Project GroupNo-01

A

Project Report

On

"Ergo Comfy 3 " Tube Welding"

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CERTIFICATE

This is to certify that

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Have a successfully completed the Project work entitled **"Design and Analysis of Vortex Tube Refrigeration System"** under my supervision, in the partial fulfilment of Bachelor of Engineering-Mechanical Engineering of Savitribai Phule Pune University.

Prof .S.V. Chanapattna **Dr. A.A. Pawar**

Head of Department

Principal

ACKNOWLEDGEMENT

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Lastly, we would thank to everyone who helped us to complete this projectabout performance.

ABSTRACT

The activity of welding specimens on a pipe that causes various problems for the body, in this activity the worker is at a risky position such as adjusting a pipe weight 8 kg, lifting the specimen and welding the pipe with the specimen and the final process is to lower the pipe that has been connected. The purpose of this study is to design workstation by the principles of ergonomics to help reduce physical worker complaints. The work posture was analyzed by the Rapid Entire Body Assessment (REBA) method. From the results of this study, it can be concluded that the welding work requires a tool in the form of a tube pipe support, a table used at a new welding workstation. With a new workstation, poor work posture can be repaired. With a new work station, there is an efficiency of 8.33 minutes of work time from previous working conditions

Index

ERGONOMICS AS A CONCEPT

The term ergonomics was coined from the Greek words ergon (meaning "work") and nomos (meaning "rules).So the literal meaning is "the rules of work," Ergonomics is the science of fitting the work-place conditions and job demands to the capabilities of the working population. The goal of ergonomics is to make the work place more comfortable and to improve both health and productivity. To meet these goals, the capabilities and limitations of workers and their tools, equipment and furniture are considered in conjunction with how they relate to particular tasks. Most people have heard of ergonomics and think it is something to do with seating or with the design of car controls and instruments. It is...but it is much more! Ergonomics is the application of scientific information concerning humans to the design of objects, systems and environment for human use. Ergonomics comes into everything which involves people. Work systems, sports and leisure, health and safety should all embody ergonomics principles if well designed.

DEFINITION

According to International Labour Organization, ergonomics is the application of the human biological sciences in conjunction with engineering sciences to the worker and his working environment, so as to obtain maximum satisfaction for the worker and at thesame time enhance productivity.

HISTORY

Later in the 19th century, Frank and Lillian Gilbert expanded Taylor's methods of “SCIENTIFIC MANAGEMENT” in the early 1900s to develop "Time and Motion Studies". They aimed to improve efficiency by eliminating unnecessary steps and actions. By applying this approach, the Gilbert’s reduced the number of motions in bricklaying from 18 to 4.5, allowing bricklayers to increase their productivity from 120 to 350 bricks per hour.

In the decades since the war, ergonomics has continued to flourish and diversify. The Space Age created new human factors issues such as weightlessness and extreme G- forces. How far could environments in space be tolerated, and what effects would they have on the mind and body? The dawn of the Information Age has resulted in the new ergonomics field of human-computer interaction (HCI). Likewise, the growing demand for and competition among consumer goods and electronics has resulted in more companies including human factors in product des

1. What is ergonomics?

Find out how it makes life better
"Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human well-being and overall system performance." International Ergonomics Association

The terms 'ergonomics' and 'human factors' can be used interchangeably, although 'ergonomics' is often used in relation to the physical aspects of the environment, such as workstations and control panels, while 'human factors' is often used in relation to wider system in which people work. On this site we generally use the term that fits most closely with the research or the industry that we are discussing.

Ergonomics is a science-based discipline that brings together knowledge from other subjects such as anatomy and physiology, psychology, engineering and statistics to ensure that designs complement the strengths and abilities of people and minimise the effects of their limitations. Rather than expecting people to adapt to a design that forces them to work in an uncomfortable, stressful or dangerous way, ergonomists and human factors specialists seek to understand how a product, workplace or system can be designed to suit the people who need to use it.

In achieving this aim, we need to understand and design for the variability represented in the population, spanning such attributes as age, size, strength, cognitive ability, prior experience, cultural expectations and goals. Qualified ergonomists are the only recognised professionals to have competency in optimising performance, safety and comfort. The CIEHF is the only body in the UK managing and representing this competency.

You usually don't notice good design, unless it's exceptionally good, because it gives us no cause to. But you do notice poor design. If you've ever got lost in an airport with poor signage, stared helplessly at a machine with incomprehensible instructions, cut your hands on poor packaging or sighed as you had to move things around to reach something you need, you know that a lack of ergonomic design can be incredibly frustrating. But it's not just the small, everyday things in which ergonomics has a role.

In the transport sector and in aviation in particular, the adoption of a human factors approach has changed the design of air traffic control systems, flightdecks and aircraft interiors. Human factors specialists are embedded within the teams that deliver our national air traffic services. They support the development of the technology that enables us to manage one of the most crowded areas of airspace in the world, whilst maintaining an exemplary safety record. New sensor and communications technologies have led to advanced glass cockpits in military and civilian aircraft; ergonomics and human factors ensures that these advances are implemented in a way that enables the human pilot to remain 'in the loop' when controlling the aircraft, as well as taking advantage of the accurate sensing and visualisation tools provided by engineering innovations. And, as passengers, we are now helped to evacuate safely from aircraft through designs of interior lights and safety information, informed by ergonomics research.

For many years, the high-hazard industries have recognised the importance of minimising the risk from human error. The nuclear sector has led the way in understanding, measuring and improving human reliability, and it has an enviable reputation, having avoided the major accidents which have marred other industry sectors, such as the Buncefield oil depot explosion. UK nuclear regulation is seen by many as the gold-standard.

In healthcare, ergonomists and human factors professionals are working in partnership with clinicians, managers and IT specialists to ensure a safe and resilient 21st century healthcare system. Much focus has been placed on improving communications between clinicians, ensuring that teams of doctors and nurses work together to make effective decisions and reduce the likelihood of harm. In addition to this important work, many pieces of equipment that we find in a clinical setting, from ambulances, to drips that deliver life-saving drugs, have been developed and evaluated by human factors experts.

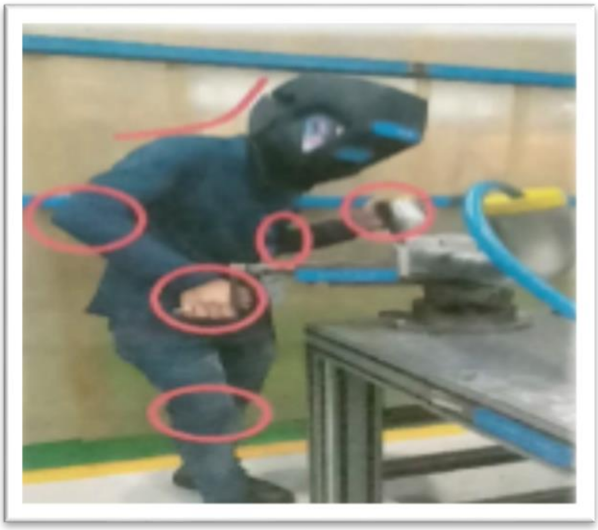
Our multidisciplinary perspective allows us to transfer our knowledge between applications, for example, ergonomists working with Great Ormond Street Hospital have studied Formula 1 pitstops in order to understand methods and efficiencies in teamwork for application in paediatric heart surgery.

2. Problem Statement

Problem Definition: While performing welding at Aviation COE, Operator facing Ergonomics issue with having 37# Ergo risk

Operator Required during tacking operation

Number Of Risk:
Hand : 8 Wrist : 5 Leg : 1
Back : 7 Elbow : 7 Neck : 4



Job holding / Damping Process

Repetition: Per 3rd Weld Joint
Yearly Weld Joint #1427

Operator during manul welding process :

People at risk
2

2. TIG Welding Definition

There are at least sixty-seven processes welders use to join metals. The type of pressure, heat, and equipment used is what makes one process different from another. TIG welding is one of the most popular welding processes. It produces high-quality welds but also requires a high level of skill. [1] Read more about TIG welding.

2.1 TIG Welding Definition

TIG welding is another name for gas tungsten arc welding. The aircraft industry created it to weld magnesium in the 1930s and 1940s. Ideally the process works like this: the welder makes an arc between the base metal and the non-consumable tungsten electrode, a type of electrode that does not melt. At the point where the arc hits the base metal a molten weld pool forms. A thin wire of filler metal is slowly handfed into the weld pool, where it melts. All the while, an inert shielding gas protects the tungsten electrode and weld pool from oxygen contamination. No fluxes are used. The finished product is a sound, slag-free weld that shares the same corrosion resistance properties as the parent metal. [2]

2.2 What Is TIG Welding Used For?

TIG welding can be used for more metals than any other type of process. For this reason, a variety of industries rely on TIG welding. It is used in the construction of spacecraft and airplanes in the aerospace industry. Auto manufacturers use TIG welding on fenders for its anti-corrosive properties. TIG welding is also widely employed in auto body repair shops. Artists appreciate the excellent quality of TIG welds using them in sculpture welding.

TIG Welding Advantages and Disadvantages

One of the greatest advantages of TIG welding is the amount of control it allows. A welder can control heat and amperage with precision using a foot or thumb remote control switch. The TIG welder is thin, which adds to the control a welder with excellent dexterity can have over the process. As a result, TIG welding is good for projects where detailed designs or curves are required on the base metal.

Operator during job tacking

Job holding/clamping process

Operator during manual welding process

- **What Is Tack Welding?**

After items to be welded together have been positioned as required, generally by clamping them on suitable fixtures, tack welds are used as a *temporary*means to hold the components in the proper location, alignment, and distance apart, until final welding can be completed.

In short-production-run manual welding operations, tack welding can be used to set up the workpieces without using fixtures. Typically, tack welds are short welds. In any construction, several tack welds are made at some distance from each other to hold edges together.

An advantage of this *provisional*assembly procedure is that if the alignment for final welding is found to be incorrect, the parts can be disassembled easily, realigned, and tack welded again.

In general, tack welding is performed by the same process that is used for the final weld. For example, aluminum-alloy assemblies to be joined by friction stir welding are tack-welded by the same process using a small tool developed for this purpose. Or electron beam tack welds, created with reduced power, are used to supplement or replace fixturing and to maintain the correct shape and dimensions during final electron beam welding.

If the final welding is performed while the elements are still clamped in a fixture, tack welding must keep the elements in place and resist considerable stresses, not sufficiently contrasted by clamping devices, that tend to separate the component.

- **Why Are Tack Welds Important?**

The temporary nature of tack welds may give the false impression that the quality of these auxiliary joining aids is not as important as that of final weld and that this operation doesn't have to be properly programmed, performed, and inspected. This is not true.

Tack welding is real welding, even if the welds are deposited in separate short beads. It performs the following functions:

- Holds the assembled components in place and establishes their mutual location
- Ensures their alignment
- Complements the function of a fixture, or permits its removal, if necessary
- Controls and contrasts movement and distortion during welding
- Sets and maintains the joint gap
- Temporarily ensures the assembly's mechanical strength against its own weight if hoisted, moved, manipulated, or overturned

- **Defective Tack Welding Risks**

When hoisted, improperly tack welded assemblies can rupture, and portions or subassemblies can fall and endanger people or damage property.Tack welding must not interfere with or degrade the quality of final welding. It must not introduce weld defects, such as arc strikes, craters, cracks, hard spots, and slag left in place.Many steels used in fabricating pipes and vessels are sensitive to rapid cooling or quenching, especially following short tack welds, because of the limited heat input required to tack weld. *Note:*Higher heat input slows the cooling rate, which minimizes the occurrence of hard and brittle microstructures.

Hard, brittle, and crack-sensitive microstructures can be formed in the heat-affected zone (HAZ) if the metal is rapidly quenched. In this case, even removing the whole tack weld by grinding may leave dangerous, invisible cracks in the base metal.

The brittle metal can crack during solidification of the weld metal or when stressed. Underbead cracks cannot be readily detected by visual inspection, and more thorough nondestructive tests may not be performed if they are deemed unimportant for such limited welds. However, these small cracks can cause the whole structure to fail.

- **Controlling Tack Weld Quality**

To ensure quality, most codes require that tack welding be performed only according to qualified welding procedures by welders fully certified in the process used for the final weld.

The requirements are applicable for any welding process used.

- **Distortion Control Procedures**

In all fusion welding processes, the sequence and the direction of the tack welds are important for distortion control. Besides maintaining the joint gap, tack welds must resist transverse shrinkage to ensure sufficient weld penetrations.

For a long seam, tack welding should start at the middle and proceed along the joint length, alternating in both directions, in proper back step or skip sequence to avoid stress buildup and deformation.Tack welds also can be placed at the joint ends and then added in the middle of each resulting distance between those already done, until the whole length is covered with the required number at the needed spacing.Why tack weld in sequences such as these? Because if tack welds are placed progressively from one end to the other, shrinkage can close the gap at the opposite end and might even cause one sheet end to overlap the other.

Because of greater thermal expansion in austenitic stainless steels, the spacing between tack welds on these materials should be much shorter than for mild steel.

4. Ergo Risk Factors

Ergonomic risk factors are the aspects of a job or task that impose a biomechanical stress on the worker. Ergonomic risk factors are the synergistic elements of MSD hazards. In the Health Effects section of this preamble (section V), OSHA discusses the large body of evidence supporting the finding that exposure to ergonomic risk factors in the workplace can cause or contribute to the risk of developing an MSD. This evidence, which includes thousands of epidemiological studies, laboratory studies, and extensive reviews of the existing scientific evidence by NIOSH and the National Academy of Science, shows that the following ergonomic risk factors are most likely to cause or contribute to an MSD:

- Awkward postures
- Cold temperatures
- Contact stress
- Force
- Repetition
- Static postures
- Vibration

Of these risk factors, evidence in the Health Effects chapter shows that force (forceful exertions), repetition, and awkward postures, especially when occurring at high levels or in combination, are most often associated with the occurrence of MSDs. Exposure to one ergonomic risk factor may be enough to cause or contribute to a covered MSD. For example, a job task may require exertion of so much physical force that, even though the task does not involve additional risk factors such as awkward postures or repetition, an MSD is likely to occur. For example, using the hand or knee as a hammer (operating a punch press or using the knee to stretch carpet during installation) alone may expose the employee to such a degree of physical stress that the employee has a significant risk of being harmed.

However, most often ergonomic risk factors act in combination to create a hazard. The evidence in the Health Effects section shows that jobs that have multiple risk factors have a greater likelihood of causing an MSD, depending on the duration, frequency and/or magnitude of exposure to each. Thus, it is important that ergonomic risk factors be considered in light of their combined

For those employers who are just beginning their programs and have little or no training and experience dealing with ergonomic risk factors, OSHA has tried to make the process of identifying them as workable as possible. Therefore, in the proposed rule OSHA has taken the ergonomic risk factors and the combination of risk factors most associated with the occurrence of MSDs and tried to present them in ways that those with more limited knowledge about ergonomics can readily identify. In this way, the ergonomic risk factors the proposed rule covers are presented in terms of specific and physically observable work activities and conditions. If any of these activities or conditions are present effect in causing or contributing to an MSD. This can only be achieved if the job hazard analysis and control process includes identification of all the ergonomic risk factors that may be present in a job. If they are not identified, employers will not have all the information that is needed to determine the cause of the covered MSD or understand what risk factors need to be reduced to eliminate or materially reduce the MSD hazards.

Although certain of the risk factors described above are easy to identify and it is not difficult to understand why they may be likely to create hazardous exposures, others are not as apparent or observable. Employers who already have ergonomics programs and persons who manage ergonomics programs should not have difficulty identifying risk factors in the workplace. Because these persons have training and experience, ergonomic risk factors are likely to be familiar concepts for them. Through the process of developing and implementing their ergonomics programs these persons have gained a good working knowledge of the ergonomic risk factors that are most likely to be present in their workplaces.

, the table in § 1910.918(c) tells employers which risk factors are likely to be relevant.

OSHA is proposing that employers use this list of physical work activities or conditions as a starting point for hazard evaluation, for several reasons. First, the list of activities and conditions is easy for employers to understand because they will be able to translate them to their own workplaces more readily than would be the case for ergonomic to risk factors. For example, "hand used as a hammer" is more easily understood than the term "contact stress," and "long reaches" graphically explains an "awkward posture" that may be a problem.

Second, the list helps employers quickly focus on the aspects of a job that are most likely to be associated with covered MSDs. At the same time, the list also identifies the risk factors that are most likely to be associated with the activities and/or conditions, which should help employers further focus their analysis. In this way the list serves as a bridge to the combinations of risk factors that studies have shown to be associated with an increased risk of developing work-related MSDs.

Third, having employers start the MSD identification and evaluation process with this list ensures that the analysis will be comprehensive. This is because the list includes the major components of work that have been associated with MSDs.

4.1 Physical work activities and conditions

The physical work activities and conditions OSHA has included in the proposed rule cover the basic physical aspects of jobs and workstations. These aspects include:

- Physical demands of work;
- Workplace and workstation conditions and layout;
- Characteristics of object(s) that are handled or used; and
- Environmental conditions.

The following table shows the physical work activities and workplace conditions that are associated with those physical aspects:

Employers who examine the job in which a covered MSD occurred to identify the physical work activities and workplace conditions and then evaluate the risk factors that OSHA has identified as potentially relevant, will be considered to be in compliance with the hazard analysis requirements of the proposed rule.

4.2 Exerting considerable force to complete a motion (forceful exertions)

It is not difficult to understand why jobs that require employees to apply a lot of physical effort may involve significant exposure to ergonomic risk factors and pose an increased risk of injury. For example, it is easy to see how much biomechanical stress employees are under when you see them grimace while trying to loosen lug nuts on an old tire, shift body weight and stance to wrench open stuck valves, or stiffen the body in order to lift a heavy or bulky object from the floor of a truck. Simply put, forceful exertions like these take more out of a person than tasks that do not require much physical effort. An easy way to confirm whether a task involves forceful exertions is to ask workers who are doing the task, or to try to do it yourself.

Performing forceful exertions requires an application of considerable contraction forces by the muscles, which causes them to fatigue rapidly. The more force that must be applied in the exertion, the more quickly the muscles will fatigue or become strained. Excessive or prolonged exposure to forceful exertions also leads to overuse of muscles and may result in muscle strain, soreness and damage. Performing forceful exertions can also irritate tendons, joints and discs, which leads to inflammation, fluid build up, and constriction of blood vessels and nerves in the area. Increased compression of nerves from the pressure imposed by inflamed tendons or muscle contractions may cause disorders of the nervous system (carpal tunnel syndrome and other nerve entrapment disorders).

Injuries related to forceful exertions can occur in any tissue or joint. As mentioned above, back injuries from overexertion are a leading cause of workplace injuries and workers' compensation cases. A number of studies also show that repeated forceful exertions of the hands and arms are associated with work-related MSDs (using tools, pinching or pushing with the fingers).

Lifting and carrying heavy objects are usually the tasks that come to mind as examples of forceful lifting tasks, but high forces are also involved in other types of jobs. These include jobs that require employees to apply pinch forces with their fingers (picking up or placing small items on an assembly line with the fingers), static forces (applying a lot of physical effort to put the last turn on a screw, pulling hard on a 30-inch wrench to loosen a bolt), and dynamic forces (tossing objects into containers). (Forceful lifting/lowering, pushing/pulling and carrying are discussed under "Manual Handling" activities and conditions below.)

4.3 Doing the same motions over and over again (repetitive motions)

Many jobs that involve repetition of the same job again and again are apparent even upon cursory observation: assembly line jobs where motions are repeated every few seconds, data processing jobs, directory assistant operators, court reporting, letter and package sorting. Repetitive motion jobs include performance of identical motions again and again, but also include repeating multiple tasks where the motions of each task are very similar and involve the same muscles and tissues.

Evidence in the Health Effects section shows a strong association between the occurrence of MSDs and jobs involving exposure to repetitive motions. The joints are most susceptible to repetitive motion injuries, especially the wrists, fingers, shoulders, and elbows. Repetitive work that is done with the foot (operating foot activated controls) or knees (climbing ladders or using a carpet kicker) may also result in an MSD.

4.4 Performing motions constantly without short pauses or breaks in between (inadequate recovery time)

Jobs that do not provide short pauses or breaks between motions or task cycles are often a problem because there may not be adequate time for muscles to recover from the effects of the exertion before the motion must be repeated. If there are no pauses between motions or the pauses are too short, the muscles cannot recover to the rested condition. Thus, the effects of the forces on the muscles accumulates and the muscles become fatigued and strained. The lack of adequate recovery time often occurs in jobs involving highly repetitive tasks. This happens when task cycle lengths are very short, which also means that the job involves a high number of cycle repetitions per minute. For example, some research shows that tendons and muscles in the wrists may not be able to recover where repeated task cycles are less than 5 seconds in length, that is, they are repeated more than 12 times per minute (Ex. 26-2).

Jobs involving constant muscle activity (static contractions) also may not provide adequate recovery time. These types of jobs may involve continuously holding hand tools (knife, paint brush, staple gun), which means that employees have constant exposure to static postures and low contraction forces.

The longer motions or job tasks are performed, the less likely that there will be adequate recovery time. The accumulation of exposure leads to muscle fatigue or overuse. In addition, where the intensity of exposure is greater, for example, in repetitive motion jobs that involve exposure to additional risk factors (force, awkward postures, or static postures), the increased forces required for the exertion also increase the amount of recovery time that is needed. Any part of the musculoskeletal system involved in moving the body is subject to injury where there is inadequate recovery time, and the recovery times needed vary by body part. For example, although employees may not be at high risk for forearm injury if task cycles are 25 seconds long or not repeated more than 3 times per minute, they may be at high risk of shoulder injury under this regimen.

4.4 Awkward postures, static postures, contact stress, vibration

The presence of any or all of these risk factors in a job, particularly jobs involving repetitive motion or forceful exertion, increases the force already required to perform job tasks and, therefore, increases the amount of time muscles need to recover from the exertions the task requires. If the recovery time is not adequate, the presence of these risk factors hastens the onset of fatigue and the effects associated with overuse of muscles, joints and tendons.

- Attaching doors on the bathroom vanity assembly line
- Capping and cupping cookies on an assembly line

4.5 Performing tasks that involve long reaches

Many job tasks involve long reaches: working overhead, putting items on a high shelf, reaching across a conveyor to put in a part or grasp an object, or bending over to reach a part in the bottom of a big supply box. These tasks expose employees to extreme awkward postures. Where long reaches are momentary and/or infrequent and the forces are low, these tasks are not a problem because there is likely to be adequate time for the body to recover between reaches. However, when long reaches are done frequently, force is involved and/or a long reach lasts more than a few seconds, the risk of harm increases.

Long reaches usually have the greatest impact on the shoulders and lower back. The shoulder is unique in its wide range of motion when compared with other joints in the body. The bony restraints are minimal, but soft tissue constrains the motion. Thus, injuries usually occur when the soft tissue is used to maintain an awkward posture and/or forceful exertion.

The back is flexed forward or extended back to extend reaches beyond the limit of the arm length. In addition, workers in repetitive jobs will often bend their back so that they can reduce the awkward shoulder posture. Bending the back forward adds the weight of the upper body to the force exerted by the back muscles and supported by the spine. Bending to the side, backwards or twisting puts the spine and back muscles in awkward postures.

4.6 Working surfaces are too high or too low

Working surfaces that are too high or too low are another way in which employees are exposed to awkward postures. Where employees must work on such surfaces for a long period, the risk of tissue damage and other MSD problems increases.

Working surfaces can be too high or too low for many employees because most working surfaces are not adjustable. For example, 30 inches is a typical height for desks, tables and other working surfaces operated from a sitting position, and 36 to 40 inches is a typical height range for working surfaces operated from a standing position. Although employees of average height may be able to work comfortably at these working surfaces, the typical heights may not work for shorter or taller employees. An assembly-line employee who is 6'5" may have to bend over significantly to assemble the parts on a conveyor that is 36 inches high, while a 5-foot employee working on a 42-inch conveyor may have to work with her elbows away from the body.

The height of working surfaces can also be too high or too low when employees must use work surfaces or workstations that were not designed for the tasks being performed. For example, typical desks (30 inches high) are not designed for computer use. Even persons of average height may have to raise their elbows and shoulders to use the keyboard on their desks. This is especially true where desk chairs cannot be raised high enough to correct the problem. Even when the employee can be raised to a good height, the feet are often left dangling above the floor.

4.7 Maintaining same work positions or posture for a long period

The chief complaint people usually make when they have worked for a long time in the same position is that they feel "stiff, sore and tired." These are some of the effects that result when tasks involve static postures (driving for several hours without a break).

Static postures increase the amount of force required to do a task because, in addition to the force required to perform the task, contraction forces must be applied to hold the body in position throughout the work shift. Maintaining the same position or posture includes a variety of things. It includes holding the arms and shoulders in a non-neutral posture without moving.

The effects of maintaining the same work positions can occur in almost any joint of the body and vary depending on body location. For example, the effect on the knees and back from squatting or kneeling for 2 hours is likely to be greater than the effect on the neck and shoulders from looking up at a monitor for the same period.

4.8 Sitting for a long time

Sitting for long periods without the opportunity to stand up and move around is another way in which employees are exposed to static loading of tissues, primarily in the lumbar area of the back. It can also affect the upper back, neck and legs. The problem is exacerbated where awkward postures are also present.

Static postures. Employees may be exposed to static postures when they must sit for a prolonged period on chairs, stools or benches that do not provide adequate lumbar support, that is, either the back rest of the seat does not provide good lumbar support or there is no back rest at all. When there is no lumbar support and the back is bent forward, the muscles of the back are trying to force the lumbar region out of it natural curve (proper alignment of the vertebrae), which places pressure on the discs and reduces blood supply to the spinal tissue. The constant exertion of the contraction forces leads to muscle fatigue.

When the back muscles become sore, people tend to slouch. In this posture more force is being placed on the back and the discs. As the static loading continues, pressure continues to be applied to the membranes of the discs and they may become stressed. Stressed discs, in turn, may put pressure on blood vessels and may pinch a nerve (sciatic nerve), which results in pain.

Even where the chair has a back rest with lumbar support to help maintain the back in a neutral position, employees still may continue to be exposed to static loading because they cannot take advantage of the back rest. This may occur when the seat pan is too big or the seat is too high for the employee. Many employees respond by sitting forward, instead of against the back rest, so that their feet can be on the ground, thus pressing the spine out of the natural curve and placing pressure on the discs.

4.9 Using hand and power tools

"Using hand and power tools" to perform physical work activities does not in itself mean that employees are exposed to ergonomic risk factors that put them at risk of injury. Rather, it is a shorthand way of alerting employers that there are aspects of tool design and use that need to be checked out to see whether ergonomic risk factors may be present. These include:

- Weight and size of tool
- Tool handles and/or grips
- Tool activation (repetitively, one finger)
- Tool kickback, vibration and maintenance

4.10 Using hands or body as a clamp to hold objects while performing tasks

Sometimes this is referred to as having the worker act as a "human clamp" or "human vise." In these situations the worker usually holds the object being worked on with one hand (often in an awkward, forceful posture) while force is applied by the other hand. The hand being used as a clamp has to hold the object while resisting the forces being applied by the other hand. Using the hand as a clamp leads to muscle fatigue and inflammation of the muscles and tendons.

The strain on the muscles and tendons in the clamping hand is especially high when the task involves static postures or contact stress. Although the hand and arms are most often used as a clamp, some larger jobs require the feet, legs, hips or torso (lateral bending of the back) to support a part while work is performed.

- Holding the head of a cow on a slippery surface while attempting to remove meat
- Holding a small part while assembling it
- Drilling a hole in a part that the worker has to hold
- Using the hips or thighs to hold a part in place while working on the part

4.11 Gloves are too large, too small or too bulky

For many jobs it is necessary or appropriate for workers to wear gloves while doing their jobs. Gloves can make grasping an object more difficult by changing the friction, decreasing dexterity, and interfering with sensory feedback. This often leads to using more muscle force than would be required without gloves. Additionally, gloves can fold, wrinkle, and bunch so that pressure points are created that result in contact stress. Gloves that fit or are less bulky may help to relieve these problems. An even better solution is to eliminate the need to wear gloves.

Examples of glove use that may rise to the level of a hazard are providing inappropriate gloves for the work, or failing to consider the worker's needs when gloves are purchased, providing thick gloves for a task that requires dexterity beyond that allowed by the gloves, or providing vibration dampening gloves and expecting levels of dexterity or force exertion that are beyond the level possible with the gloves.

4.12 Manual handling (lifting/lowering, pushing/pulling and carrying)

Forceful manual handling activities are a leading cause of workplace injury and illness. Lower back MSDs from lifting account for a large percentage of all workers' compensation cases. Studies discussed in the Health Effects section indicate that employees performing manual handling tasks have a significantly higher risk of back injury where they are exposed to force, repetition and/or awkward postures in the job.

The physical work activities and conditions included on the manual handling list in the proposal are ones that are likely to be a significant problem because they are ones in which the major ergonomic risk factors associated with manual handling tasks are present: force and awkward postures/static postures. This discussion about physical work activities and conditions in manual handling tasks is organized by task (lifting, pulling). Manual handling tasks are discussed only where the physical work activities and conditions and ergonomic risk factors are likely to be a significant problem.

4.13 Objects or people are heavy (lifting, lowering, pushing, pulling, carrying)

Workers lift, lower and move items every day. The heavier the weight that has to be lifted, lowered and/or moved, the more force the worker will have to exert. The heavier the weight, the closer the contraction required of the muscles will be to their maximum capability. When muscles contract at or near their maximum, they fatigue more rapidly and the likelihood of damage to the muscle and other tissues involved in the activity increases. In most situations involving lifting, lowering and moving heavy objects or people, the predominant risk factor is force. Manual handling of heavy objects exposes employees to high forces and will usually have the greatest impact on the back. Another aspect of weight that should be considered is a sudden shift in weight. Workers are more often able to accomplish a manual handling task without injury when they are prepared. When a patient's legs suddenly buckle while they are being transferred or a load within a package or container shifts, the worker may not be physically or mentally prepared for the weight.

- ### Lifting and Lowering

In lifting and lowering, force is the risk factor that most often needs to be addressed. Although there may be a perception that lifting is more problematic than lowering, they both require the worker to exert the forces commensurate with the weight of the object. The actual forces exerted by the worker are determined by the weight of the object. It is obvious that lifting containers weighing 25 pounds is considerably easier than those weighing 50 pounds and that more people are capable of lifting the smaller amount. Posture can play a major role in the force required when moving an object. If that object can be held or lifted closer to the body, the muscle forces required in the back are less. Bulky containers present more of a problem when being lifted than do those with the same characteristics, including weight, that are compact. Finally, the frequency with which an object is lifted or lowered and the times it must be supported may be important in determining the risk presented by the job.

- Lifting a resident, who has little ability to assist, from the toilet to a wheelchair
- Lifting a 150 pound package from a loading dock into a van

- **Pushing and Pulling**

When pushing and pulling objects, the weight of the object or conveyance, including its contents, affects the force required of the worker. Often workers have to slide objects on a table or flat surface. In these cases the weight and the friction characteristics of the object and the surface are the prime determinants of the force required. Secondarily, the posture or reach may affect the degree of risk presented by the job. Where conveyances such as carts are used, the force required is generally determined by the characteristics and weight of the cart and contents. For very heavy carts, stopping and controlling the cart can sometimes be as difficult and important as pushing or pulling it to the desired location.

- Pushing a 300 pound pump away from the paper machine or
- Pushing a heavy cart up a sloped ramp

- **Carrying**

For carrying the weight, distance and object characteristics affect the forces required. Often the forces are exerted statically for some period of time when carrying. Additionally, the worker's body is in motion and the stability and biomechanics of the activity may be much worse than in a simple lifting or lowering situation. Examples might be carrying heavy parts from one work area to another, carrying containers from production to a pallet or storage area, or carrying packages when delivering them to a customer.

- Carrying several 50-pound bags of feedstock material to the basement
- Carrying a resident of a nursing home to the bath tub

4.14 Horizontal reach is long (Distance of hands from body to grasp object to be handled)

Workers who are lifting/lowering, pushing/pulling or carrying are greatly affected by the distance that the hands are from the body during the activity. The forces required to manually move an object by the muscles in the back and shoulder are increased significantly as the load is moved away from the body. The resulting compression on bone and cushioning tissues is also significantly increased. The impact on the musculoskeletal system increases dramatically as the object or weight (center of gravity for bulky objects) is farther from the body. When moving objects or people, the distance away from the worker's body affects the forces for a lift or carry. Two characteristics of a lift requiring a long horizontal reach make it harder on the worker. The first is that the worker's own body weight must be supported and lifted in addition to the weight of the object. The second is that the torque required puts the muscles at a greater mechanical disadvantage when the objects being lifted are at a greater distance from the body joint involved. Because of the mechanical disadvantage, the predominant risk factor in these situations is force, which is increased because of the risk factor of awkward posture (long reach) present. The awkward posture involved in long reaches requires higher muscle forces to lift or move the same weight as would be necessary if the reach were shorter. The problem becomes worse when either greater weight or greater distance is required. Lifting, lowering and/or carrying items when a long horizontal reach is required will usually have the greatest impact on the shoulders, arms and back.

○ Lifting and Lowering

For lifting and lowering where the horizontal reach is long, force is the factor that needs to be addressed. This is usually accomplished by reducing the reaches or the weight. Examples would include reaching for a product on the far side of a conveyor, reaching to a parts supply bin that is on the far edge of the work surface, lifting a large box with a center of gravity at some distance from the body, lifting or lowering something on the far side of a barrier, placing packages on the far side of a pallet, or assisting a patient in sitting.

○ Pushing and Pulling

For pushing and pulling tasks, there may be reaches that are long; however, these are not usually a problem unless there is simultaneous lifting or unless the pushing and pulling direction is side to side rather than in and out. Moving objects from side to side is much less efficient than toward and away from the body.

4.15 Pushing a heavy box on a non-powered conveyor

○ Carrying

There are times when workers carry an object that cannot be rested against the body, so the arms are in a position that is similar to that of a long reach. This also happens when carrying a large box or container. When this happens the force risk factor is probably the most important, followed by the awkward and static posture risk factors.

- Carrying a hot pack used in extruding plastic to the repair cart
- Carrying a carboy of nitric acid

4.16 Vertical reach is below knees or above the shoulders (Distance of hands above the ground when the object is grasped or released)

Workers who are lifting/lowering, pushing/pulling or carrying must exert more effort if the vertical position of the hands (when the object is started in motion) is above or below 30" (Snook 1978, Ex. 2-26; Ayoub et al. 1978, Ex. 26-1416; Snook and Ciriello 1991, Ex. 26-1008). The forces required by the muscles in the back and shoulder are increased significantly as the hands near the floor or move above the shoulders. The NIOSH lift equation reduces the recommended lift by 22.5% if the lift occurs at or above shoulder level.

In addition to the force, the resulting compression on bone and cushioning tissues increases the likelihood of an injury. Ideally the hands are at (or slightly below) waist level when manual handling begins. Manual handling tasks that require the hands to be lower than the knees or higher than mid-torso put the worker at a biomechanical disadvantage, which requires the muscles to exert more force than if the starting point is near waist height. Low starting points require bending or squatting, which adds stress to the back and knees, respectively, due to the awkward posture. When the lifted object is below the worker's knees, he or she must bend forward, thus stretching the muscles in the back into an awkward and less efficient lifting posture. In addition, from a stooped posture the worker must lift the weight of the torso up as the object is lifted.

When an object is lifted above mid-torso heights, the thrust of the lifting force shifts from the larger/stronger muscles of the back to the smaller muscles of the shoulder. As the load is raised higher, the muscles of the shoulder become the primary movers. When material is lifted overhead, control of the lift becomes important. If the weight of the load were to suddenly shift while being lifted overhead, the resulting awkward posture, combined with the weight and distance of the load from the lower spine, could tear tendons, ligaments and muscles.

Lifting and Lowering

In lifting and lowering from or to low or high positions, awkward posture is a risk factor that often needs to be addressed. The awkward posture makes the muscles less efficient, and results in higher muscle forces than would be required if the lifting or lowering took place with the load within 10 inches of the waist.

- Picking up a 35-pound spool of yarn from a peg above shoulder height
- Picking a 40-pound item from a 60" high shelf in a grocery warehouse
- Lifting a 50 pound motor off a pallet

Pushing and Pulling

When pushing or pulling objects, the height of hands affects the amount of force needed. When the hands are slightly above waist height, the worker gets the most from the muscles. As the hands are moved lower or higher, the worker's posture becomes more awkward and requires more force from the muscles.

- Pushing a cart with the hands above mid chest height
- Pulling a wooden pallet across the floor

Carrying

Carrying an object combines the static loading of the muscles with the loading caused by the awkward vertical position of the load. The combination of static and awkward postures greatly increases the fatigue on the muscles. Maintaining a stooped posture to carry a load places strain on the muscles of the back and shoulder as well as the spinal discs. Not only is the back supporting the weight of the object, but also the weight of the upper body. Carrying loads above shoulder height cannot be maintained for prolonged periods of time because the shoulder muscles will fatigue. The exception is when the weight of the load is rested on the skeletal system and the arms merely balance the weight (carrying objects on the head, carrying trays of food on the shoulder).

- Carrying large, bulky boxes of machine parts where the worker is unable to carry the box with a horizontal hold
- Carrying a large piece of furniture down steps

4.17 Objects or people are moved significant distance (pushing, pulling, carrying)

In producing products or even services it is often necessary to move objects or people. This may be done by a worker pushing, pulling or carrying the item. Almost invariably this involves forceful exertions. The method of movement, the force required, and the distance to be moved are the important aspects of the job that will determine the presence of MSD hazards. The higher the force required and the longer the distance to be moved, the more likely it is that the job will present a problem. Force is the predominant risk factor when objects are moved, and it can be mitigated by using carts or other conveyances. This type of job is most likely to have adverse affects on the back, shoulders and arms.

- **Lifting and Lowering**

Lifting and lowering is usually involved in a job of this type when the object is to be carried. For the lifting and lowering part of the job, the discussion of "objects or people moved are heavy," above, should be consulted. The carry part of the task involves force and static postures. The weight of the object and the distance affect the force required and the time spent in static and forceful postures, respectively. Carrying puts the body in a dynamic activity where the stability is less than when the body is stationary. Examples of movement distances that might rise to the level of a hazard are moving a patient from the bed to the bath, lifting a tire from the floor to above the head, or carrying a heavy part from a pallet to a workstation.

- ### Pushing and Pulling

When pushing or pulling an object for a significant distance, the forces required and the distance moved are the important aspects of the job. If a cart or conveyance is used, the force to push or pull it is almost always the risk factor of concern. Sometimes large or heavy objects are moved by sliding them across the floor. This usually involves high forces and is better done in other ways such as using a cart or powered mover.

- Pushing a cart of restaurant supplies from the delivery truck to the restaurant
- Pushing a patient on a gurney to physical therapy.

Carrying

Once again, the weight of the object and the distance it must be carried are the important factors. The effect of these on the worker can be reduced by providing some form of conveyance.

- Carrying trash cans to the garbage truck
- Carrying water bottles to the cooler

4.18 Bending or twisting during manual handling

Bending or twisting while manual handling creates an awkward posture and changes the way forces are distributed in the spine. When the spine is in its natural position, forces are directed along the bony structure and distributed into the tissue as the spine curves. However, bending and twisting redirects the forces, placing more compressive and shear forces on the discs. Psychophysical studies have reported that there is a decrease in the maximum acceptable weight of lift (MAWL) in the range of 8% to 22% where twisting of the torso is involved (Garg and Badger 1986, Ex. 26-121; Mital and Fard 1986, Ex. 26-182; Garg and Banaag 1988, Ex. 26-951). Experiments by Adams et al. (1980, Ex. 26-701) indicate that combined bending and twisting of the spine reduces the tissue tolerance of the intervertebral discs, predisposing them to rupture.

When an object to be lifted is below the worker's knees, he or she must bend forward, thus stretching the muscles in the back into an awkward and less efficient lifting posture. In addition, from a stooped posture the worker must lift the weight of the torso up as the object is lifted. Lifting from a stooped posture also creates a situation where the worker can accelerate the torso as they lift.

Marras and Granata (1995, Ex. 26-1383, and 1997b, Ex. 26-169) found that increased velocity and acceleration in trunk lateral bending and twisting result in measurable increases in both compressive and shear forces experienced by the intervertebral discs.

Lifting and Lowering

In lifting and lowering, awkward posture is the risk factor that most often needs to be addressed. The awkward posture makes the muscles less efficient and results in higher forces than would be required if the lift or lower were ±10 inches from the waist.

- Moving 30 pound motors from a workstation to a conveyor perpendicular (90) to the workstation
- Moving a patient from the bed to a wheelchair
- Loading luggage into the cargo hold of an airplane

4.19 Object is bulky, slippery or has no handles (lifting, lowering, carrying)

Lack of good hand holds or good coupling between the hand and the object can result in higher grasp forces, higher other hand/arm forces, higher back forces, or the adoption of awkward postures to secure a stable relationship with the load. The predominant risk factors involved are force and awkward postures, which usually affect the back, hands, wrists and fingers.

- ### Lifting and Lowering

When lifting and lowering an item in which the coupling is poor, the worker has to adapt. Sometimes this involves having the hands or center of gravity of the load at considerable distance from the body, which increases the forces required of the back in awkward postures. Sometimes the hands have to bend around the box corners, resulting in considerable force being exerted in an awkward posture. Bulky loads cause the worker to bend the back more. Open boxes with poor coupling may be picked up with pinch grips on the tops of the box sides, which results in high forces and an ineffective grip.

- Lifting a 40-pound fuel pump out of a tank of mineral oil,
- Lifting wet watermelons out of a box (which requires the worker to use excessive grip force)
- Lifting a patient with little ability to assist out of bed

- ### Pushing and Pulling

Hand forces will tend to be higher when pushing or pulling bulky items or those that have poor coupling

4.20 Pushing a large box of potatoes in a product warehouse

- **Carrying**

The problems of carrying an object with poor coupling or that is bulky are very similar to those involved in lifting and lowering. These problems are exacerbated by the static loading required when carrying any distance.

- Carrying a keg of beer
- Carrying machined parts to a degreaser
- Carrying a side of beef

4.21 Floor surfaces are uneven, slippery or sloped

Surfaces that are not level require the worker to compensate by placing the body in an awkward posture. When the spine is in its natural position, forces are directed along the bony structure and distributed into the tissue as the spine curves. However, awkward postures both redirect the forces, placing more compressive and shear forces on the discs and placing the muscle in a less efficient position. In addition, to move an object manually, the forces exerted by the feet need to be resisted by the forces that push back from the floor. When the floor is slippery or sloped, the worker must expend more energy resisting the natural tendency for the feet to slip. If the load should shift while the worker is on an uneven, slippery or sloped surface, an injury becomes more likely. Poor floor conditions can affect the footing and the ease of movement of carts. Force is the risk factor that is usually exacerbated by poor floor surfaces and the back is the usual location of MSDs that are brought on by problems of floor surfaces. Lack of good footing will result in added stress on the postural muscles and other tissues.

- **Lifting and Lowering**

In lifting and lowering, awkward posture is the risk factor that most often needs to be addressed. The awkward posture makes the muscles less efficient and results in higher forces. The higher forces lead to fatigue and inflammation.

- Shoveling grain
- Lifting bags of laundry from a wet floor

- **Pushing and Pulling**

Pushing or pulling on an uneven, slippery, or sloped surface can result in a sudden increase in the force needed to move or stop an object. The increase in force alone can tear muscles or strain tendons enough to cause an injury. When the increase in force occurs when the body is in an awkward posture due to the surface, then a muscle or tendon strain is more likely, due to the inefficient position of the muscles.

- Pushing a laundry hamper across a wet floor
- Pushing a file cabinet on a carpeted floor
- Pushing a wheelchair through gravel
- Pushing a cart on a cracked concrete floor

- **Carrying**

Carrying an object while walking on uneven, slippery or sloped surfaces causes the body to continually shift to accommodate the changing working surface.

- Carrying boxes of metal scraps down steps
- Carrying boxes of paper up a ramp into the computer room

5. Rodgers Muscle Fatigue Analysis

Muscle Fatigue Analysis The Muscle Fatigue Analysis was proposed by Rodgers as a means to assess the amount of fatigue that accumulates in muscles during various work patterns within 5 minutes of work. The hypothesis was that a rapidly fatiguing muscle is more susceptible to injury and inflammation. With this in mind, if fatigue can be minimized, so should injuries and illnesses of the active muscles. This method for job analysis is most appropriate to evaluate the risk for fatigue accumulation in tasks that are performed for an hour or more and where awkward postures or frequent exertions are present. Based on the risk of fatigue, a Priority for Change can be assigned to the task.

Using the task identification sheet, divide a job into tasks and determine what percent of the shift each task is done. Identify which tasks are perceived as “difficult” by people on the job. Do the analysis on the primary tasks performed (those done for more than 10% of the shift) and on any tasks considered “difficult”, no matter how much of the job they constitute. Use a separate Task sheet for each task. For a task and for each body region, assess the three job risk factors by assigning each factor a rating by category.

The task data sheet provides a format for this process. Descriptions of Effort Levels for the different body regions, Continuous (single) Effort Duration and Effort Frequency are provided on the data collection form. Within a body region, once an Effort Level is chosen to represent the task, the assignment of Continuous Effort Time and Efforts per Minute should be associated with the chosen effort. Notes: If the effort level is high enough that most workers cannot accomplish it, if the continuous effort duration is greater than 30 sec, or if the frequency is greater than 15 / min, then there is sufficient reason to assign a Very High priority for change. The Priority for Change is found by locating the combination of scores in the various categories in the table on task identification data sheet. Note: A combination of 3 and 3 for Duration and Frequency is not possible.

The table provides an indication of relative risk for fatigue within a category. The earlier the combination of categories is in the list the lower the fatigue should be (i.e., it is better)

BEFORE :

Body Part	Effort Level Descriptions				Effort Level (a)	Continues Effort Time (b)	Efforts /Minute (c)	Risk Level (d)	Notes/Comments
	Light (1)	Moderate (2)	Heavy (3)	Right or Left Side	1 = Light 2= Moderate 3= High 4= Very High	1 =<6 sec 2=6-20 sec 3=>20-30 sec 4 =>30 sec	1 = <1/min 2=1-5/min 3 =>5-≤15/min 4= >15/min		
Shoulders ! Upper Back	Arms slightly away from sides, arms extended with some support	Arms away from body. no support, working overhead	Exerting forces or holding weight with arms away from body or overhead	Right	3	3	2	Very high	
				Left	3	3	2	Very high	
Arms/ Elbows	Arms away from body, no load: light forces/ lifting near body	Rotating arm while exerting moderate force	High forces exerted with rotation; lifting with arms extended	Right	2	2	2	Moderate	
				Left	2	2	2	Moderate	
Hands! Fingers! Wrists	Light forces or weights handed close to body straight wrists. comfortable power grips	Grips with wide or narrow span moderate wrist angles, esp flexion. use of gloves with moderate forces	Pinch grips, strong wrist angles, slippery surfaces	Right	2	3	2	Moderate	
				Left	2	3	2	Moderate	
Neck	Head Turned partly to side or back or forward slightly	Head turned to side; head fully back; forward about 20 degrees	Same as moderate but with force or weight; head stretched forward		3	2			
Back	Leaning to side or bending, arching back	Bending forward no load. lifting mod-heavy loads near body, overhead work	Lifting or exerting force while twisting, high force or load while bending		3	2			
Legs/ Knees Ankles/ Feet/ Toes	Standing, walking. without bending or leaning, weight on both feet	Bending forward, leaning on table; weight on one side; pivoting while exerting force	Exerting high forces while pulling or lifting: crouching while exerting force	Right	2	3	2	Moderate	
				Left	1	3	2		

AFTER :

Body Part	Effort Level Desciptions				Effort Level (a)	Continuos Effort Time (b)	Efforts /Minute (c)	Risk Level (d)	Notes/Comments
	Light (1)	Moderate (2)	Heavy (3)	Right or Left Side	1 = Light 2= Moderate 3= High 4= Very High	1 =<6 sec 2=6-20 sec 3=>20-30 sec 4 =>30 sec	1 = <1/min 2=1-5/min 3 =>5-≤15/min 4= >15/min		
Shoulders ! Upper Back	Arms slightly away from sides, arms extended with some support	Arms away from body. no support, working overhead	Exerting forces or holding weight with arms away from body or overhead	Right				Very high	
				Left				Very high	
Arms/ Elbows	Arms away from body, no load: light forces/ lifting near body	Rotating arm while exerting moderate force	High forces exerted with rotation; lifting with arms extended	Right	1	2	2	Moderate	
				Left	1	2	2	Moderate	
Hands! Fingers! Wrists	Light forces or weights handied close to body straight wrists. comfortable power grips	Grips with wide or narrow span moderate wrist angles, esp flexion. use of gloves with moderate forces	Pinch grips, strong wrist angles, slippery surfaces	Right	1	2	2	Moderate	
				Left	1	2	2	Moderate	
Neck	Head Turned partly to side or back or forward slightly	Head turned to side; head fully back; forward about 20 degrees	Same as moderate but with force or weight; head stretched forward						
Back	Leaning to side or bending, arching back	Bending forward no load. lifting mod-heavy loads near body, overhead work	Lifting or exerting force while twisting, high force or load while bending						
Legs/ Knees Ankles/ Feet/ Toes	Standing, walking. without bending or leaning, weight on both feet	Bending forward, leaning on table; weight on one side; pivoting while exerting force	Exerting high forces while pulling or lifting: crouching while exerting force	Right				Moderate	
				Left					

6. What Is Return on Investment (ROI)?

Return on investment (ROI) is a performance measure used to evaluate the efficiency or profitability of an investment or compare the efficiency of a number of different investments. ROI tries to directly measure the amount of return on a particular investment, relative to the investment’s cost.

To calculate ROI, the benefit (or return) of an investment is divided by the cost of the investment. The result is expressed as a percentage or a ratio.

KEY TAKEAWAYS

- Return on Investment (ROI) is a popular profitability metric used to evaluate how well an investment has performed.
- ROI is expressed as a percentage and is calculated by dividing an investment's net profit (or loss) by its initial cost or outlay.
- ROI can be used to make apples-to-apples comparisons and rank investments in different projects or assets.
- ROI does not take into account the holding period or passage of time, and so it can miss opportunity costs of investing elsewhere.

6.1 How to Calculate Return on Investment (ROI)
The return on investment (ROI) formula is as follows:

ROI= Current Value of Investment-Cost of Investment/ Cost of Investment

"Current Value of Investment” refers to the proceeds obtained from the sale of the investment of interest. Because ROI is measured as a percentage, it can be easily compared with returns from other investments, allowing one to measure a variety of types of investments against one another.

6.2 Understanding Return on Investment (ROI)
ROI is a popular metric because of its versatility and simplicity. Essentially, ROI can be used as a rudimentary gauge of an investment’s profitability. This could be the ROI on a stock investment, the ROI a company expects on expanding a factory, or the ROI generated in a real estate transaction.

The calculation itself is not too complicated, and it is relatively easy to interpret for its wide range of applications. If an investment’s ROI is net positive, it is probably worthwhile. But if other opportunities with higher ROIs are available, these signals can help investors eliminate or select the best options. Likewise, investors should avoid negative ROIs, which imply a net loss.

For example, suppose Jo invested $1,000 in Slice Pizza Corp. in 2017 and sold the shares for a total of $1,200 one year later. To calculate the return on this investment, divide the net profits ($1,200 - $1,000 = $200) by the investment cost ($1,000), for a ROI of $200/$1,000, or 20%.

With this information, one could compare the investment in Slice Pizza with any other projects. Suppose Jo also invested $2,000 in Big-Sale Stores Inc. in 2014 and sold the shares for a total of $2,800 in 2017. The ROI on Jo's holdings in Big-Sale would be $800/$2,000, or 40%.

6.3 Limitations of Return on Investment (ROI)

Examples like Jo's (above) reveal some limitations of using ROI, particularly when comparing investments. While the ROI of Jo's second investment was twice that of the first investment, the time between Jo's purchase and sale was one year for the first investment but three years for the second.

Jo could adjust the ROI of the multi-year investment accordingly. Since the total ROI was 40%, to obtain the average annual ROI, Jo could divide 40% by 3 to yield 13.33% annualized. With this adjustment, it appears that although Jo's second investment earned more profit, the first investment was actually the more efficient choice.

ROI can be used in conjunction with the rate of return (RoR), which takes into account a project's time frame. One may also use net present value (NPV), which accounts for differences in the value of money over time, due to inflation. The application of NPV when calculating the RoR is often called the real rate of return.

6.4 Developments in Return on Investment (ROI)

Recently, certain investors and businesses have taken an interest in the development of a new form of the ROI metric, called "social return on investment," or SROI. SROI was initially developed in the late 1990s and takes into account broader impacts of projects using extra-financial value (i.e., social and environmental metrics not currently reflected in conventional financial accounts).[1]

SROI helps understand the value proposition of certain environmental social and governance (ESG) criteria used in socially responsible investing (SRI) practices. For instance, a company may decide to recycle water in its factories and replace its lighting with all LED bulbs. These undertakings have an immediate cost that may negatively impact traditional ROI—however, the net benefit to society and the environment could lead to a positive SROI.

There are several other new flavors of ROI that have been developed for particular purposes. Social media statistics ROI pinpoints the effectiveness of social media campaigns—for example how many clicks or likes are generated for a unit of effort. Similarly, marketing statistics ROI tries to identify the return attributable to advertising or marketing campaigns.

So-called learning ROI relates to the amount of information learned and retained as a return on education or skills training. As the world progresses and the economy changes, several other niche forms of ROI are sure to be developed in the future.

6.5 What is a good ROI?

What qualifies as a "good" ROI will depend on factors such as the risk tolerance of the investor and the time required for the investment to generate a return. All else being equal, investors who are more risk-averse will likely accept lower ROIs in exchange for taking less risk. Likewise, investments that take longer to pay off will generally require a higher ROI in order to be attractive to investors.

ROI Calculation

- Time (before) to weld one joint 8 min Demand 1427 = 11416 min (190.26 Hrs)
- Time (after) to bend one tube - 2.5 min Demand 1427 => 3567.5mins (59.45 Hrs)
- Saving = 130.81 Hrs. * $ 40 = $ 5232.2
- Future Scope – $50*100 = $5,000 saving
- Total Saving- = **$5232.4 (A)**
-

Annual Operational Savings (A) = $5232.4

+

Injury Prevention Savings (1)$ 38,500

Cost of Solution (C)= $8

=

5466.84

7 . Some Ways to Reduce Ergonomic Risks

Engineering Improvements. Engineering improvements include rearranging, modifying, redesigning, or replacing tools, equipment, workstations, packaging, parts, or products. These improvements can be very effective because they may reduce or eliminate contributing factors. (For example, if your job requires sitting for long periods of time, having an adjustable seat or foot stool so that your knees are higher than your hips helps protect your lower back.)

Administrative Improvements. Administrative improvements include changing work practices or the way work is organized.

- Providing variety in jobs
- Adjusting work schedules and work pace
- Providing recovery time (i.e., muscle relaxation time)
- Modifying work practices
- Ensuring regular housekeeping and maintenance of work spaces, tools, and equipment
- Encouraging exercise Personal Protective Equipment. Safety gear, or personal protective equipment (PPE), includes gloves, knee and elbow pads, footwear, and other items that employees wear. In the whole group, small groups or pairs identify and write in specific examples of the listed ergonomic risks and possible solutions for each risk.

What makes these risk factors become a hazard for the worker(s)? Just because there is a risk factor occurring in the workers' task does not mean that it is a hazard that will produce a MSD for the worker(s). Why? Individual capabilities and combination of risk factors increase the potential for injury. Look at the same tasks (different shift, different line, different statures, men versus women, etc.) performed by many workers. Are many of the workers experiencing similar MSD from performing the same tasks? Have they missed work, had surgery or taken personal leave days. That will help identify the potential hazard(s) which can be identified to the union, to the safety committee, or to management in order to identify solutions. The workers can provide management help in identifying the root cause of the hazard(s) that is resulting in the effects (MSDs) the workers are experiencing. A common barrier is not accurately identifying the cause of the ergonomics hazard with management spending time and money without seeing reduction or elimination in the effects (the MSD injuries). Several workers providing insight on the potential cause focuses on the source of the problem and holds credibility. Management will be more apt to listen to the workers when they provide the "best" solution. If you have been working in pairs or small groups, reconvene with the whole group and share what you have come up with.

Analyzing your work station & identifying solutions

Think about your current or a previous job. While you are working do you stay in one area or move around? Do you focus on one task or do multiple tasks? How do you spend your time at work? What are the different tasks you do throughout the day? Now think about the ergonomic risk factors that we have been talking about. Can you identify one or two possible

ergonomic hazards at your job? Use the box below to list a few potential ergonomic hazards at your workplace

Now we are going to break up in to groups of 4-5 people. Each person should briefly describe their work station and mention one or two possible ergonomic hazards. The group should zero in on one hazard and come up with a list of ways to address it. Designate a note taker and report back person..

Taking Action

- You have identified some ergonomic hazards in your workplace that could harm you or your coworkers. But you are hesitant to bring it up with your supervisor or manager because you are worried about how they will react. Will you get in trouble? You are not even sure if your coworkers will go along with making changes to how things are set up and the work is organized. How can you convince your supervisor and your coworkers about the need for a change?
- First, do your homework. Does your workplace have a health and safety program in place? Is there a safety committee where you work? Have others noticed the hazard? Has it been brought to management’s attention in the past?
- Safety in numbers. Speak to co workers who are also affected by the hazard. Get them to work with you on fixing the problem.
- Think it through. What are all the possible solutions to the problem? Can you eliminate the hazard? Is there an engineering or technical fix? Are there administrative changes that will address the hazard? Would personal protective equipment do the trick? Be ready to justify your suggestions and address possible counter arguments. Be ready to address common barriers to change
- Put it in Writing. When you are ready to bring your concern to management, put down your concerns in writing. That way you can be clear and you also have a record of bringing up your concerns.

The Definition of Kaizen

Kaizen is a term that refers to on-going or continuous improvement. The definition of kaizen comes from two Japanese words: ‘kai’ meaning ‘change’ and ‘zen’ meaning ‘good’. The Japanese philosophy was first introduced by Toyota back in the 1980s and has since been adopted by thousands of companies around the globe. This lean transformation encourages an improvement culture that gradually increases quality, efficiency, and profitability.

So, what is kaizen exactly? Well, it is statistical process control that improves quality in every aspect of your business. Employees are empowered to suggest ideas that address common problems so that they don’t reoccur. By tackling issues head-on, they aren’t allowed to persist and grow into bigger challenges. This grassroots approach delivers incremental improvements that add up to big wins. This lean digital transformation has begun, saving frontline employees precious time and empowering them at the same time.

- **How Was Kaizen Developed?**

Kaizen was made famous by the Japanese car manufacturing company, Toyota. In the 1980s, Toyota led the charge in developing a business process for catching issues in production as soon as they occurred. If something wasn’t right, then the entire production line would be shut down so that staff could identify a solution. This would then be implemented so that the problem didn’t occur again. Over time, these small improvements to the Toyota production system enabled it to become one of the most efficient and reliable in the world. As other companies sought to emulate Toyota’s results, they turned to the Kaizen philosophy as a way of replicating their success.

- **What Is Kaizen Helpful For (Benefits of Kaizen)?**

The Kaizen approach is beneficial for a wide variety of business models and operational philosophies. It can improve work processes, eliminate waste, improves quality and increases the profitability of your company. Although it’s not a quick-fix, implementing Kaizen can lead to consistent and long-term growth. Let’s look at some of the ways that Kaizen can improve the workplace and overall business results.

- **Continual Improvement for Your Product & Services**

Implementing the Japanese philosophy to business results in product and service improvements. You’re able to address those tiny issues that affect product quality, leading to returns and replacement costs. As a result of quality improvements, customer satisfaction increases because they experience fewer negative issues. This enhances your brand’s reputation and results in priceless word of mouth, which leads to increases in sales volumes and revenues.

- **Delivers a Competitive Advantage**

In modern business, it can sometimes be tough to maintain a clear advantage over your competitors. If they have greater investment behind them or are more agile when it comes to innovation, you might struggle to stay ahead of the pack. But lean kaizen can give you a distinct advantage over others in your industry and establish you as the dominant leader. You can establish the root cause of how to increase productivity. By improving your quality, productivity, and efficiency, you can extend a lead that others are unable to match (no matter how much money they invest in R&D or marketing). This process improvement mindset also results in an up-skilled workforce, which creates long-term value for your company.

- **Encourages Grassroots Thinking**

Kaizen isn't a process that only affects management. It's implemented by frontline employees in the company, no matter what their role or seniority. Over time, employees begin to think in different ways about how they approach their daily tasks. It encourages staff to take the initiative and suggest improvements to how things are done, instead of feeling powerless in their roles. As these ideas are taken on board and the results come to fruition, they begin to see the value and impact of their input. This makes frontline employees more inclined to provide additional feedback that continues to benefit the company. It's common for employees at a grassroots level to understand issues more clearly than upper management because they deal with or solve them every day. This makes them better suited to finding practical solutions so it's vital to get them engaged.

- **A Culture of Continual Improvement**

Businesses that implement Kaizen usually have a highly-engaged workforce. By improving the company processes and products, they also improve the culture too. Employees are empowered to make changes and know that their opinions matter. They understand that their contributions can result in a meaningful change which helps to create a sense of fulfillment. This filters throughout the organization and results in a positive shared culture and more enjoyable place to work.

- **Avoids Information Silos**

One thing that companies often struggle with is siloed thinking. Information isn't communicated between different departments or managerial levels which leads to frustration on all sides. Breakdowns in communication can have costly results, both in terms of finances and morale. But Kaizen opens up these channels and facilitates more productive interactions between teams. People are encouraged to share ideas and suggestions so that it becomes a natural part of daily work life. This leads to greater collaboration and increased trust between departments.

- **Boosts Workplace Productivity**

Productivity is under the microscope in almost every business. When times get tough, we're encouraged to achieve bigger results with fewer resources. It can seem like an uphill battle and a constant source of pressure. But Kaizen enables you to improve productivity by increasing your efficiency. Fewer quality issues and product returns boost the overall output of the organization. Improvements in company culture and employee engagement mean that staff are naturally inclined to put more into their work. This results in the kind of productivity that can't be forced through reprimands or bought with bonuses.

- **Enhances Creativity**

Companies are often looking for more creative ways to approach challenges in business. But the very nature of creativity means there's no rule book or instructions to follow, so fostering it in the workplace can be tricky. However, the Kaizen work approach encourages staff to think creatively on a daily basis. It requires them to come up with solutions to unexpected issues as they arise and teaches them how to think outside of the box. This creates a culture of creativity where people are empowered to come up with new ideas and share them openly.

- **Improves Teamworking**

The improvements to company culture, removal of siloed thinking, and encouragement of grassroots initiative all contribute to greater teamworking. Staff are more inclined to communicate and collaborate with others as they strive to improve the company. Instead of relying on team-building days twice a year, Kaizen delivers a constant teamwork initiative that drives meaningful results. By harnessing the power of cross-functional collaboration, you’ll develop a strong and resilient workforce.

- **What Is Kaizen Going to Look Like Day-To-Day?**

Implementation of kaizen is part philosophy and part process, which can make it hard to imagine in day-to-day terms. Does it mean endless meetings? Lots of training before we can implement it? Extra paperwork and admin tasks? The good news is, implementing Kaizen doesn’t have to be complicated. It can work in harmony with your existing setup and be tailored to meet your precise needs.

The Kaizen process can be summarized down to just four steps: PDCA – Plan Do Check Act. Here’s a quick overview of what each step entails:

- ✓ Plan – define your objective and how you’ll achieve it.
- ✓ Do – implement the plan and make any changes required to ensure it works.
- ✓ Check – evaluate the results and identify opportunities for improvement.
- ✓ Act – make adjustments based on what’s found in the previous step.

By taking this PDCA approach to workplace projects, you can maximize their efficiency and improve their final outcomes. If a Kaizen event does occur, then you take immediate steps to address it and brainstorm ideas for preventing its reoccurrence. If it’s something particularly serious or resource-intensive, then a Kaizen blitz may be required.

- **How Does It Compare With Other Improvement Processes?**

You might also be wondering how the Kaizen definition compares with other continuous improvement tools. Gemba walks and the 3M’s are both popular methods for identifying ongoing improvement. So, what are the key differences and which tools are most suitable for your business needs?

Kaizen Benefits :

- ✓ **Worthy targets**

Kaizen as a method of improvement is not only beneficial to the business. It is also beneficial to employees, customers and the organization as a whole. This management theory is applicable to most types of businesses. Kaizen recognizes and rewards the efforts of employees. By so doing, it gives them a sense of worth in the organization.

- ✓ **Improved teamwork**

One of the major kaizen advantages is improved teamwork. Kaizen is a quality improvement tool driven by teamwork. It does not benefit only a selected few, but everyone involved in the business process. As the kaizen team solves problems together, they develop a bond and build team spirit. Thus, employees are able to work with a fresh perspective, an unbiased mind and without prejudice. In addition, teamwork helps build cross-functional collaborations. Since skilled workers from different departments implement kaizen, team members are able to refine their skills. Most often, the biggest opportunities for improvement lies where one process flows into another. Cross-functional collaborations enable employees with different experiences to learn from one another and solve problems together. Therefore, this one kaizen advantage is that it improves teamwork and cooperation amongst employees.

- ✓ **Kaizen builds leadership skills**

Every kaizen team must have a team leader. The team leader is responsible for organizing the kaizen team and coordinating implementation. The kaizen team leader makes sure that everyone is performing their roles successfully. The team leader is also responsible for sourcing for help when additional resources are required. Nevertheless, s/he does not have to be in a management role to qualify as a team leader. Thus, another kaizen advantage is that it presents an opportunity for employees to take on leadership roles.

- ✓ **Improved efficiency**

A major kaizen advantage is improved efficiency. Kaizen improvements boost the quality of services. It helps businesses implement new process improvements, boost efficiency and enhance time management. For example, Toyota Manufacturing Company employs kaizen in its production process. First of all, they deploy muscle-memory training to train their employees on how to assemble a car. Muscle-memory training helps them to achieve accurate results. Hence, their employees are able to work with precision.
Also, immediately an automotive plant reaches its peak in terms of efficiency, the company removes a few workers from that plant. By so doing, Toyota Manufacturing is able to minimize errors and maximize productivity.

- ✓ **Improved Standard Work Document**

Implementing changes during kaizen results to a new and improved Standard Work Document. Standard Work Document, also called standardized work, is a tool that forms the foundation of kaizen improvements. It contains the current best practice guiding a business. Sometimes, this is the main aim of implementing kaizen. In addition, Standard Work Document serves as the base for future improvements. It also serves as a tool for measuring employee performance and educating new employees about improvements. In essence, kaizen helps businesses develop a Standard Word Document.

- ✓ **Improved employee satisfaction**

Another kaizen advantage is that it improves employee satisfaction. Kaizen involves the employees when implementing changes for improvements. Employees can make suggestions and creative input for changes through a suggestion system like team meetings. When employees are involved in decision making, it gives them a sense of belonging and worth. They are eager to implement changes and think of new ways to improve the processes. By so doing, the employees are motivated and productivity increases. Also, employees are more willing to take ownership of process improvements. Rather than falling back on old methods, they become advocates of quality improvements.

- ✓ **Better safety**

Improving safety on the work floor is a kaizen advantage for business. Safety is improved when businesses implement ideas that clean up and organize workspace. By so doing, employees have better control of business process equipment. Employees are also encouraged to make suggestions to improve safety on the work floor. This helps to minimize accidents and other related injuries. Hence, employees become more efficient and manage their time properly. However, safety is a responsibility of management as well.

- ✓ **Waste reduction**

Kaizen reduces wastes in business processes. This is another major kaizen advantage. Kaizen is the responsibility of everyone. Therefore, management and staff are responsible for identifying areas that constitute waste in the business process. By implementing constant changes, they can determine the root cause of wastage and fix them. By so doing, waste is eradicated from the business process and cost is reduced. Furthermore, resources are used more judiciously, and the business becomes more profitable.

The method of continuous improvement applied in kaizen helps businesses to achieve great successes. No business grows overnight. It requires a lot of patience and hard work. This also includes recognizing areas of improvements and making necessary changes.