Ergonomics
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A. Overview of Ergonomics

1. Introduction

FLOTRON provides products that can significantly reduce the risk of the occurrence of accidents and work-related musculoskeletal disorders (MSDs). By providing mechanical assist for product positioning, the employee is exposed to significantly lower risks for excessive force, particularly while in an awkward posture. Designs that also provide a method for proper angle and height positioning minimize awkward postures of the shoulders, neck, wrists, and back. These design features reduce the occurrence of strains and sprains as well as musculoskeletal disorders associated with repetitive trauma such as carpal tunnel, tendinitis, and low back pain.

2. Definition of MSD

Musculoskeletal disorders (MSDs) are characterized by an abnormal condition of a person's muscles, tendons, tendon sheaths, nerves, bursas, blood vessels, bones, joints, or ligaments resulting in a change in structure or damaged motor or sensory function. Musculoskeletal disorders are often work-related and cost the country an estimated a half billion dollars per year.

Musculoskeletal disorders generally develop over periods of weeks, months, or even years if not treated early. Recovery may require weeks, months, or years. In some cases recovery may never be complete. The disorders are multifactorial in that they include physical, organizational, psychosocial, and sociological risk factors. Symptoms of MSDs can include swelling in the joints, limited range of motion, numbness or tingling sensations, and loss of strength.

Some examples of typical musculoskeletal disorders are, summarized from *Work Related Musculoskeletal Disorders (WMSDs): A Reference book for Prevention (1995):*

Tendon-related	Tendonitis at the shoulder, elbow, wrist, hand, or ankle; de Quervain disease (a wrist disorder)
Nerve-related	Carpal tunnel syndrome, thoracic outlet syndrome, spinal nerve root compression
Muscle-related	Tension neck syndrome
Joint (bone and cartilage)	Osteoarthritis
Circulatory or Vascular type disorders	Hypothenar hammer syndrome (a disorder of the hand)
Bursa-related	Knee bursitis

3. Work related Causes of MSDs

Two types of workplace exposure risk factors have been identified: Physical and psychosocial. Physical risks associated with the occurrence of musculoskeletal disorders are force, motion, vibration, and cold. Specific psychosocial risk factors include physical pace of work, time pressure in processing or responding to information, and low decision latitude. Usually organizational changes are required to reduce psychosocial risk factors.

FLOTRON products address reducing two of the four physical risk factors associated with workrelated musculoskeletal disorders – force and joint angle. FLOTRON accomplishes this by providing mechanical aids for adjusting the work-piece for improved human interaction.

Physical stressors of force, joint angle, vibration, and cold are typically measured using three properties of: (1) Magnitude (e.g., “how much”), (2) Repetition (e.g., “how many times”), and (3) Duration (e.g., “how long”). For example, if an employee is required to exert force while performing a task, the risk would be measured by asking the questions: (1) How much force? (2) How many times is the force exerted? (3) How long is the force exerted? Additionally, if an awkward posture is also a risk factor, the question “how much” would be answered with a measure of degrees indicating how far from an ideal posture the worker is required to be in.

The table below summarizes the risks and measurement properties.

Physical stress	Property		
	Magnitude	Repetition Rate	Duration
Force	Forceful exertions	Repeated exertions	Sustained exertions
Joint Angle	Extreme postures and motions	Repeated extreme postures and motions	Sustained postures and motions
Vibration	High vibration level	Repeated vibration exposure	Long vibration exposure
Cold	Cold temperature	Repeated cold exposure	Long cold exposure

Let's look at a healthy working posture. When working, the person wants to be allowed to work such that their body is in a neutral posture – or better stated – a low risk posture. In a low risk posture the fingers are slightly curved toward the palm of the hand, the long axis of the wrists are in line with the long axis of the forearm, the forearms are positioned such that the two palms face each other, and the back and neck are straight. There are two low risk postures for the elbow, depending upon the task: 90 degrees or 180 degrees. The upper arm should hang parallel with the spine with the elbows close to the body. Good engineering design encourages employees to use a healthy working posture when performing job duties. FLOTRON designs it's production aids to encourage healthy working postures and minimize the musculoskeletal disorder risks of posture and motion.

FLOTRON holding fixtures help employees to position assemblies so they can reduce the risk of unhealthy body postures while performing job duties. Tilt and height adjustment features are the key to controlling awkward postures of the back and shoulders. Tilt and rotation features also contribute to reducing awkward postures of the wrists and forearms.

The National Research Council and the Institute of Medicine, in 2001, summarized the research related to musculoskeletal disorders. They report that research has found a strong biomechanical relationship between risk of low back disorder reports and exposure to physical loading in the workplace and that appropriate reduction of work exposure can decrease the risk of low back disorders. FLOTRON'S products assist in reducing the risk of low back disorders by providing mechanical assists to move and position work pieces.

4. Statistics on Injuries and Illnesses

A total of 1.7 million injuries and illnesses that required recuperation away from work beyond the day of the incident were reported in private industry workplaces during 1999, according to a survey by the Bureau of Labor Statistics, US Department of Labor. (See www.bls.gov.) Of these 1.7 million, 40 thousand were associated with assembly operations. Sprains, strains, and tears accounted for the most frequent type injury and illness, accounting for 740 thousand incidents, or 2 of every 5 incidences. Most involved back injuries and illnesses. The second highest type of injury and illness, bruises and contusions, followed at only 156 thousand.

The US department of Labor also gathers statistics on the occurrence of musculoskeletal disorders, defined as an injury or disorder of the muscles, nerves, tendons, joints, cartilage, and spinal discs. These do not include disorders caused by slips, trips, falls, motor vehicle accidents, or similar accidents.

In 1999 over 582 thousand musculoskeletal disorders were reported, accounting for more than one out of three of the injuries and illnesses involving recuperation away from work. The manufacturing industry accounted for the second highest reported number of musculoskeletal disorders at 150 thousand with the median number of 8 days away from work for each incidence. Analyzed by occupation, assemblers accounted for 18 thousand of the incidences requiring recuperation away from work with a median of 9 days away from work.

The cost for each of these incidences does not only include workers' compensation costs but also the indirect costs of lost wages, lost productivity, staffing and personnel, administrative, and lowered morale. Conservative estimates of these costs range from $45 to $54 billion annually for musculoskeletal disorders reported as work related. What does it cost your company to have a key employee absent from work for eight days?

5. Cost Justification

Documented case studies for the effectiveness of ergonomics programs are provided in a Government Accounting Office (GAO) report (Report number: *GAO/HEHS-97-163, August 1997*). Of five ergonomic programs studied, all were found to save significant amounts of money. The programs were studied from approximately 1993 though 1996 with the exception of Texas Instruments which was started in 1991. Three of the programs were related to manufacturing. Here are some the impressive results for Texas Instruments (TI), AMP Incorporated (AMP), and Navistar International Transportation Corporation (Navistar):

a. Workers Compensation

All five facilities reported in the GAO report experienced a reduction in total workers' compensation costs for MSDs ranging from 91% to 35%.

Company	Reduction
TI	2.59 million down to 224 thousand (91% reduction)
AMP	73 thousand down to 28 thousand (62% reduction)
Navistar	1.39 million down to 544 thousand (61% reduction)

b. Reduction of lost Workdays

All three of the manufacturing facilities in the GAO report experienced a reduction in lost workdays.

Company	Reduction
TI	reduction of 66 days in lost workdays
AMP	reduction of 78 days in lost workdays
Navistar	reduction of 122 days in lost workdays

TI and Navistar also experienced a reduction in restricted workdays of 15 and 35 respectively. AMP had an increase in restricted workdays but accredited the increase due to their success at bringing employees back to work.

c. Average cost per MSD Worker's Compensation Claim

All three manufacturing facilities had a reduction in the average cost PER musculoskeletal claim.

Company	**Before**	**After**	**Difference**
TI	$ 21,946	$ 5,322	$ 16,624
AMP	$ 6,601	$ 2,512	$ 4,089
Navistar	$ 9,518	$ 4,860	$ 4,658

d. Reduction in Injury and Illness Incidence Rates

All three manufacturing facilities had a reduction in the rate of injury and illnesses.

Company	Reduction
TI	4.0 per 100 people
AMP	5.7 per 100 people
Navistar	6.1 per 100 people

e. Productivity

Officials at several of the facilities studied by the GAO said that as the ergonomics program evolved, goals needed to change as well, from reducing workers' compensation costs to increasing productivity and quality.

Navistar - By minimizing employees' stressful hand exertions during a windshield installation process, for example, the Navistar facility was also able to increase the quality of the installation, reducing a high rate of warranty claims.

AMP - By identifying a newly automated way of extracting remnant metals when electronic connectors are stamped they not only eliminated awkward positions for employees but also reduced the volume of scrap waste and enhanced the quality of recycled metals made from these scrap metals.

Facility officials also reported improved employee productivity, quality, and morale since implementing the ergonomics programs, although evidence of these outcomes was primarily anecdotal.

f. Quality

Another approach to justifying ergonomic improvements is with the quality of the work performed. An ideal ergonomic solution will not only increase the quality of worker output but also the speed. Sometimes, however, an equipment change may actually slow a part of the production process but, if evaluated from a quality standpoint the improvement can still be cost justified by:

- Considering the total manufacturing cycle time, i.e., reducing problems caused by poor quality early in the assembly process may reduce problems later in the assembly process.
- Higher quality will reduce the amount of rework.
- Higher quality will reduce warrantee claims.

B. Holding Fixture Ergonomics

FLOTRON holding fixtures provide a range of options for work-piece rotation as well as height adjustment. An important aspect of a fixture design is the ability to change the position of the work-piece relative to its tilt or rotation. Changing the tilt of a work-piece allows the user to more easily perform a job duty by:

- Controlling glare off the work-piece.
- Improving line-of-sight to the work-piece.
- Reducing how far or high the user needs to position their arms to access the work-piece.

It is also desirable to minimize the tendency for the user to bend their neck forward more than 15 to 20 degrees. Excessive forward flexion of the neck and torso is typical when performing fine detailed work because:

- The employee moves their head closer to the work piece to improve their vision to see the fine detail.
- The employee must view the work-piece from a particular viewing angle.
- The employee needs to use a magnifying lense or other assembly aid that requires the user to flex their neck to use the aid.

It is not uncommon in industry to use an overhead crane or forklift to turn over a large assembly. This type of procedure can be a safety problem if not done correctly and with great care. Precision rotation of the assembly can also be difficult. In every case, the safety and precision of this type of handling will be totally up to the skill and ability of the crane/forklift operator. FLOTRON highly recommends avoiding this potential problem by using the appropriate rotational holding fixture.

The correct holding fixture will provide safe, comfortable and convenient access to multiple sides of a work-piece. This is a big advantage compared to manually flipping over a work-piece on a bench or the floor. A FLOTRON holding fixture can be used to safely and conveniently achieve the best angle of tilt and best height for maximum comfort and efficiency of the user. Most FLOTRON fixtures are adjusted in height prior to loading the work-piece onto the fixture, however if needed, the hydraulic option offered on the 500 and 700 series fixtures can adjust the height while the work-piece is mounted on the fixture.

The height of the user's elbow and the height of the item being worked on have a major impact on the user's neck, shoulder, and back posture. For low force work tasks, position the user's elbow at the same height as the work-piece being worked on (including the height of the fixture, platform, or subassembly). For tasks that require more force, lower the work-piece height relative to elbow height. The work-piece should be moved higher than elbow height for fine detailed work to better accommodate visual or cognitive requirements as well as provide more arm support.

Some rules of thumb are to position working height as follows:

- Position point of operation 6 inches above elbow height for fine work like proofing documents or inspecting small parts.
- Position point of operation 4 inches above elbow height for precision work like mechanical assembly.
- Position point of operation at the same height as elbow for writing or light assembly.
- Position point of operation 4 inches below elbow height for heavy or medium work like packaging.

When working on large pieces it is likely that the working height is going to change during a work session. The employees have to work at various locations on the larger piece, often changing their working height. The recommended approach is to adjust the height of the work-piece using the standard tilt feature or the optional hydraulic risers that allow the employees to work at the appropriate elbow height throughout their work session. There is probably no more appropriate application for height-adjustable fixtures than applications that require users to work on large objects. The justification for an adjustable height fixture is even stronger when you add to the situation more than one employee using the fixture because of different elbow heights.

Prior to purchasing a rotational holding fixture with adjustable height features, it is important to determine the necessary range of adjustment given the size of the employees, the size of the product being worked on, the amount of force needed, and the tasks to be performed.

One last important ergonomic aspect of FLOTRON holding fixtures is their mobility. In many assembly and production applications, a part must be moved many times from one assembly area to another. Each time a part is removed and remounted to another fixture, the chance of part damage and injury to personnel arises. By mounting the part onto the FLOTRON holding fixture only once and then rolling the fixture with the mounted part from assembly area to

assembly area, the chance of damage or injury is greatly reduced. Usually, the total handling and assembly time is also greatly reduced, making pay back occur over a very short time. A side benefit of the mobile fixture concept is a more flexible use of floor space. As needs change, the fixtures are easily moved to new areas.

C. Extractor Ergonomics

FLOTRON PCB board extractor tools can reduce the risk of musculoskeletal disorders (MSDs), increase the size of the employee pool that can perform the task, improve job performance, and reduce employee injury. Powerful and repetitive hand and finger activities have been associated with MSDs of the hand, like carpal tunnel syndrome, tendonitis, and trigger finger. FLOTRON extractors reduce both the magnitude and type of force required by the user to remove a circuit board, which will reduce the risk of MSDs. FLOTRON'S extractor tools also expand the pool of employees that can perform the task of board removal. Concerns about an employee's upper body strength can be significantly reduced when a FLOTRON board extractor is used.

FLOTRON'S circuit board extractor tools allow the employee to use a "hand (power) grip". A "hand grip" is preferred to the "pinch grip" or a "finger push" action when excessive muscular forces must be exerted while removing a PCB board. Because the posture of an employee's upper body may not be in an ideal position when a circuit board is removed and the direction of extraction may not be the most efficient, it is even more important that the exerted force required to remove the board is generated by a "hand grip" as opposed to a "pinch grip".

Often, on non-flight aerospace hardware or many types of commercial electronic chassis, ejector levers are provided at each of the two front corners of a PCB board to ease board removal. Ejector levers, which are mounted to the board, take up board space, can add weight and size to the board and consequently are seldom used on flight hardware. However, when they are used on non-flight hardware and in conjunction with high extraction force connectors,

the high forces required to remove a board may result in high loads on the employee's two fingers that are pushing on the ejector levers.

High loads can contribute to the development of MSDs of the fingers, wrists and hands. It may also be difficult for the employee to apply equal force to both ejector levers because of the location or orientation of the board. Uneven force can cause the board to retract at an angle that will tend to make it jam. This will further increase the necessary force to remove it, possibly cause damage to the board and increase the time required to remove the board. FLOTRON'S extractor tools guide and apply the extraction force in line with the board's motion. This minimizes the tendency to jam and so minimizes the force required by the extractor and the employee. The "hand grip" action of a FLOTRON extractor effectively spreads the load over four fingers as compared to two fingers with ejectors. The lower force per finger, the higher loads attainable with a "hand grip" action and the elimination of the tendency to jam will lead to much lower chance of MSDs. It will also reduce the task time to a few seconds and reduce the risk of injury to the employee and to the board.

FLOTRON extractor tools greatly reduce the risk of injury to the fingers and hands, especially when compared to attempting to manually grasp the board or when compared to using many other styles of extractors/ejectors. One other type of extractor that is seen in industry is nothing more than a handle with two hooks. Typically the employee hooks onto the board and pulls using his/her own unaided physical arm strength. Although the force is distributed over four fingers, sometimes the force required to disengage the board from the connector is so high that when the connector releases the board the user's hand jerks back rather violently with many possible negative results including injury to the operator and/or damage to the board.

FLOTRON'S extractors greatly improve the safety of the extraction operation because they effectively control the motion of the extraction process. When using a FLOTRON extractor, the connector "pops loose" at about 0.12" of extractor stroke. Although the board releases and retracts at a high rate of speed (just as above), the extractor handle quickly bottoms out at about 0.31" of stroke, stopping the rapid motion of the released board. The user then pulls the already released board out of the chassis slots with almost no required force using a simple arm motion. Because arm strength and motion are not used to "pop loose" the connector, much better control is afforded. By "popping loose" the connector using a "hand grip" action, the person's strength is more easily applied to the extraction process. The use of a "hand grip", as opposed to a "finger grip" or "push", reduces the force exerted by the employee, thereby decreasing the risk of MSDs. Reducing the strength requirements of employees is also important considering our average workforce age continues to increase and the range of their physical capacities continues to decrease.

FLOTRON also makes two-handled extractor models to be used when an unacceptable level of extraction force is required for only one hand. The two-handled models utilize the grip force of both hands and effectively double the available extraction force. Both the single or two-handled models can be used with the left or right hands. FLOTRON also provides custom designs to meet your specific requirements.

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