a mild but reversible freezing cold injury that involves no loss of tissue. Frostbite, however, is irreversible and involves the formation of ice crystals and disruption of cells. Its localized effects include freezing the tissue and damaging the capillary walls of the frostbitten area. The cell wall permeability is increased and fluid is released into the tissue causing local inflammation. Freezing cold injury most commonly affects the most peripheral parts of the body or extremities – the toes, fingers, nose, ears and cheeks (Wald and Stave, 1994).

CHAPTER 2

EFFECTS OF LOW TEMPERATURES

2.1 Health Factors Affecting Cold Tolerance

In Chapter 1 we discussed injuries related to cold exposure but there are other factors that can affect the extent of injury and likewise cold tolerance. Individual factors can influence the body's ability to maintain certain temperatures and avoid injury in a cold environment. Cold exposure can lead to hypothermia and, ultimately, death depending on the environmental, physiological and clothing variables. The individual factors are body size, shape, age, gender, subcutaneous fat, physical fitness, smoking habits, previous cold injury, drugs and alcohol (Bensel and Santee, 1997). Table 2-1 shows the individual factors affecting cold tolerance.

Body size is a cold tolerance factor because larger individuals are favored by their surface to mass ratio (Plog et al., 1996). They have "thermal inertia" due to greater total heat storage with greater mass. Proportionally, smaller adults have a greater area for heat loss. The body shape and length of extremity also matters because of the surface to mass ratio (Bensel and Santee, 1997). A tall person loses more heat to the environment than does a short person. Likewise, shorter extremities have a reduced surface to mass ratio. Subcutaneous fat, on the other hand, will provide insulation. The amount of heat lost to the environment is less when the individual has more subcutaneous fat. The physical fitness level of a person will also determine their tolerance to a cold environment. Regular exercise increases blood circulation for the body and total heat production. Physical activity also increases the proportion of lean body mass for heat production.

Table 2-1. Factors affecting cold tolerance (Bensel and Santee, 1997).

FACTORS	EFFECTS
Body size	Surface to mass ratio favors larger adults.
Body shape	Shorter extremities result in less heat lost.
Subcutaneous fat	Subcutaneous fat provides insulation.
Physical fitness	Regular exercise increases total heat production.
Age	Younger adults are more resistant to cold injury due to their low body mass.
Gender	Women have lower skin temperature in cold than men.
Smoking habits	Vasoconstriction action causes increased cooling of extremities.
Previous cold injury	Predisposes an individual to subsequent cold injury.
Drugs and alcohol	Alcohol-induced vasodilation causes rapid initial heat loss.

Circulation plays a big part in cold tolerance especially with older adults. They tend to have poorer circulation and less lean body mass for heat production. Younger adults have better circulation and are more resistant to cold injury than older adults. The very young have a lower body mass and are less tolerant to cold. Gender is also a factor that can affect cold tolerance. A study was carried out on sex differences in subjects exposed to 10°C for 2 hours wearing standardized clothing (Tanaka, 1972). Women were found to have less heat production than the men do. Yet, males had a decrease in mean skin temperature during cold exposure than females. Tanaka inferred from these results that female subjects might possibly have the ability of acclimatization to winter cold. A similar experiment was performed by Osada et al (1972). The authors concluded that females were much more tolerant to cold than males, especially in winter, because they could resist to cold by lowering their heat loss from the body surface without remarkable increase in the metabolism. These results are both possibly due to the female body size and shape or amount of subcutaneous fat insulation (Itoh, 1974).

Various personal habits also have an affect to cold tolerance. People with smoking habits experience the vasoconstrictive action of nicotine that causes an increased cooling of the extremities, Individuals with a previous cold injury such as frostbite are predisposed for a subsequent injury. Additional clothing should be worn by workers with an increased risk of cold injury. Drug and alcohol use may modify the central temperature regulation. Vasodilation that is alcohol induced will counter heat conservation and cause a rapid initial heat loss (Plog et al., 1996). Other conditions that may prevent work in the cold include exertional angina, asthma, peripheral vascular disease, coronary artery disease and thermoregulatory disorders (Wald and Stave, 1994). Medical surveillance of these factors and conditions is necessary for selecting individuals to work in cold environments. This criteria requires 1) physical and mental qualifications needed for the specific job, 2) medical evaluation of the person's physical and psychological ability to work in the cold and 3) identification of specific medical conditions that may be contraindication s to working in the cold.

2.2 Effects of Performance on Work Tasks

Virtually anywhere in the world, cold is a physical hazard that can affect workers both indoors and outdoors. Workers at risk include those in construction, farmers, fishermen, utility workers, lumberjacks, soldiers, petroleum workers, police officers, firefighters, postal workers, butchers and cold storage workers. Cold injuries occur sporadically in the civilian populations, in both recreational and occupational settings. Historically cold injuries have presented problems for military campaigns such as the armies of Xenophon (400 B.C.), Hannibal (218 B.C.), Napoleon (1812-13), and Hitler (1941-42). All suffered a significant number of injuries due to cold (Whayne and DeBakey, 1958).

The environment itself and the clothing worn to protect against it attribute to the performance effects associated with low temperatures. Movement due to the weight and bulk of the clothing increases an energy cost. Just by adding 1 kg to the mass of footwear increases energy cost as much as adding 5 kg to the mass of a load carried on the torso (Soule and Goldman, 1969). Layers of cold weather clothing restrict arm movements and limit waist flexion. Walking in layered clothing systems increase energy costs by 3% to 4%, an increase beyond that due to weight change (Teitlebaum and Goldman, 1972). The frictional resistance between layers attribute this increase. Another variable is the hobbling effect or the interference with joint movements due to bulk clothing. Boots that are bulky may be incompatible with workplace features such as small ladders, steps and footholds. Hoods may interfere with head movement, hearing and vision. Dexterity capabilities with cold weather gloves were found to be inferior to the performance of bare hands even after extensive practice (Lyman, 1957).

The ability to perform manual tasks affects productivity in a low temperature environment. Handwear can cause interference, as a result, some may compromise hand protection in order to work in the cold. Clark (1961) found that dexterity was impaired when hand skin temperatures fell between 18°C and 13°C. Tactile discrimination was noticeably impaired at finger temperatures below 6°C (Provins and Morton, 1960). The way in which body temperatures interact to affect manual performance is complex, particularly core, hand skin temperatures and cooling rates. Manual operations were found to be impaired by the appearance of diminished blood flow to the fingers, decreased muscle temperature, increased viscosity of the synovial fluid in the finger joints, and lower responsiveness of the skin receptors (Lockhart et al., 1975).

Tasks that have a cognitive component were found to be impaired by cold temperatures. Teichner (1958) found that simple reaction time was unaffected down to –37°C. Attention from the primary task was momentarily diverted due to distracting environmental stimuli, such as physical discomfort. Enander (1987) found that simple addition was unaffected at 4°C but the digit classification error increased. Teichner and Wehrkamp (1954) studied subjects performing a pursuit-tracking task and found a decrement starting at 13°C. An increase in delayed responses was found at –3.3°C for performing tasks of a vigilant nature (Poulton et al.,1965).

CHAPTER 3

ROLE OF CLOTHING

3.1 The Layer Principle

The objective of cold weather clothing is to provide adequate insulation, allow the wearer to function efficiently and prevent overheating while working. Dressing in layers is a key factor when preparing to work in the cold. Three main components comprise the layered system: inner, intermediate and outer. Rather than one or two thick layers, a number of thin layers are recommended (Bensel and Santee, 1997). A delicate balance exists with matching the metabolic heat production to the addition or removal of clothing.

Layers of clothing are removed or opened when activity is increased and replaced or closed when activity is decreased. Ventilation should occur to prevent the clothing to become wet with perspiration. This moisture may condense in the garment and lower the insulation value by promoting heat loss through evaporation from wet skin and clothing. Each opening that makes ventilation and clothing removal easier also comprises the wind resistance and water penetration capability of the clothes. The environmental conditions and activity level will determine the quantity and extent of each layer. A decreased activity level should immediately signal the addition of clothing and torso-extremity protection for working in the cold (Bensel and Santee, 1997).

3.2 Protection Factors

Two main factors for cold weather workwear design depend on keeping the torso warm and preventing sweat build-up. The upper torso and arms should have few seams in the outer layer and all seams factory-sealed. A two-way zippered front is suggested with openings in the outer and intermediate layer. All zippers should be made of plastic with pull tabs that can easily be handled with mittens and gloves. An adjustable drawcord in the bottom hem of the outer layer will keep the cold out when shifting positions. The bottom hem of each layer should extend to the hips or lower and overlap the clothing of the lower torso. The lower torso and legs should also have an outer layer with a few seams that are all factory-sealed. Zippered side openings in the outer and intermediate layers will accommodate removal of layers over boots. The bottom hem of the outer layer should extend over boot tops. Finally, layers should stay in place for the upper torso when arms are raised and for the lower torso during crouching and bending (Bensel and Santee, 1997).

The extremities are the next focus in the protective layering system. They include the head, hands and feet. Since 30% of body heat is lost through the head some type of headwear should be worn (Wald and Stave, 1994). The inner layer of headwear should cover the head, neck and provide some coverage for the face. The intermediate layer should include a cap covering the ears and an insulated hood attached to the jacket. Finally the outer layer calls for a wind and water-resistant hood, if necessary. The hood should extend beyond the face to direct warm air from within the clothing out past the face. A desirable feature in headwear can include a malleable wire around the hood edge to allow for adjusting the opening and accommodate environmental and visual requirements (Bensel and Santee, 1997).

A successful layering for the hands usually involves gloves and mittens. The inner layer should include thin gloves covering the wrists. The intermediate layer should have insulated gloves or mittens covering the wrists. Wind and water-resistant insulated mittens with long gauntlets extending over the wrists, onto the forearms comprise the outer layer. The handwear should stretch and re-conform to the changing dimensions of the hand. The fingers should not be constricted to interfere with circulation and possible lowering of hand temperatures. The seams should not be located at the fingertip where they can interfere with dexterity and result in heat loss (Bensel and Santee, 1997).

Cold injuries to the feet are very subtle yet dangerous. Numb feet may cause individuals to not realize that they are the victims of trench foot or frostbite. Keeping the feet dry and applying the layering principle are key in preventing such injuries. The inner layer of footwear should consist of thin socks covering the ankles. Then one or more pairs of thick sock extending above the ankles. The outer layer may include permeable boots with insulated insoles or impermeable, vapor barrier boots with insulated insoles. Finally an optional waterproof gaiter for low-top permeable boot may complete the outer cover. Boots should fit loosely enough to accommodate underlying sock layers allow toes to move freely. The risk of cold injury can be minimized by replacing damp socks and insoles frequently during use to avoid moisture build-up. Socks should be clean and discarded if worn areas are visible (Bensel and Santee, 1997).

3.2.1 Exposure Guidelines

The Threshold Limit Values (TLV's) objective is to keep the core body temperature from falling below 36°C (96.8°F). Workers can repeatedly be exposed to the TLV's without hazardous health effects. TLV's are also used to prevent cold injury to the extremities of the body. The core body temperature should not be allowed to drop below 35°C (95°F) although some cold injury signs and symptoms would be expected (Wald and Stave, 1994). Maximum exposure time depends on air temperature and ambient air movement. Plog et al, 1996). The TLV for Cold Stress contains specific re-warming schedules since the environmental conditions may become very cold (ACGIH Threshold Limit Values and Biological Exposure Indices, 1992-1993).

Unprotected skin should not be allowed continuous exposure when the equivalent chill temperature is less than -32°C (-25.6°F). Hand protection is required when bare hands perform fine work for more than 10-20 minutes in an environment below 16°C (60.8°F). Special provisions for keeping the worker's hands warm should be established to maintain manual dexterity. At temperatures below –1°C (30.2°F) thermal insulating material should cover metal handles. Anti-contact gloves should be worn to prevent contact frostbite if necessary. A warning should be given at temperatures below –7°C (19.4°F) to each worker at least daily by the supervisor. This notification will help remind workers to avoid inadvertent contact of bare skin with cold surfaces. Finally, hands should be protected by mittens if the air temperature is –17.5C (0F) or less (Wald and Stave, 1994).

3.2.2 Prevention Methods

Education and awareness are the most important prevention methods. Workers can use this safety and health information to make safe personal decisions regarding the cold environment. Signs and symptoms of a cold-related injury can be identified through a buddy system or self-aid. A proper protective clothing system is the best tool for shielding workers and preventing cold injuries. Training should be performed on how to wear and work in cold-weather clothing. The key principles worker should know are insulation, layering and ventilation (Reed and Anderson, 1984). Prevention of cold injuries is very important because some treatments are relatively ineffective, such as treatment for trench/ immersion foot.

3.2.3 Auxiliary Heating of the Body

Devices were developed to heat the body with chemically activated hand warmers and even whole body garments powered by electricity (Scott, 1988). These devices have been inserted in both socks and boots. A study showed that 3 W supplied to each hand and 7 W to each foot adequately maintained skin temperatures above 4.4°C. This research was performed on sedentary men outfitted in arctic clothing while exposed for a 6-hr period to an ambient temperature –40°C and a wind speed of 4.5 m/s (Goldman, 1964). The auxiliary heating devices are limited in use due to lack of access to power, limited durability of heating elements, high production costs, burden of leads between the power supply and the clothing, and temperature regulators that cause hot spots or burning sensations on the skin (Haisman, 1988). These devices try to heat the body by keeping the workers warm and the clothing less bulky (Bensel and Santee, 1997).

3.3 Summary

Although third in line to engineering and administrative controls, protective clothing is the workers personal defense against a low temperature environment. Training for the use of protective clothing should be provided to all employees. A guide to appropriate clothing maintenance is best remembered by the mnemonic **COLD** (Wald and Stave,1994):

- Keep clothing **C**lean to ensure maximum insulation.
- Avoid **O**verheating by adding or removing insulating layers as appropriate.
- Wear clothing **L**oose and in **L**ayers to allow free blood circulation, trap dead-space air, and adapt to changes in the workload or environment.
- Keep clothing **D**ry to ensure maximum insulation.

CHAPTER 4

WORKPLACE ENVIRONMENT AND SURVEY

In Chapter 3, we discussed the role of clothing and its protection factors. This chapter will evaluate the adequacy of the protective clothing worn by workers in the Order Pick Department and compare it to the layering principle previously described. In addition, a description of the tasks and workplace environment is provided.

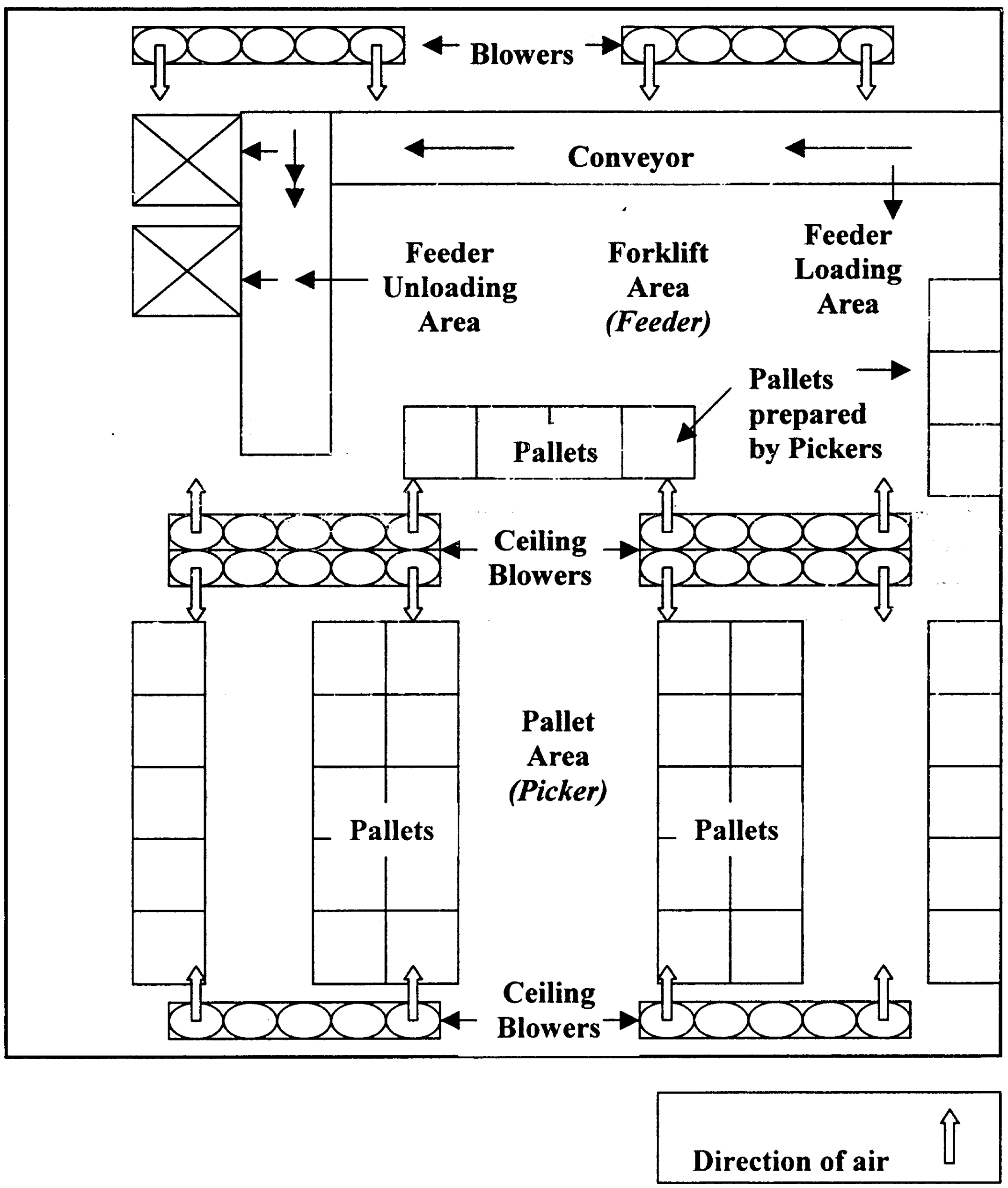
4.1 Workplace Description

The Order Pick department processes orders that include layer and case quantities as well as full pallet quantities. Single product pallet loads are transported to this area by a conveyor. Fork trucks then move the pallets to the picking location. Orders are picked manually and stacked on pallets using electrically powered pallet jacks. Completed orders will be stretch wrapped with bar code labels attached inside and outside the stretch wrap. All pallets leaving the picking area will pass through an identification system and then be conveyed to either the truck dock or back to the refrigerated storage area separate from Order Pick. The temperature in this department varies from about 32° to 40°F. The room dimensions are approximately 150 feet in width by 200 feet in length. The ceiling height reaches to about 27 feet. Figure 4-1 shows a sketch of the workplace.

Forty blowers keep the room at a stable low temperature. An administrative attempt was performed to increase the worker's comfort in terms of controlling blower times. The blowers were programmed to start only at night when the majority of the employees were not working. However, the nightshift still had to endure the lower temperatures. There are a total of 15 male employees in the Order Pick department.

The employees work an average of about nine hours per shift, 5 days a week. The workers each receive one lunch break that lasts approximately thirty minutes. During this time the workers exit the refrigerated warehouse and spend their lunchtime in an ambient environment, such as the cafeteria or the break room.

Figure 4-1 Workplace sketch.



4.2 The Tasks of Workers

All fifteen employees work in either of the two positions: Pickers or Feeders. Although the employees rotate between these two jobs, the frequency may so minimal that they will be working as a "Picker" for several months at a time. The regular type of clothing protection consists of safety shoes, gloves, a hat/ cap, thermal undershirt and an insulted jumpsuit. The jumpsuit is composed of a polyester-cotton blend quilted insulation material to help keep employees warm. In addition, this jumpsuit is windproof, abrasion resistant and water repellant. The employees wear the type of clothes that may easily be removed or added in the event they feel uncomfortably warm or cold. In that case, a simple adjustment like removing the gloves or cap will help stabilize their body temperature to their comfortable level.

4.2.1. "Picker" Duties

The responsibilities of the Picker consist mostly of manually handling the cases. Majority of the time is spent lifting and setting the cases onto a pallet. Once the pallet is built according to the customer's order the Picker enters the data into the computer. There is very little time spent on the data entry compared to the actual picking portion of the duties. Each cases can range in weight from 15 to 30 pounds. The Picker can either drive the forklift to the picking area or use a hand pallet. He has an ergonomic advantage with the pallet on the forklift. Setting the forks to waist height will eliminate the squatting actions of the lift if picking was done at floor level. The Picker uses his whole body to lift and set the cases. Since the job consists of mostly manual work the employee's metabolism increases and raises his body temperature. Once the pallet is customized the Picker will transfer it to the Feeder's area for loading.

4.2.2 "Feeder" Duties

The responsibilities of the Feeder consist of operating the forklift and wrapping machine. Forklift operation is sedentary and mainly utilizes the upper body. The Feeder drives to the conveyor or Picker's area to pick up a pallet. He will then get off the forklift to turn on and start the wrapping machine. The Feeder uses his whole body to accomplish this task in about 3 minutes. The rest of the time is spent driving to load and unload pallets. At times the Feeder may wait as long as ten minutes for the right slot to unload the picked pallet. Once the pallets are loaded onto the conveyor according to the customer's order the Feeder enters the data into the computer.

4.3 Questionnaire Form

A questionnaire form was distributed to employees of the Order Pick department (Figure 4-2, 4-3). This workplace survey was used to help identify extent of cold stress and methods to minimize these affects on workers in the refrigerated warehouse. The survey form was separated into three main sections 1) Personal History, 2) Physical Condition, and 3) Work Performance. Workers were informed that this was a confidential survey and the information will be used only for research purposes. Questionnaires were distributed to employees who presently and previously worked in this refrigerated area. A total of eight forms were completed out of the 20 distributed. Personal history information included the employees name (optional), height, weight, gender, date of birth, ethnic background, smoking status, medication use and physical exercise frequency. These questions were included to evaluate the physical factors that could affect cold tolerance.

Figure 4-2 Employee questionnaire page 1 of 2.

[illegible]

17) Do you feel tired/ fatigue early vs. late in your shift?

Please describe:

18) Describe changes, if any, in your physical condition early vs. late in your shift:

a) Describe symptoms and part(s) of body affected:

19) Describe changes, if any, to your physical condition in the beginning of the shift compared to after a break:

20) Describe changes, if any, to your present physical condition compared to when you initially began working in Order Pick:

[illegible] PERFORMANCE

21) How many breaks do you take per day? a) Length per break?

22) Describe any changes in your work performance after a break vs. early in your shift:

23) Is clothing a burden to your work performance?

a) If so, which articles of clothing?

b) Performing what type of task?

24) Describe changes, if any, in your work performance early vs. late in your shift:

25) Can you provide any suggestions to minimize the affects of cold stress in Order Pick?

Thanks for your cooperation...

Figure 4-3 Employee questionnaire page 2 of 2.

WORK[illegible] [illegible]
Order Pick Department

Note:*This is a confidential survey and will be used for educational/ research purposes only.* The answers to this survey will help identify methods of minimizing cold stress affects on workers in refrigerated warehouses.

PERSONAL HISTORY

1) Name - ______________________________

2) Height - ______________ **3) Weight -** ____________ **4) Gender -** ________

5) Date of Birth ______________ **6) Ethnic Backround -** ______________

7) Do you smoke? yes no a) If so how often? ____________

8) Do you use medication? yes no

9) Do you participate in physical exercise? yes no

a) How long? ____________ per day b) How many days? ______ days per week

10) Do you have any previous cold injuries i.e. frostbite? yes no type: ____________

a) If so, what part(s) of body? ______________________

b) When did you sustain such cold injury? ______________________

11) How long have you worked in Order Pick? ______ years ______ months

12) How long as Picker? ____________ a) Please describe duties: ____________

____

b) If lifting involved, approx. weight per case: ____________ lbs. c) Lifts per hour: ____________

13) How long as Feeder? ____________ a) Please describe duties: ____________

____

____

14) What clothing protection do you wear against the cold? ______________

____

15) How many hours do you work per week? ______________

16) What is your approximate caloric intake for a mid-shift meal: ______________

____

Thanks for your cooperation...

Page 1 of 2

More specific questions included previous cold injury, length of employment within the company and the refrigerated department, types of clothing protection worn, hours worked per week and approximate caloric intake. These questions were asked mainly to determine a link between length of employment and the worker's physical condition. Physical condition questions were asked primarily to evaluate long-term health affects due to working in the refrigerated environment. Specifically the employee was asked if he felt fatigued or tired, early compared to late in his shift. They were also asked to describe any changes to their physical condition early in their shift compared to late. The symptoms and parts of the body were asked to determine if any short term or immediate changes occurred to their physical condition. The worker was also able to note if he felt any physical difference in the start of the shift compared to after coming back from break. Finally, a long-term question was asked regarding any presently noticeable changes compared to when he first started working in the refrigerated department.

The final section involved questions related to work performance. Workers were asked how many breaks they take throughout the shift and the duration. Another question involved any work performance changes after a break compared with the beginning of the shift. The survey also asked whether clothing felt like a burden and affected work performance. In addition, the type of clothing and performing what particular task was inquired. The worker was even able to provide any suggestions to help minimize the effects of cold stress in Order Pick department. The employee's opinion is sometimes overlooked when modifying the work environment, therefore, it is of utmost importance to involve them in every aspect of the project.

The workers often provide valuable information for the modifications since they are the ones who perform functions in the workplace and not the engineers. The completed employee surveys are located in the Appendix.

4.4 Productivity Observations

Productivity observations were also performed on the Picker and Feeder for 5-minute intervals at the following time periods: 1) Post-Shift Start, 2) Pre-break, 3) Post-break, and 4) Pre-Shift End. These observations were performed on two individuals four times a day for one week. The methodology was to determine if the low temperature environment had an impact on worker performance and productivity. The "Picker" and "Feeder" tasks were observed to monitor levels of production output as described below.

4.4.1 Cases Picked Manually

The "Picker" manually handled each case and set it on the forklift-raised pallet. The number of cases were counted during 5-minute intervals and recorded on a table (see Table 4-1). These measurements were taken four times a day, for one week. The Picker was informed of the observation and that he should work as normal.

Table 4-1. Productivity table, Cases picked manually.

	CASES PICKED - MANUALLY				
	Monday	Tuesday	Wednesday	Thursday	Friday
Post-Shift Start					
Pre-Break					
Post-Break					
Pre-Shift End					

4.4.2 Cases Picked by Forklift

The "Feeder" loaded a pallet onto the forklift and unloaded it at the proper location on the moving conveyor. The number of pallets was counted within the 5-minute intervals at four periods throughout the shift. The Feeder was also informed of the observation and that he should work as normal.

Table 4-2. Productivity table, Cases picked by forklift.

CASES PICKED - FORKLIFT					
	Monday	Tuesday	Wednesday	Thursday	Friday
Post-Shift Start					
Pre-Break					
Post-Break					
Pre-Shift End					

Several variables may affect the outcome of both task observations such as the uneasiness of being observed, sickness, hunger and thoughts of working on the next task or even going home. Chapter 5 evaluates the productivity study results and discusses what factors and effects may or may not be attributed to the cold environment.

CHAPTER 5

WORKPLACE DESIGN CONSIDERATIONS

In Chapter 4, we discussed the working conditions and the questionnaire survey distributed to the employees of the refrigerated warehouse. The surveys provided valuable information about modifying the workplace to make such environmental adjustments as implementing administrative and engineering controls, providing personal protective equipment and training awareness. In this chapter, we review the results of the survey and evaluate the cold stress effects on worker performance.

5.1 Survey Results

The workplace survey was conducted in the Order Pick department and questionnaires were distributed to employees who presently and previously worked in this refrigerated area (See Figure 4-1 and 4-2). A total of eight forms were completed out of the 20 that were distributed. Table 5-1 shows the results of the survey as well as the breakdown of answers for each case.

The workers height ranged from 65 inches to 76 inches with a mean of 71 inches. The average weight was 195 pounds with a range of 150 to 234 pounds. The workers were all male with an age mean of 42 years. Their ages ranged from 29 to 56 years old. The average length of employment was 4.3 years. Ethnic backgrounds included 2 African Americans and 6 Caucasians. The response to the smoking inquiry was split 50-50 where four employees indicated they were smokers and 4 were non-smokers. Only two employees specified that they were taking some sort of medication.

Table 5-1. Survey results.

	Case #	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	Avg.
(inches)	**Height**		69	73	76	65	67	76	72	71
(pounds)	**Weight**	205	205	175	216	160	150	215	234	195
	Gender	male	male	male	male	male	male	male	male	m
	Age		43	29	56	39	38	34	54	42
(years)	**Length of Employment**	0.2	0.3	4	7	0.8	14	1.5	6	4.3
	Ethnic Backround	Afr. Amer.	caucasian	caucasian	caucasian	caucasian	caucasian	caucasian	Afr. Amer.	
	Smoke	no	no	no	yes	yes	yes	no	yes	
	Medication	no	no	no	no	yes	no	no	yes	
(hour)	**Physical Exercise**	1		1	0.75	1	1		1	1
	Previous Cold Injuries	no	no	no	no	no	no	no	no	no
	Hours Worked /week	45	40	50	57	45	50	45	52	48
Fatigue	**Early**	X								
	Late		X	X	X		X		X	X
Physical Changes	**Early**			none	colder/ slower					
	Late	back pains	finger/ knee		runny nose	achy/ knees joints	colder quicker	legs/ arms hurt, joints	cold hands and toes	X
Physical Changes	**Early**		red skin	none	none	none				
	After Break	colder/fans	face,ears get hot						being cold	
Physical Condition	**Present**	weary	headaches	none	none	runny nose			being cold	X
	First started									
Changes	**Early**	none			none					
	After Break	none							re-adapt	X
Changes	**Early**									
	Late in shift	more energy			easier to move			easier		X
Clothing a Burden?			yes			no		no	no	
Suggestions to minimize Cold Stress		turn off fans		raise temp.	change fan times		deflect wind	less fans on	warmer gloves, shoes	

A total of six workers indicated they performed some type of physical exercise on a regular basis. The average length of exercise lasted about an hour. None of the employees experienced previous cold injuries. This fact is encouraging since it does not predispose them to subsequent cold injuries. The hours worked each week ranged from 40 to 57 hours with a mean of 48 hours. These hours are typical of a union environment where employees work at least 40 hours with overtime when necessary.

In response to the physical condition questions, only one employee noted that he was fatigued early in his shift versus late. Whereas, five workers indicated that they felt tired or fatigued late in their shift compared to the early part. Similar responses were seen when workers were asked to evaluate any changes to their physical condition throughout the day. Seven workers indicated that they noticed physical changes late in their shift compared to the early part. Physical symptoms included a runny nose and pain in the back, hand, knee and feet joint pains. One worker mentioned that early in the shift he feels colder and tends to work slower rather then later in the shift.

Feeling cold due to blowers concerned two employees after coming back from break while one employee indicated his face had a reddish tone soon after he started to work. Employee # 2 also stated that his face and ears become hot soon after coming back from break. Only four employees noticed changes in their present physical condition compared to when they first started their employment. The answers varied from presently feeling more headaches and weariness to a runny nose and just feeling cold. The blank spaces were interpreted to mean that the employees did not experience these symptoms to the same extent when they first started as they do to this point in their employment.

Changes to work performance comprised the last section of questions to evaluate whether the refrigerated environment affects their job and in turn their comfort level. This section was used to tie all the initial information together and make a determination. After break one employee found he has to re-adapt to the low temperature environment, especially after break. There were more missing responses regarding their work performance in this section than the other two. Later in the shift two employees found it was easier to move compared to when they initially started work. One found he had more energy to work later in the shift but not much energy to start off. Three employees stated that clothing was not a burden while one answered that it was.

Workers also provided suggestions for improving the workplace and minimizing the effects due to cold stress. These recommendations included turning off the blowers, changing blower times, installing barriers to deflect wind, put less blowers in operation, raise the temperature in the Order Pick department and providing warmer clothing such as gloves and shoes for protection against the cold. In conclusion, this workplace survey did help identify the individual effects of cold stress and some methods to minimize these effects on the workers in the refrigerated warehouse.

5.2 Productivity Study Results

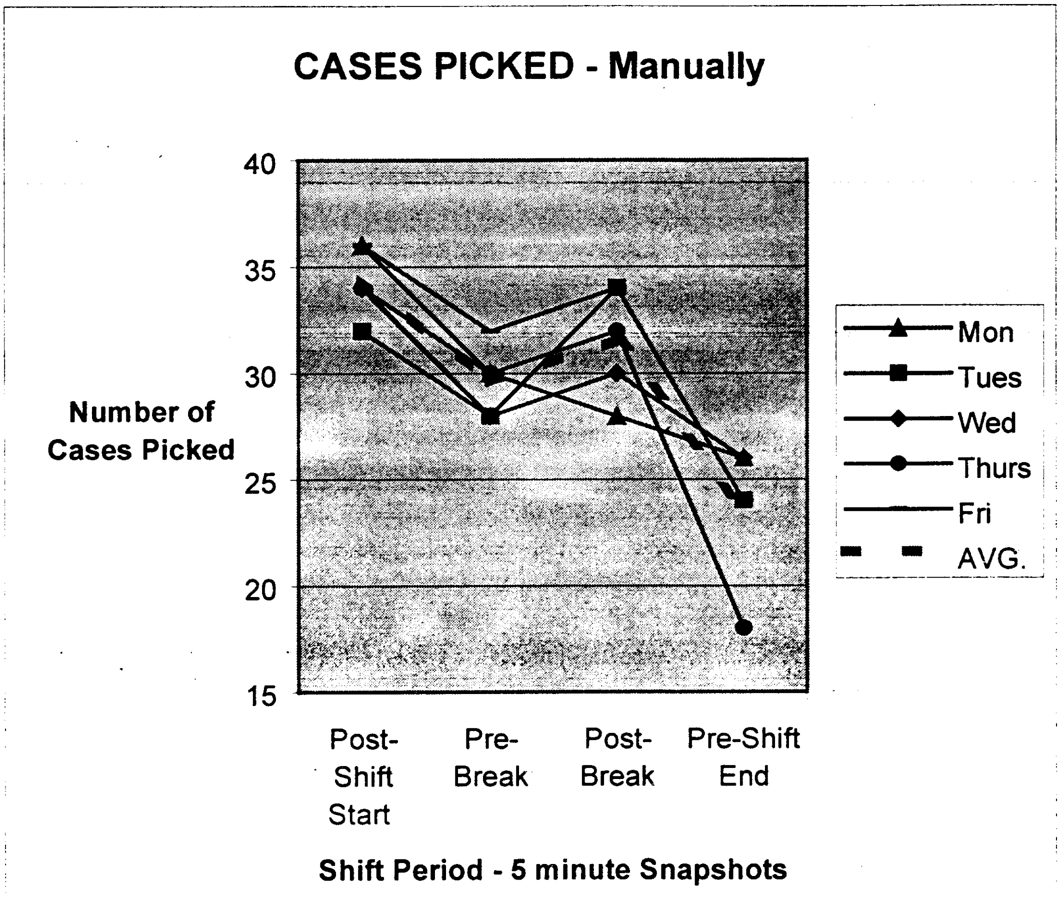
The Picker results are seen in Table 5-2 and Figure 5-1. The Feeder results are shown in Table 5-3 and Figure 5-2. The table results showed production values at each shift period: 1) Post-Shift Start, 2) Pre-break, 3) Post-break and 4) Pre-Shift End. An overall average was calculated at each shift period for the entire workweek. This data was then plotted to display the figure results and evaluate trends over the entire week. The lower y-values were removed to help clarify individual production output quantities. The standard deviation was also calculated as a measure of variability.

Table 5-2. Productivity study results, Cases picked manually.

CASES PICKED – Manually							
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**AVG.**	**S.D.**
Post-Shift Start	36	32	34	34	36	**34**	**1.7**
Pre-Break	30	28	28	30	32	**30**	**1.7**
Post-Break	28	34	30	32	34	**32**	**2.6**
Pre-Shift End	26	24	26	18	24	**24**	**3.3**

The Picker was observed to handle an average of about 34 cases in the first five minutes of his shift (Post-Shift Start). The production rate decreased by 12% when he was observed again right before break time (Pre-Break). There was a 6% increase after the worker came back from break (post-break) compared to five minutes before he left for break (pre-break). A 25% decrease was seen during the last five minutes of his shift (pre-shift end) compared to when he first got back from break (post-break). Productivity significantly decreased an average total of 30% when the worker finished his shift (pre-shift end) compared to when he initially started (post-shift start). The standard deviation for the four shift periods was 1.7, 1.7, 2.6 and 3.3, respectively.

Figure 5-1. Productivity results, Cases picked manually.



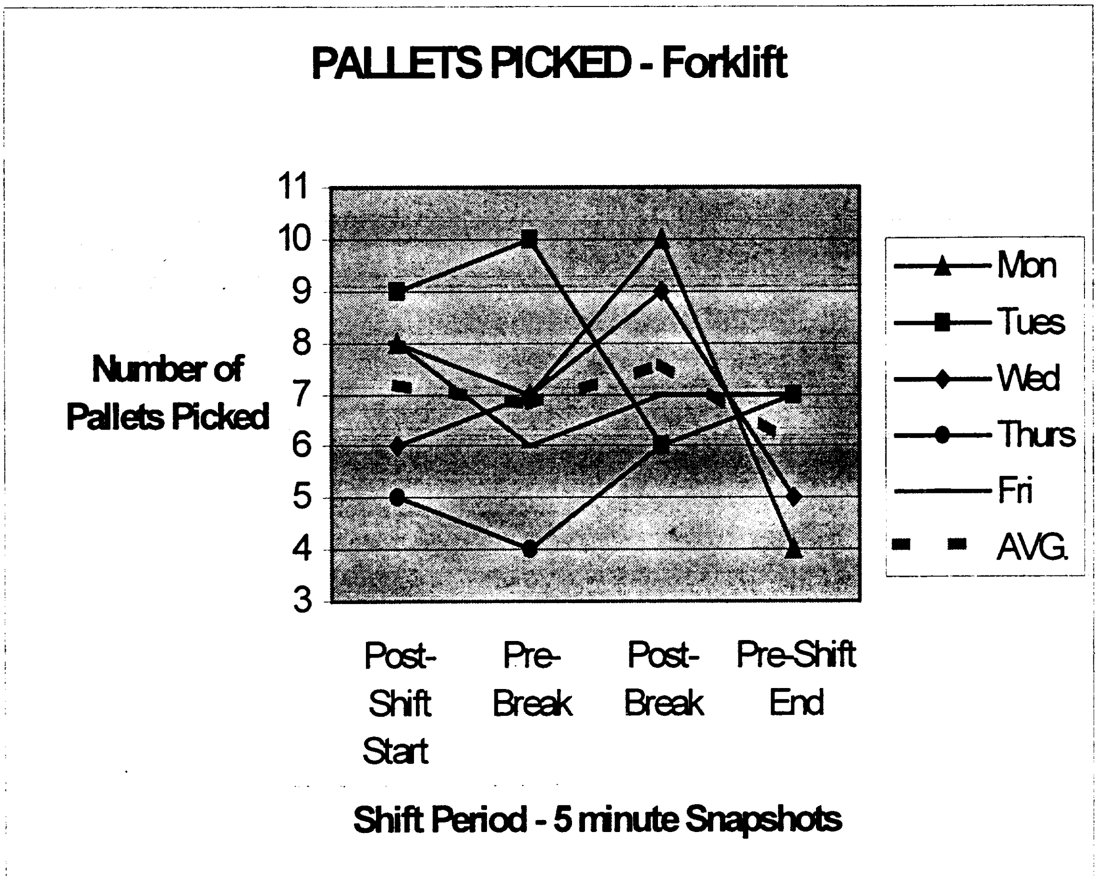
The Picker was observed to start off the shifts at a higher performance rate than when he was preparing to leave on break. A second downward trend was seen when the worker came back from break until he was preparing to go home. The dotted line designates the average for the shift periods and confirms both downward trends. However, right after break time the worker's production output increased to just below where he initially started with the exception of Monday.

Table 5-3. Productivity study results, Cases picked by forklift.

PALLETS PICKED - Forklift							
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**AVG.**	**S.D.**
Post-Shift Start	8	9	6	5	8	**7.2**	**1.64**
Pre-Break	7	10	7	4	6	**6.8**	**2.17**
Post-Break	10	6	9	6	7	**7.6**	**1.82**
Pre-Shift End	4	7	5	7	7	**6**	**1.41**

The Feeder was observed to load and unload about seven pallets in the first five minutes of his shift. The production rate slightly decreased by 6% when he was observed again right before break time. There was an 11% increase in the first five minutes after the worker came back from break compared to five minutes before he left for break. A 21% decrease was seen during the last five minutes of his shift compared to when he first got back from break. Productivity significantly decreased an average total of 17% when the worker finished his shift compared to when he initially started. The standard deviation for the four Feeder shift periods was 1.64, 2.17, 1.82 and 1.41, respectively.

Figure 5-2. Productivity study results, Cases picked by forklift.



The Feeder was observed to start off the shifts at performance rates ranging from 5-9 pallets picked per five minutes. Monday, Thursday and Friday showed decreasing productivity trend towards break time compared to when the Feeder first started. With the exception of Tuesday an upward productivity trend was seen right after coming back from break compared to the 5 minutes before break. Two days showed a downward productivity trend towards the end of the shift compared to at the beginning while 2 other days did not. Friday remained flat for that period. The dotted line designates the average for the shift periods and confirms both slight downward trends.

The following information in this chapter discusses specific job and environmental improvements that was partially gained from the valuable participation and responses that the employees provided.

5.3 Engineering and Administrative Controls

The worker's discomfort is affected by factors such air velocity, work load, radiant heat and clothing insulation. Extra clothing that is bulky will eventually reduce the worker's mobility. An increased workload and radiant heat load improve comfort in the cold but increases in air velocity result in increased discomfort (Eastman Kodak Company, 1983). Improvements to reduce discomfort and improve worker performance caused by these factors are summarized below.

Convective heat loss from the body increases when exposed to high air velocities, thus increasing the discomfort in the cold. A lowered skin temperature can also increase the gradient for heat transfer out of the body. Increasing the skin's insulation may counteract this heat (Eastman Kodak Company, 1983). The environment in the refrigerated warehouse is controllable due to the fact that it is indoors. Since the blowers operate only at night several techniques can help solve the air velocity problems for the night shift workers.

Raising the lower temperature limit in Order Pick is an ideal solution but only if the new temperature will not compromise the quality of the product. The blowers will not operate as often, therefore, improving the comfort level for the night shift workers. Barrier shields or deflectors are another solution that will protect the worker from the direct impact of the air velocity. Another suggestion is to investigate whether the actual work area is in an ideal location. A simple relocation to another area may reduce local drafts that contribute to worker discomfort. The cases in Order Pick may be moved to areas where the blowers are not directed towards the working area and there is minimal direct contact with the worker. Another suggestion is to keep the worker and the product separate. Hallways may be designed for the worker to limit his or her exposure to the cold. The product would be in rooms on the right and left of the hallway. The worker would walk down the hallway with a hand jack and enter each room briefly to retrieve the needed product. The hallway may reduce their cold exposure by a number of hours since the worker wouldn't need to stay in the refrigerated area all day.

In certain areas where it may not be possible to increase the ambient temperature, providing a radiant heater may be justified to increase the worker's comfort. Similar to a spot-cooling zone in a hot environment, these heaters may increase comfort in certain work areas (Eastman Kodak Company, 1983). This type of re-warming technique was used in other studies to improve worker comfort and reduce the effects of cold stress (Ceron et al., 1995). The cabs of cranes and other equipment may benefit from these types of heat sources. On the other hand, enclosing an entire machine would help reduce the cold exposure and at the same time increase worker comfort. A heated and enclosed forklift, for instance, would be ideal in the Order Pick department particularly for the "Feeder" since that is where his time is primarily spent.

Metal objects should be covered by a thermal insulating material to reduce heat lost to the environment. Small improvements such as replacing the metal knobs on the forklift steering wheel with plastic ones can help minimize cold effects. Cold surface contact may also become a problem if water moisture from the skin freezes to the surface, resulting in skin adhesion to surface in question. Gloves should be worn when making contact with surfaces colder than 0°C (32°F). Aside from the obvious metal objects, focus should be set on any object that the workers touch that can result in increased heat loss, particularly the forklift seat for the Feeders. The seat can be covered with a special thermal insulating cover since he spends a considerable amount of time operating the forklift.

Workers also pointed out the initial cold shock they felt when first entering Order Pick at the beginning of the shift. This is due to switching temperature environments from an ambient 70°F in the cafeteria to a colder 32°F - 40°F in the work area. A "temperature controlled break room" may help ease this transition. According to a few surveys it takes the workers some time to "get used to" the low temperature environment each day. Another way to increase worker comfort is to increase or even out the workload (Wyndham and Wilson-Dickson, 1951). However periods of no activity or standing may result in a greater discomfort. The amount of sweating that occurs during physical activity will reduce the clothing's effectiveness. This in turn will make the worker feel colder in the subsequent recovery period (Enander et al., 1979). An effective general rule is to increase the workload to counteract cold exposure only if the person cannot sweat too much while working.

According to the Metabolic Demands for Industrial Tasks table the Feeder performs "Heavy" work that corresponds to power truck operation task (Eastman Kodak Company, 1983). The Feeder's energy expenditure is between 280-350 W (240-300 kcal/hr). The Picker performs "Very Heavy" work that corresponds to handling moderately heavy cases to and from a pallet. The energy expenditure is between 350-

420 W (300-360 kcal/hr) (Eastman Kodak Company, 1983). The workload should be spread more evenly over the shift to help reduce worker discomfort. Periods of intense and then sedentary activity should be avoided. Even though such work patterns may be difficult to control, training and awareness will assist the employee in making the work pace decisions to the maximum extent possible.

5.4 Personal Coping Strategies

Training and cold stress awareness are both essential topics that can help protect the workers in the Order Pick department. Since the air temperatures are below 41°F (5°C) employees should be informed that cold stress is a hazard and the company should take further appropriate steps. Proper protective clothing has already been provided to employees. However, cold stress awareness can be increased. Employees can then practice self-determination and cold stress hygiene (Plog et al., 1996). Fluid replacement is a key factor in practicing cold stress hygiene. In cold weather the body requires a large amount of fluids. Since dehydration can occur when fluid intake is reduced, a worker's perception of thirst and the desire to drink is suppressed in the cold. Drinks that may help reduce fatigue should be centered around warm, sweet and non-caffeinated fluids. A decrease in mental alertness, reduced work capacity, and decreased ability to support blood pressure as body temperature drops are factors attributed to dehydration (Wald and Stave, 1994). Employees should also be encouraged to eat a normal, balanced diet keeping in mind that working in the cold requires 10-15% more calories (Young, 1992).

One of the main issues in managing cold stress is personal protection. Insulated suits that keep the workers warm will increase their thermal comfort thus increasing productivity. Workers should also be educated and trained in the proper use of clothing, especially when the effectiveness is compromised. Whole body protection should be ensured in the form of adequate, insulated and dry clothing (Plog et al, 1996). Topics in the training class would include selecting insulated clothing with special attention to the extremities.

5.5 Summary

The employee questionnaires showed evidence that changes are needed. All eight workers expressed concerns regarding the cold environment. This type of feedback indicates there is worker discomfort. This type of discomfort can be distracting and lead to unsafe behaviors and actions. Recommendations provided will help minimize the effects of the low temperature environment and increase the workers thermal comfort. The productivity studies for both the Feeder and Picker showed a decreasing trend in productivity towards the lunch break compared with the beginning of the shift. Similarly, a downward productivity trend occurred towards the end of the shift compared to when they first came back from lunch break.

This type of trend may be due to physical fatigue that occurs in other jobs without a cold environment. However, the steepness of the trend may be much less. The cold environment would then still be a factor in productivity output. The Feeders and Pickers are required to cope with two separate issues. The first is simply performing their work responsibilities. The second issue in addition to their job is the cold environment. The additional cold factor reinforces the need for training the employees on cold stress awareness. As a result, the training awareness, engineering and administrative controls will help the workers make judgements to better cope with the cold and maintain their work performance.

CHAPTER 6

CONCLUSIONS

Workplace temperature can strongly influence how effectively a task is being performed. Cold conditions where manipulation tasks are done can lead to decreases in productivity and potentially unsafe actions because of a loss of finger flexibility. Exposure to conditions outside the thermal comfort zone can produce discomfort. This type of discomfort can distract a worker from the task at hand and increase the potential for unsafe acts (Eastman Kodak Company, 1983). A pro-active approach to the design of the workplace is suggested by performing a preliminary safety design review. This review may help catch hazards immediately and prevent long-term problems. There would be a significant cost savings in the design phase since it is more expensive to make modifications once the work area is up and running. The safety review may include questions that consider if the work area has temperature extremes according to exposure guidelines. Attempts can then be made to implement engineering controls.

At this point in time there are an insufficient number of studies performed on the effects of cold stress on worker performance. That may be due to the fact that an in-doors workplace is considered "controllable" and that any needed changes are left to the employer. There is more emphasis placed on the prevention, training and awareness of heat stress rather than cold stress even though both temperature extremes can be deadly. One possible reason may be that people can acclimatize to hotter environments rather than colder ones. In this day and age of state-of-the-art technology it is surprising to discover that we have come no closer to protecting people from indoor cold than providing them with chemically activated sock warmers and electrically powered garments.

It is evident from the questionnaires that the workers are in need of workplace improvements. Small modifications such as installing blower barriers and insulating metal parts are highly recommended. The larger investments include enclosed heated forklifts or a thermal transition room. However, their price can easily be justified by performing trial operations and observing the production output. The productivity studies showed a decreasing productivity trend for both tasks as the shifts progressed. The Picker's productivity significantly decreased an average total of 30% when the worker finished his shift (pre-shift end) compared to when he initially started (post-shift start). The Feeder's productivity also decreased an average total of 17% when the worker finished his shift compared to when he initially started. Both figures are averaged over an entire week. The workers' sense of discomfort from the questionnaires has an effect on their work performance and productivity. The extent of this effect can be discovered with the help of further studies.

Future research studies performed on cold stress effects should include more data from a larger group of workers. A plot over several weeks is suggested to compare a Monday to Wednesday to Friday production output. Questionnaires are highly recommended since the workers are the ones who know the workplace and can suggest ideas for improvement and modification. These changes, however small, will increase worker comfort and result in a safer, more efficient operation that benefits both the worker and the employer.

APPENDIX

Employee Surveys

[illegible] SURVEY
[illegible]

Note: *This is a confidential survey and will be used for educational/ research purposes only.* **The answers to this survey will help identify methods of minimizing cold stress affects on workers in refrigerated warehouses.**

PERSONAL HISTORY

1) Name [redacted]

2) Height - ______ **3) Weight -** 205 **4) Gender -** ______

5) Date of Birth ______ **6) Ethnic Backround -** ______

7) Do you smoke? yes (no) **a) If so how often?** ______

8) Do you use medication? yes (no)

9) Do you participate in physical exercise? (yes) no

a) How long? 1hr per day b) How many days? 8 days per week

10) Do you have any previous cold injuries i.e. frostbite? yes (no) type: ______

a) If so, what part(s) of body? ______

b) When did you sustain such cold injury? ______

11) How long have you worked in Order Pick? ______ years 2 months

12) How long as Picker? ______ a) Please describe duties: Picking order

b) If lifting involved, approx. weight per case: 6 lbs. c) Lifts per hour: 120cs.

13) How long as Feeder? ______ a) Please describe duties: ______

14) What clothing protection do you wear against the cold? FRIDGAWEAR

15) How many hours do you work per week? 45 HRS

16) What is your approximate caloric intake for a mid-shift meal: ?

Thanks for your cooperation... Page 1 of 2

PHYSICAL CONDITION

17) Do you feel tired/ fatigue early vs. late in your shift? ~~NO~~ - YES, BUT

Please describe: LATER IN SHIFT I GET ENERGY. ( ) ITS JUST GETTING STARTED.

18) Describe changes, if any, in your physical condition early vs. late in your shift: IN ORDER PICK? I GET BACK PAINS BY THE END OF SHIFT, BECAUSE OF BENDING

a) Describe symptoms and part(s) of body affected: ~~BACK~~ MY LOWER BACK

19) Describe changes, if any, to your physical condition in the beginning of the shift compared to after a break: ~~MAYBE~~ MAYBE AFTER 2ND BREAK THE CONDITIONS ARE DIFFERENT BECAUSE THE FANS MAKE IT A BIT CHILLY - COLD FANS TURN ON AT (10:00)

20) Describe changes, if any, to your present physical condition compared to when you initially began working in Order Pick: ~~A~~ OTHER THEN THE LIFTING AND BENDING, THE COLD ARE ~~[illegible]~~ KINDA WARES YOU OUT!

WORK PERFORMANCE

21) How many breaks do you take per day? 2 **a) Length per break?** 20 mins/30min

22) Describe any changes in your work performance after a break vs. early in your shift? STAYS THE SAME PRETTY MUCH.

23) Is clothing a burden to your work performance? —

a) If so, which articles of clothing? —

b) Performing what type of task? —

24) Describe changes, if any, in your work performance early vs. late in your shift: EARLY - I JUST HAVE TO PUMP MY SELF UP LATE - IM PUMPED UP - LATER - I'M WORE OUT FROM the cold

25) Can you provide any suggestions to minimize the affects of cold stress in Order Pick? MAYBE TROPICANA CAN TURN DOWN THE FANS SOME ~~[illegible]~~ I DOESN'T HAVE TO BE SO DAMN COLD!!

Thanks for your cooperation...

WORKPLACE SURVEY
Order Pick Department

Note: *This is a confidential survey and will be used for educational/ research purposes only.* **The answers to this survey will help identify methods of minimizing cold stress affects on workers in refrigerated warehouses.**

PERSONAL HISTORY

1) Name - [redacted]

2) Height - 5'9" **3) Weight -** 205 **4) Gender -** Male

5) Date of Birth 8/25/57 **6) Ethnic Backround -** Caucasion

7) Do you smoke? yes (no) a) If so how often? ____

8) Do you use medication? yes (no)

9) Do you participate in physical exercise? yes (no)

a) How long? ____ per day b) How many days? ____ days per week

10) Do you have any previous cold injuries i.e. frostbite? yes (no) type: ____

a) If so, what part(s) of body? ____

b) When did you sustain such cold injury? ____

11) How long have you worked in Order Pick? ____ years 4 months

12) How long as Picker? 4 months a) Please describe duties: Drive claw to pick Canadian.

b) If lifting involved, approx. weight per case: ____ lbs. c) Lifts per hour: ____

13) How long as Feeder? ____ a) Please describe duties: ____

14) What clothing protection do you wear against the cold? 2 shirts, 2 sweatshirts + heavy jacket.

15) How many hours do you work per week? 40

16) What is your approximate caloric intake for a mid-shift meal: ?

Thanks for your cooperation...

PHYSICAL CONDITION

17) Do you feel tired/ fatigue early vs. late in your shift? Yes

Please describe: Tired Later in Shift

18) Describe changes, if any, in your physical condition early vs. late in your shift:

a) Describe symptoms and part(s) of body affected:

Fingers & Knees get Stiff + Achy.

19) Describe changes, if any, to your physical condition in the beginning of the shift compared to after a break: My Face + Ears Feel Very hot. Skin gets Red. Sometimes get headache + Feel Lightheaded

20) Describe changes, if any, to your present physical condition compared to when you initially began working in Order Pick: Had Similar Symptoms working on Front Dock Downstairs

WORK PERFORMANCE

21) How many breaks do you take per day? 1 a) Length per break? 20 minutes

22) Describe any changes in your work performance after a break vs. early in your shift:

23) Is clothing a burden to your work performance? Yes

a) If so, which articles of clothing? Gloves

b) Performing what type of task? Handling Paper Work.

24) Describe changes, if any, in your work performance early vs. late in your shift:

25) Can you provide any suggestions to minimize the affects of cold stress in Order Pick?

Thanks for your cooperation...

WORKPLACE SURVEY
Order Pick Department

.ote: This is a confidential survey and will be used for educational/ research purposes only.
The answers to this survey will help identify methods of minimizing cold stress affects on workers in refrigerated warehouses.

PERSONAL HISTORY

1) Name [redacted]

2) Height - 6 foot 1 inches **3) Weight** - 175 **4) Gender** - M

5) Date of Birth 11/29/71 **6) Ethnic Backround** - [redacted]

7) Do you smoke? yes (no) a) If so how often? ____

8) Do you use medication? yes (no)

9) Do you participate in physical exercise? (yes) no

a) How long? 60 per day b) How many days? 4 days per week

10) Do you have any previous cold injuries i.e. frostbite? yes (no) type: ____

a) If so, what part(s) of body? N/A

b) When did you sustain such cold injury? N/A

11) How long have you worked in Order Pick? 4 years ____ months

12) How long as Picker? All a) Please describe duties: Making spilt pallets

b) If lifting involved, approx. weight per case: 5 lbs. c) Lifts per hour: 150

13) How long as Feeder? N/A a) Please describe duties: ____

14) What clothing protection do you wear against the cold? Freezer Suit

15) How many hours do you work per week? 50

16) What is your approximate caloric intake for a mid-shift meal: 500

Thanks for your cooperation...

PHYSICAL CONDITION

17) Do you feel tired/ fatigue early vs. late in your shift? late in shift

Please describe:

18) Describe changes, if any, in your physical condition early vs. late in your shift: NONE

a) Describe symptoms and part(s) of body affected:

19) Describe changes, if any, to your physical condition in the beginning of the shift compared to after a break: NONE

20) Describe changes, if any, to your present physical condition compared to when you initially began working in Order Pick: NONE

WORK PERFORMANCE

21) How many breaks do you take per day? 1 a) Length per break? 25

22) Describe any changes in your work performance after a break vs. early in your shift:

NONE

23) Is clothing a burden to your work performance? No

a) If so, which articles of clothing?

b) Performing what type of task?

24) Describe changes, if any, in your work performance early vs. late in your shift:

NONE

25) Can you provide any suggestions to minimize the affects of cold stress in Order Pick?

I really dont think it has to be that cold up there.

Thanks for your cooperation...

WORKPLACE SURVEY
Order Pick Department

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The answers to this survey will help identify methods of minimizing cold stress affects on workers in refrigerated warehouses.

PERSONAL HISTORY

1) Name - [redacted]

2) Height - 6'4" **3) Weight -** 216 **4) Gender -** MALE

5) Date of Birth 12-29-43 **6) Ethnic Backround -** WHITE MALE

7) Do you smoke? (yes) no a) If so how often? 1/2 PACK A DAY

8) Do you use medication? yes (no)

9) Do you participate in physical exercise? (yes) no

a) How long? 45 min per day b) How many days? 7 days per week

10) Do you have any previous cold injuries i.e. frostbite? yes (no) type: ______

a) If so, what part(s) of body? ______

b) When did you sustain such cold injury? ______

11) How long have you worked in Order Pick? ABOUT 7 years ? months

12) How long as Picker? 7 YEARS a) Please describe duties: PICK SPECIAL ORDERS FOR CUST.

b) If lifting involved, approx. weight per case: ? lbs. c) Lifts per hour: ______

13) How long as Feeder? ______ a) Please describe duties: ______

14) What clothing protection do you wear against the cold? REF. WEAR JACKET

15) How many hours do you work per week? 40 PLUS MAYBE 16 TO 18 HR OT

16) What is your approximate caloric intake for a mid-shift meal: 700

Thanks for your cooperation...

PHYSICAL CONDITION

17) Do you feel tired/ fatigue early vs. late in your shift? A LITTLE TIRED LATE

Please describe: NORMAL 8 HRS OF WORK

18) Describe changes, if any, in your physical condition early vs. late in your shift:
ITS COLDER AN SLOWER MOVING EARLY

a) Describe symptoms and part(s) of body affected: FEET - HANDS - HEAD
RUNNY NOSE

19) Describe changes, if any, to your physical condition in the beginning of the shift compared to after a break: NONE

20) Describe changes, if any, to your present physical condition compared to when you initially began working in Order Pick: NONE

WORK PERFORMANCE

21) How many breaks do you take per day? 1 a) Length per break? 20 min

22) Describe any changes in your work performance after a break vs. early in your shift:
NONE

23) Is clothing a burden to your work performance? NO

a) If so, which articles of clothing?

b) Performing what type of task?

24) Describe changes, if any, in your work performance early vs. late in your shift:
LATER IN THE DAY IT IS WARMER AND EASYER TO MOVE

25) Can you provide any suggestions to minimize the affects of cold stress in Order Pick?
RAISE TEMP IN ORDER PICK AND ~~TIME~~ CHANGE TIMES THE BLOWER COME ON

Thanks for your cooperation...

WORKPLACE SURVEY
Order Pick Department

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PERSONAL HISTORY

1) Name - [redacted]

2) Height - 5 feet 5 inches **3) Weight** - 160 lbs **4) Gender** - MALE

5) Date of Birth 10-24-60 **6) Ethnic Backround** - Irish, Italian, Polish and Russian

7) Do you smoke? (yes) no **a) If so how often?** 3

8) Do you use medication? (yes) no

9) Do you participate in physical exercise? yes no
a) How long? one to two per day b) How many days? 7 days per week

10) Do you have any previous cold injuries i.e. frostbite? yes (no) type: ____
a) If so, what part(s) of body? ____
b) When did you sustain such cold injury? ____

11) How long have you worked in Order Pick? ~~[illegible]~~ years 10 months

12) How long as Picker? 10 Months a) Please describe duties: To Pick orders For Routes + CB + T.T.
b) If lifting involved, approx. weight per case: 75 lbs. c) Lifts per hour: From 150 to 200

13) How long as Feeder? ____ a) Please describe duties: ____

14) What clothing protection do you wear against the cold? ____

15) How many hours do you work per week? 40 to 50

16) What is your approximate caloric intake for a mid-shift meal: Do not Know

Thanks for your cooperation...

PHYSICAL CONDITION

17) Do you feel tired/ fatigue early vs. late in your shift? N/O

Please describe: ______

18) Describe changes, if any, in your physical condition early vs. late in your shift:

NOT AS Ache

a) Describe symptoms and part(s) of body affected: Knees + Joints Ache

19) Describe changes, if any, to your physical condition in the beginning of the shift compared to after a break: NONE

20) Describe changes, if any, to your present physical condition compared to when you initially began working in Order Pick: Runnie Nose

WORK PERFORMANCE

21) How many breaks do you take per day? Two a) Length per break? 20 min + 30 min

22) Describe any changes in your work performance after a break vs. early in your shift:

______

23) Is clothing a burden to your work performance? NO

a) If so, which articles of clothing? ______

b) Performing what type of task? ______

24) Describe changes, if any, in your work performance early vs. late in your shift:

NONE

25) Can you provide any suggestions to minimize the affects of cold stress in Order Pick?

______

Thanks for your cooperation...

WORKPLACE SURVEY

Order Pick Department

Note: *This is a confidential survey and will be used for educational/ research purposes only.* **The answers to this survey will help identify methods of minimizing cold stress affects on workers in refrigerated warehouses.**

PERSONAL HISTORY

1) Name - [redacted]

2) Height - 5"7 **3) Weight -** 150 **4) Gender -** Male

5) Date of Birth 03-03-62 **6) Ethnic Backround -** European

7) Do you smoke? (yes) no a) If so how often? A Pack a Day

8) Do you use medication? yes (no)

9) Do you participate in physical exercise? (yes) no

a) How long? 1 hour per day b) How many days? 5 days per week

10) Do you have any previous cold injuries i.e. frostbite? yes (no) type: ______

a) If so, what part(s) of body? ______

b) When did you sustain such cold injury? ______

11) How long have you worked in Order Pick? 14 years — months

12) How long as Picker? 14 a) Please describe duties: ______

b) If lifting involved, approx. weight per case: 20# lbs. c) Lifts per hour: 1500/8 hr.

13) How long as Feeder? — a) Please describe duties: —

14) What clothing protection do you wear against the cold? Depends on time of the day and temperature. long-sleeved thermal + jeans - no gloves no hat.

15) How many hours do you work per week? About 50 hours

16) What is your approximate caloric intake for a mid-shift meal: ______

Thanks for your cooperation...

PHYSICAL CONDITION

17) Do you feel tired/ fatigue early vs. late in your shift? ~~Yes~~ YO after 10-12

Please describe: feel fatigued, metabolism slows down, colder quicker, maybe need more breaks.

18) Describe changes, if any, in your physical condition early vs. late in your shift:

a) Describe symptoms and part(s) of body affected:

19) Describe changes, if any, to your physical condition in the beginning of the shift compared to after a break:

20) Describe changes, if any, to your present physical condition compared to when you initially began working in Order Pick:

WORK PERFORMANCE

21) How many breaks do you take per day? 2 **a) Length per break?** 20 Minut.

22) Describe any changes in your work performance after a break vs. early in your shift:

23) Is clothing a burden to your work performance?

a) If so, which articles of clothing?

b) Performing what type of task?

24) Describe changes, if any, in your work performance early vs. late in your shift:

after

25) Can you provide any suggestions to minimize the affects of cold stress in Order Pick?

It would be a good idea if they used deflector on the units, also it would help if they kept the unit behind the stacker shut off. Because as the night goes along the cold air freezes the stacker, preventing it from working properly.

Thanks for your cooperation...

WORKPLACE SURVEY
Order Pick Department

Note: *This is a confidential survey and will be used for educational/ research purposes only.* **The answers to this survey will help identify methods of minimizing cold stress affects on workers in refrigerated warehouses.**

PERSONAL HISTORY

1) Name - [redacted]

2) Height - 6-4 3) Weight - 215 4) Gender - Male

5) Date of Birth 11/05/66 6) Ethnic Backround - German

7) Do you smoke? yes (no) a) If so how often? ______

8) Do you use medication? yes (no)

9) Do you participate in physical exercise? yes (no)

a) How long? ______ per day b) How many days? ______ days per week

10) Do you have any previous cold injuries i.e. frostbite? yes (no) type: ______

a) If so, what part(s) of body? ______

b) When did you sustain such cold injury? ______

11) How long have you worked in Order Pick? 1 years 6 months

12) How long as Picker? 1 YR + 6 months a) Please describe duties: I Bin Picking Routes + CBS + TTS since I'm up Here

b) If lifting involved, approx. weight per case: 35 lbs. c) Lifts per hour: ______

13) How long as Feeder? 1 YR a) Please describe duties: After picking I will stay In order pick stocking the Room up for, the next shift

14) What clothing protection do you wear against the cold? Jump suit

15) How many hours do you work per week? 40 + overtime

16) What is your approximate caloric intake for a mid-shift meal: ______

Thanks for your cooperation...

PHYSICAL CONDITION

17) Do you feel tired/ fatigue early vs. late in your shift?

Please describe:

18) Describe changes, if any, in your physical condition early vs. late in your shift:

a) Describe symptoms and part(s) of body affected: AFTER SITTING ON HILO WHEN THE UNITS ARE ON, MY LEGS + ARM STARTS TO HURT

19) Describe changes, if any, to your physical condition in the beginning of the shift compared to after a break:

20) Describe changes, if any, to your present physical condition compared to when you initially began working in Order Pick: WHEN PULLING WOOD DOWN STAIRS, MY BODY FEELS FINE, WHEN I COME UP STAIRS TO ORDER PICK THAT'S WERE I HAVE TROUBLE WITH MY ARM SOME TIMES THE BOXS HAVE TO MUCH GLUE

WORK PERFORMANCE

21) How many breaks do you take per day? 3 - 4 THIS IS WITH 0 **a) Length per break?**

22) Describe any changes in your work performance after a break vs. early in your shift:

23) Is clothing a burden to your work performance? NO

a) If so, which articles of clothing?

b) Performing what type of task?

24) Describe changes, if any, in your work performance early vs. late in your shift:

IF I'M PICKING ROUTES I HAVE A JUMP ON THE COLD

25) Can you provide any suggestions to minimize the affects of cold stress in Order Pick?

HAVE ONLY TWO UNITS ON

Thanks for your cooperation...

WORKPLACE SURVEY
Order Pick Department

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PERSONAL HISTORY

1) Name - [redacted]

2) Height - 6" 3) Weight - 234 4) Gender - Male

5) Date of Birth 1-21-46 6) Ethnic Backround - Black American

7) Do you smoke? (yes) no a) If so how often? Everyday, All day

8) Do you use medication? (yes) no

9) Do you participate in physical exercise? (yes) no

a) How long? ONE per day b) How many days? ONE days per week

10) Do you have any previous cold injuries i.e. frostbite? yes (no) type: ____

a) If so, what part(s) of body? N/A

b) When did you sustain such cold injury? N/A

11) How long have you worked in Order Pick? 6 years ____ months

12) How long as Picker? 6 yrs. a) Please describe duties: Hi Low Driver, stack juices

b) If lifting involved, approx. weight per case: 15 lbs. c) Lifts per hour: ____

13) How long as Feeder? N/A a) Please describe duties: N/A

14) What clothing protection do you wear against the cold? Winter Suit, Sweat Pants, Sweater Hat, Gloves, Boots

15) How many hours do you work per week? 12 Hours

16) What is your approximate caloric intake for a mid-shift meal: I don't Know.

Thanks for your cooperation...

PHYSICAL CONDITION

17) Do you feel tired/ fatigue early vs. late in your shift? YES

Please describe: JUST TIRED.

18) Describe changes, if any, in your physical condition early vs. late in your shift:

BEING cold while WORKING.

a) Describe symptoms and part(s) of body affected: HANDS AND TOES.

19) Describe changes, if any, to your physical condition in the beginning of the shift compared to after a break: BEING COLD.

20) Describe changes, if any, to your present physical condition compared to when you initially began working in Order Pick: BEING cold.

WORK PERFORMANCE

21) How many breaks do you take per day? 1 a) Length per break? 20 minutes

22) Describe any changes in your work performance after a break vs. early in your shift:

On break you are warm, Return to ORDER Pick - you become cold

23) Is clothing a burden to your work performance? NO

a) If so, which articles of clothing? N/A

b) Performing what type of task? N/A

24) Describe changes, if any, in your work performance early vs. late in your shift:

SAME-AS-ABOVE.

25) Can you provide any suggestions to minimize the affects of cold stress in Order Pick?

WARMER GLOVES, AND WARMER SHOES

Thanks for your cooperation...

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