Integrating Ergonomics with Process-Engineering

Josh Kerst, CPE, CIE

Humantech, Inc.

Ann Arbor, MI 48108

Take a walk around your facility, as if you were seeing it for the first time. Note how many of your production employees, technicians, and maintenance staff are bending, stretching, reaching, leaning, or pushing to perform their daily tasks. You could be looking at major health and safety threats-not to mention costly wasted time and effort. Once you see your facility through your newly acquired **ergo eyes** it is easy to understand how this working environment can either broadcast a performance-punishing or a performance–enhancing message to employees.

Health and safety professionals and process engineers can play a critical role in redefining process-based activities in terms of ergonomic acceptability. This redefinition applies to equipment “outfit” specification as well as addressing equipment “retrofit”. The primary goal of these activities is to insure that a master design plan (outfit & retrofit) includes prudently investing in equipment that will support human performance and influence health and safety, quality, and production efficiency.

In this paper, I describe a nine-step procedure that process engineers and health and safety professionals can use to positively influence the work environment. In addition, applications tools are described which can significantly help the often-elusive task of quantifying the exposure to ergonomic risk factors, which could, over time, contribute to

the development of musculo-skeletal disorders. The purpose of these efforts is to provide employees with easy-to-use ergonomic recognition skills, guidance on the evaluation of the severity of the concerns and methods to support control measures as they are identified.

Step 1 - Identify Your Opportunity

Conventional wisdom holds that productivity is elusive and that it is something that must be force-fed into people. By contrast, successful managers know that productivity is a natural byproduct of the fundamental motivation of people for self-respect and the desire to be conscientious contributors. Productivity is a natural condition, and it is not something created, however, it is something you must not hinder. It is also something you must investigate to understand where opportunities exist.

Process-based engineers and health and safety professionals have to gain the attention of managers by clearly articulating the benefits of effective ergonomics. This may involve some education on risk management, as well as collecting a little data within your company and organizing it in a way that speaks to their priorities.

The fields of health and safety and industrial hygiene are driven by the concept of risk management. The assumption of risk management is to proactively identify employees at risk and control these situations to reduce the opportunity for injury and illness. A health and safety program would never be effective if it were driven solely by consequence management. For example, it would make no sense if we waited for an employee to experience chemical burns and toxic exposure before we put personal protective equipment and fume control systems in place, we would have an injury for nearly every situation in our facility.

Still most ergonomic initiatives in the process-based environment are driven solely by consequence management. Only the work tasks that have resulted in injury or illness are targeted for ergonomic job improvements. Incorporating more data into an ergonomic risk management process as part of the total health and safety risk management program

can result in major savings for your company and more focused identification of the opportunity.

Data should include:

- Technician Feedback
- Production/Quality Bottlenecks and Barriers
- Injury/illness statistics
- Ergonomic Checklist- Ergo Action Form (see below)

One such checklist that has been used is called the Ergonomic Action Form. Employees can complete one of these forms any time they observe an ergonomic challenge. The terms used are very simple (i.e., washrag, comfort zone, butts up) and the participants write down the activity on the corresponding line of the term they observe. Space is provided on the back (not shown) to list potential corrective measures for further review.

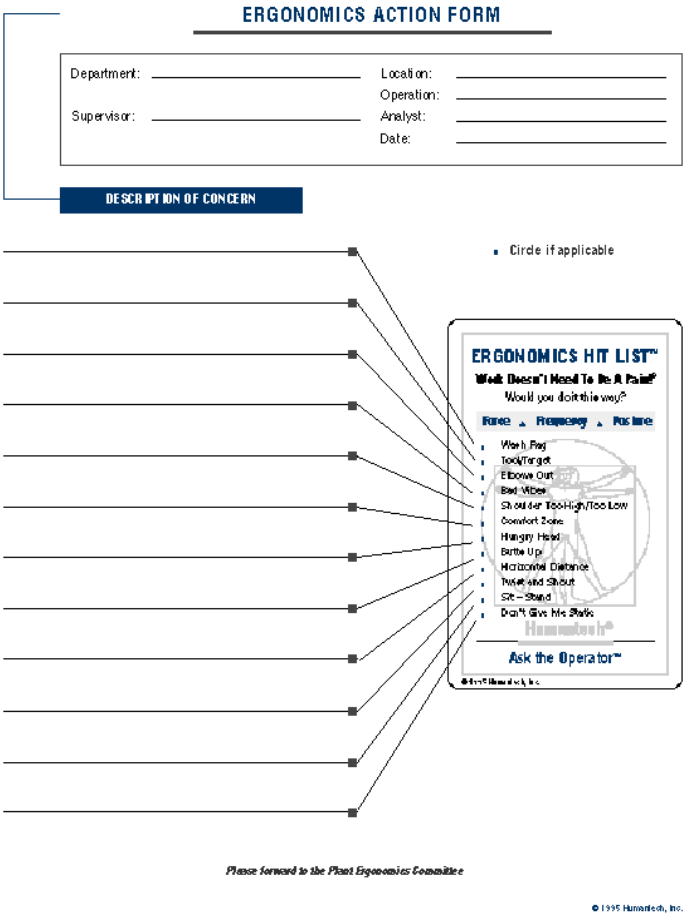


Figure 1. Ergonomic Action Form

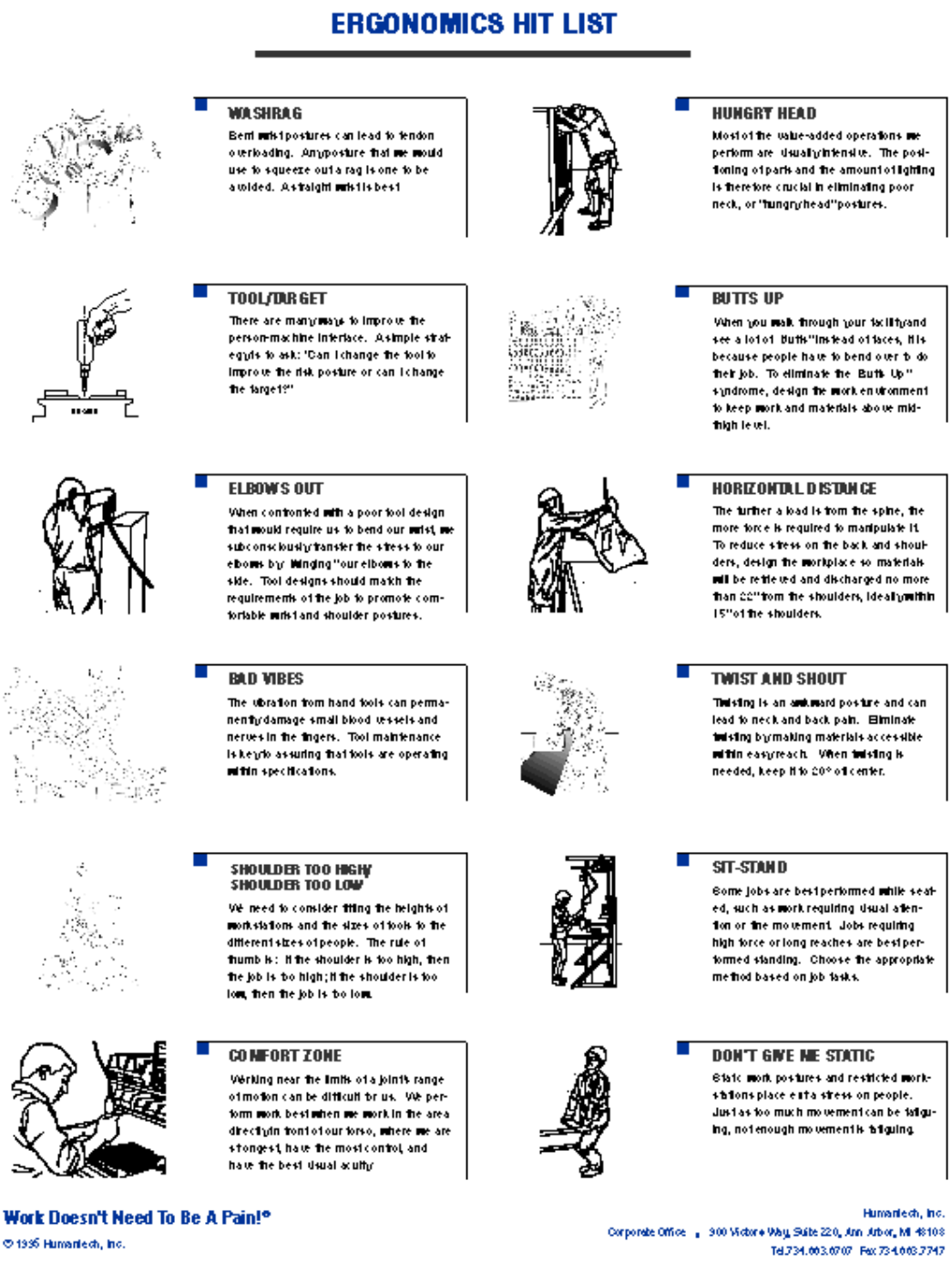


Figure 2. Ergonomic Action Form - Definitions

Step 2 - Form a Cross-Functional Team and Provide Skill-Based Training

A general understanding of where the opportunities exist should be the result of step 1. Deployment of a cross-functional ergonomics team to investigate and address these issues is the next step. Such a team could include maintenance personnel, technicians, area mangers, engineering, and health and safety personnel. It is imperative that this team consists of members who are stakeholders in the benefits of their efforts. They should be given both the education to analyze ergonomic concerns but also be enabled to do something about the issue. Priority should be given to the recruitment of maintenance staff for these teams to support the engineering improvements. They provide insight into strenuous tasks that may only be performed periodically. Maintenance can also be resourceful at addressing the issues with appropriate countermeasures using in-house resources when they have received the appropriate ergonomic training.

High-Impact Ergonomics Training

Establishing an effective ergonomic team for your company requires the focused development of applied skill sets. By definition, the term ergonomics is comprised of two parts: (1) *ergo* - meaning work, and (2) *nomics* - meaning to study. Simply put, ergonomics is the study of work. Teams for these process-based organizations should not only study work, they must study how people interact with equipment, analyzing the motions and methods used to reduce non-value added activity.

Ergonomics training programs are an investment in time and money. To optimize this investment three critical success factors are required:

1 - High impact training is applied training focused on building relevant skills for your team including evaluation of risk factors at a workstation and implementation of job improvements. The content must be directed to the relevant skills they will be asked to perform and they must practice it. These learning-by doing classes must clearly identify the desired performance objectives for the participants and give them both pre and post evaluations for confirmation of these skills.

2 - The training must be presented in simple methods and tools to deal with complex issues. The use of checklists, structured guidelines, and spreadsheet calculations provide shortcuts to identifying and measuring problems. These tools should support the team to spend more time on solving problems, thereby reducing injuries and illness and saving your company money.

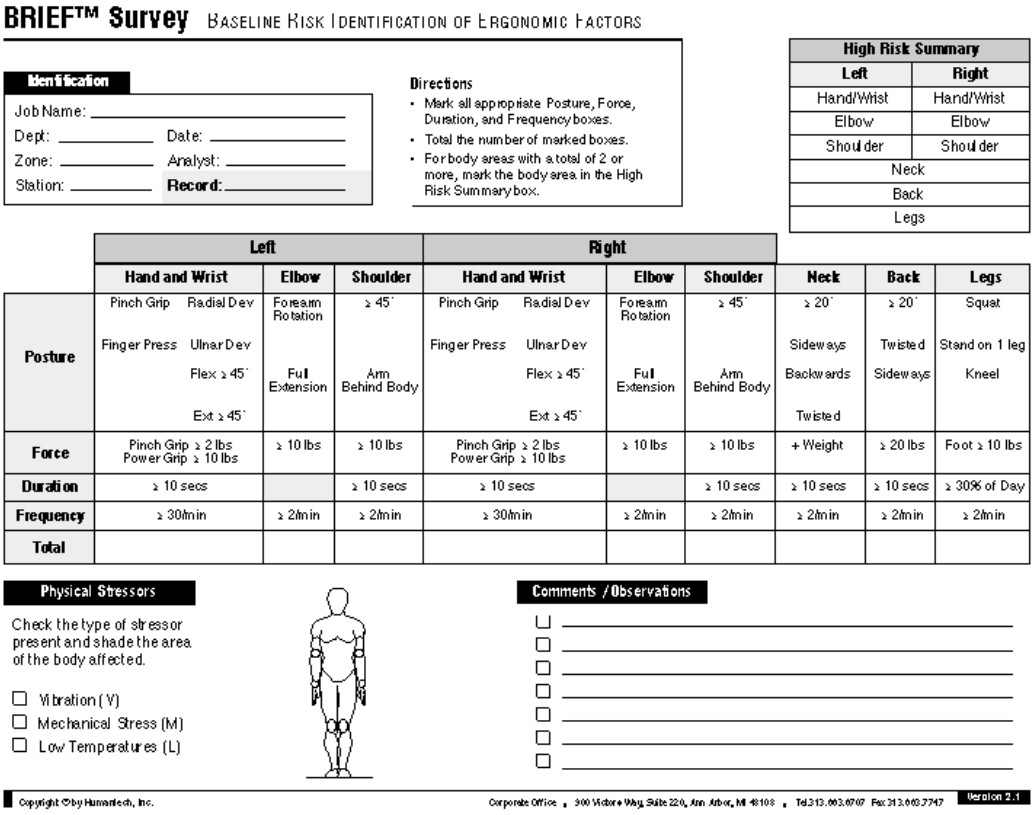
3 - Adult learning theory principles must be followed. This includes providing skill reinforcement through practice and relevant examples which are meaningful to them. Site specific case studies are a great way to get a head start on the work improvement process and lets participants use real-world experience.

Step 3 - Quantify Specific Problems within the Current Process

Armed with a need to proceed and an empowered assessment team it is now time to apply ergonomic principles and deploy quantitative assessment tools to investigate the possible human performance issues and problems to particular process-based ergonomics challenges. The task requires understanding work as defined by its baseline components. To achieve this, an objective, reproducible ergonomic assessment survey is used to quantify ergonomic risk into the following categories.

- Force - forces applied to create movement or stability.
- Frequency - repetitive or prolonged movements necessary to complete the required job tasks.
- Postures - joint angles and range of motion.
- Duration - prolonged applications of forces and posture.

The sample survey, illustrated in figure 3, is the **BRIEF**^{TM}, the Baseline Risk Identification of Ergonomic Factors produced by Humantech (Ann Arbor, MI). Using this survey, an observational approach is used to assess the postures, forces, frequency and duration of postures in the hands/wrists, elbows, shoulders, neck, back, and legs. A score is generated for each body segment from the total of confirmed risk categories. That is, one point is given for each category: posture, force, duration, and frequency with a maximum possible score of four for each body segment. A score of three points or higher indicates the body segments are deemed to be high risk.



BRIEF™ Survey BASELINE RISK IDENTIFICATION OF ERGONOMIC FACTORS

Identification

Job Name: _____

Dept: _____ Date: _____

Zone: _____ Analyst: _____

Station: _____ **Record:** _____

Directions

- Mark all appropriate Posture, Force, Duration, and Frequency boxes.
- Total the number of marked boxes.
- For body areas with a total of 2 or more, mark the body area in the High Risk Summary box.

High Risk Summary	
Left	**Right**
Hand/Wrist	Hand/Wrist
Elbow	Elbow
Shoulder	Shoulder
Neck	
Back	
Legs	

	Left			Right					
	Hand and Wrist	**Elbow**	**Shoulder**	**Hand and Wrist**	**Elbow**	**Shoulder**	**Neck**	**Back**	**Legs**
Posture	Pinch Grip Radial Dev Finger Press Ulnar Dev Flex ≥ 45˚ Ext ≥ 45˚	Forearm Rotation Full Extension	≥ 45˚ Arm Behind Body	Pinch Grip Radial Dev Finger Press Ulnar Dev Flex ≥ 45˚ Ext ≥ 45˚	Forearm Rotation Full Extension	≥ 45˚ Arm Behind Body	≥ 20˚ Sideways Backwards Twisted	≥ 20˚ Twisted Sideways	Squat Stand on 1 leg Kneel
Force	Pinch Grip ≥ 2 lbs Power Grip ≥ 10 lbs	≥ 10 lbs	≥ 10 lbs	Pinch Grip ≥ 2 lbs Power Grip ≥ 10 lbs	≥ 10 lbs	≥ 10 lbs	+ Weight	≥ 20 lbs	Foot ≥ 10 lbs
Duration	≥ 10 secs		≥ 10 secs	≥ 10 secs		≥ 10 secs	≥ 10 secs	≥ 10 secs	≥ 30% of Day
Frequency	≥ 30/min	≥ 2/min	≥ 2/min	≥ 30/min	≥ 2/min	≥ 2/min	≥ 2/min	≥ 2/min	≥ 2/min
Total									

Physical Stressors

Check the type of stressor present and shade the area of the body affected.

- ☐ Vibration (V)
- ☐ Mechanical Stress (M)
- ☐ Low Temperatures (L)

Comments / Observations

- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____

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Figure 3. Baseline Risk Identification of Ergonomic Factors

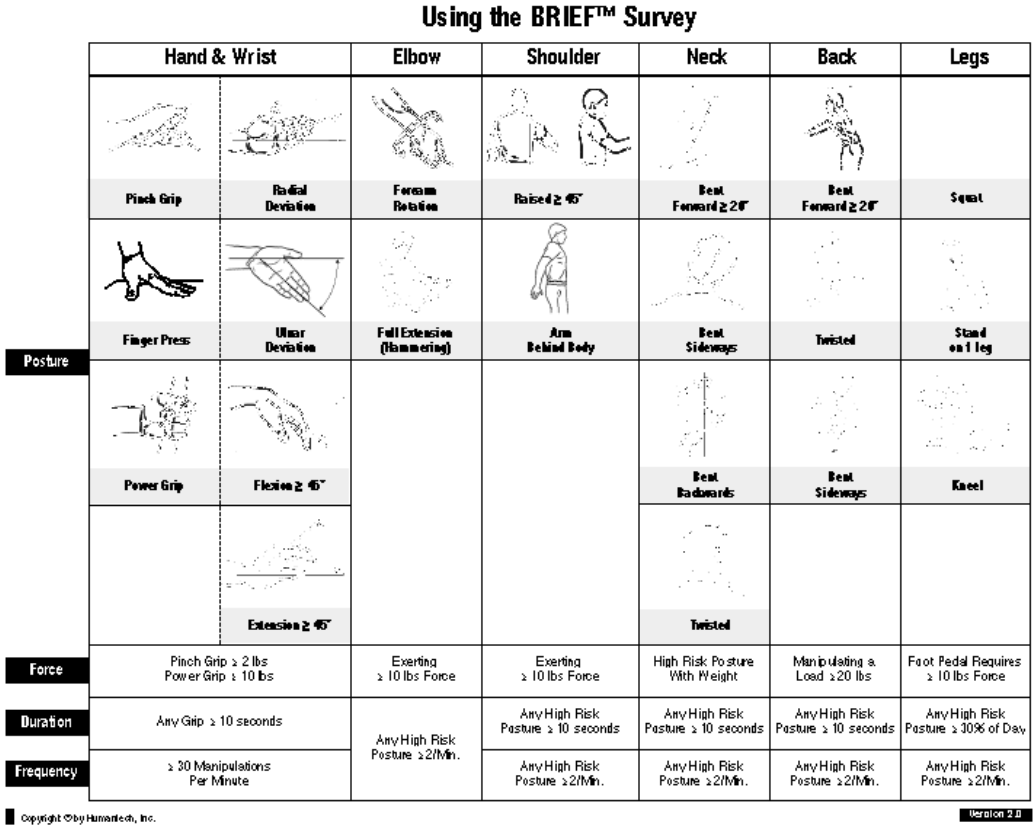

Figure 4. Baseline Risk Identification of Ergonomic Factors

This analysis is the main source for identifying point of motion constraints. These are job elements that require awkward postures and high forces. Risk areas of the body and problematic tasks can now be targeted and a baseline measure exists to track your job improvement efforts. The root cause of these outages is wasted human efforts that are poorly supported by our bodies biomechanically. Additional assessment tools such as the 1991 NIOSH Lifting Equation, Design & Build Guidelines (Humantech, 1997) can also be helpful in defining specific problems.

4 - Define Your Desired Outcomes

Once the challenges are thoroughly documented both qualitative and quantitatively it is now time for the team to agree on a project goal - is it to eliminate the identified problem or to limit employee exposure to an acceptable level? Once the goal is established, a measure for performance can be agreed upon and tracked. The assessment tools can help you drive the process by quantitative goals and outcomes that are not reliant on body count of injuries and illnesses or even discomfort. This risk management approach chronicles the mismatches between people and equipment. The more non-neutral postures observed, the more challenging the workplace and the more opportunities for improvement that exist.

Possible process engineering design goals can include:

- Designing bag handling, charging areas, valves, pump overhauls, storm water valves, and tooling to match the requirements of people, in support of good productivity and health by adhering to design and build criteria.
- Accommodating differences in strength and body size among different workers for material handling tasks such as moving pumps during overhaul and compressed gas handling. These can be analyzed using the NIOSH lifting equation to determine acceptability
- Removing barriers to productivity and human performance by focusing on the value of the work and understanding technician feedback using the BRIEF™ survey.

5 - Define Solutions to Address Root Causes

Develop a list of the solutions to the specific problems you have identified. One helpful technique to do this is by analyzing the wasted or non-value added motion that people

use. When defining waste, Henry Ford once said: “If it doesn’t add value, it’s waste.” Motions that do not add value are waste. Unfortunately, in many process-based operations, a significant portion of the time on task is non-value added. To become more efficient, we must control and minimize wasteful activities that also increase the risk of injuries. The book *The New Manufacturing Challenge* (Kiyoshi Suzaki, 1987) describes seven wastes typical to systems.

To achieve efficiency and add value, the following must be controlled.

• Overproduction
• Waiting Time for Processing
• Materials Spending Excess Time in Transit
• Unnecessary Processing
• Excess Surplus of in-process materials
• Excess Human Motion required to retrieve, place, and combine
• Product Defects & Errors

Though ergonomic intervention does not directly affect all of the identified wastes, it does facilitate reductions in transportation, motion, processing, and production defect/error wastes.

Designing the Integrated Environment

Once it is established that all functions should be value-added to meet customer needs, a major change is required in the interpretation of the physical-working environment. Factors to be considered in an effective process design include;

- Providing adequate personal access space around valves and pumps, the floor plan or footprint and its effects on value-added motion
- Workstation factors related to the support of job function, i.e., storage space, worksurface area for multi-task activities, and equipment accessibility.
- Meeting Human Factors guidelines for the design of sitting and standing work.

Design Tip #1 : Use the OHIO (Only Handle It Once) Principle

As previously mentioned, transportation waste increases the time that components spend in production systems. In many cases, transportation waste also creates ergonomic risk by introducing multiple handling of products. When facilities are not designed to support

multiple product-oriented work, material has to be moved between departments. Typically, product is loaded into containers, and a batch, or large lot size, and is delivered to the subsequent area. Upon arrival, the product is removed from the bin and processed or charged into a vessel. This sequence is repeated until the process is complete and the cycle begins. As components and containers increase in size, operators tend to subject themselves to awkward postures during handling and transportation. When multiple handling occurs, operators employ these postures more frequently, magnifying ergonomic risk. Advance determination of product flow patterns and centralized storage locations can reduce the time and effort while minimizing multiple handling. The farther items are stored from the central work area, the more time is lost. These non-value added movements also create ergonomic risks. As movement lengths increase, operators take their body joints to its full range of motion. These types of postures that stretch the musculoskeletal system to its limit increase ergonomic risk and cycle time.

Design Tip # 2: Avoid Design Amnesia & Design for a Variety of People

People often suffer amnesia when it comes time to redesign their work environment. Design amnesia is defined as replicating past performance punishing designs in new areas and refurbishment's due to lack of forethought. People often justify these situations by using such phrases as:

- This is how we have always done it
- That is our standard
- It only comes this way

• Because..... often shortened to the word ‘Cause

Through process engineering modifications, a work area can be tailored to coincide with human Anthropometry (the study of human measurements) to minimize extreme postures, improve task efficiency, and provide a safe work environment. To prevent motion waste while promoting ergonomically correct postures:

- Minimize the distances to retrieve materials and equipment.
- Store materials at heights that do not increase bending or overhead reaching.
- Position work surfaces at heights that promote neutral postures.

Design Tip # 3: Assign Work to Appropriate Height

Operator-attributed defects and errors are a sure sign that the work area design is not supporting human capabilities (Meyers, 1990). One of the greatest mis-matches in work area design comes from requiring intensive inspection and heavy work at the same work area. Heavy work requires lower working heights while visual inspection requires higher working heights. Combining the two leads to awkward body postures, reduced accuracy from fatigue, and ultimately unidentified errors. Work content should be assigned to work heights accordingly. When possible, heavy work should be avoided altogether in favor of activities more suited to human capabilities like low forces, un-programmed activity (non-repetitive), and decision-making. Whenever possible work should follow these guidelines.

Hand Heights - Ranges for Standing Work	
Precision Work	**40” to 50”**
Light Work	**35” to 45”**
Heavy Work	**29” to 39”**

Figure 5. Hand Heights for Standing Work

Step 6 - Evaluate the Solutions For Feasibility

Develop an approximate cost for the problems identified and plot it against the proposed impact. Using the existing analysis tools, define which solutions are easy to implement and which are challenging. Develop an estimate of the resource allocation to solve the problem and rank the recommendations on the basis of severity of the problem, and the cost to fix it. Best practice is to plot your recommendations on an axis of impact versus difficulty.

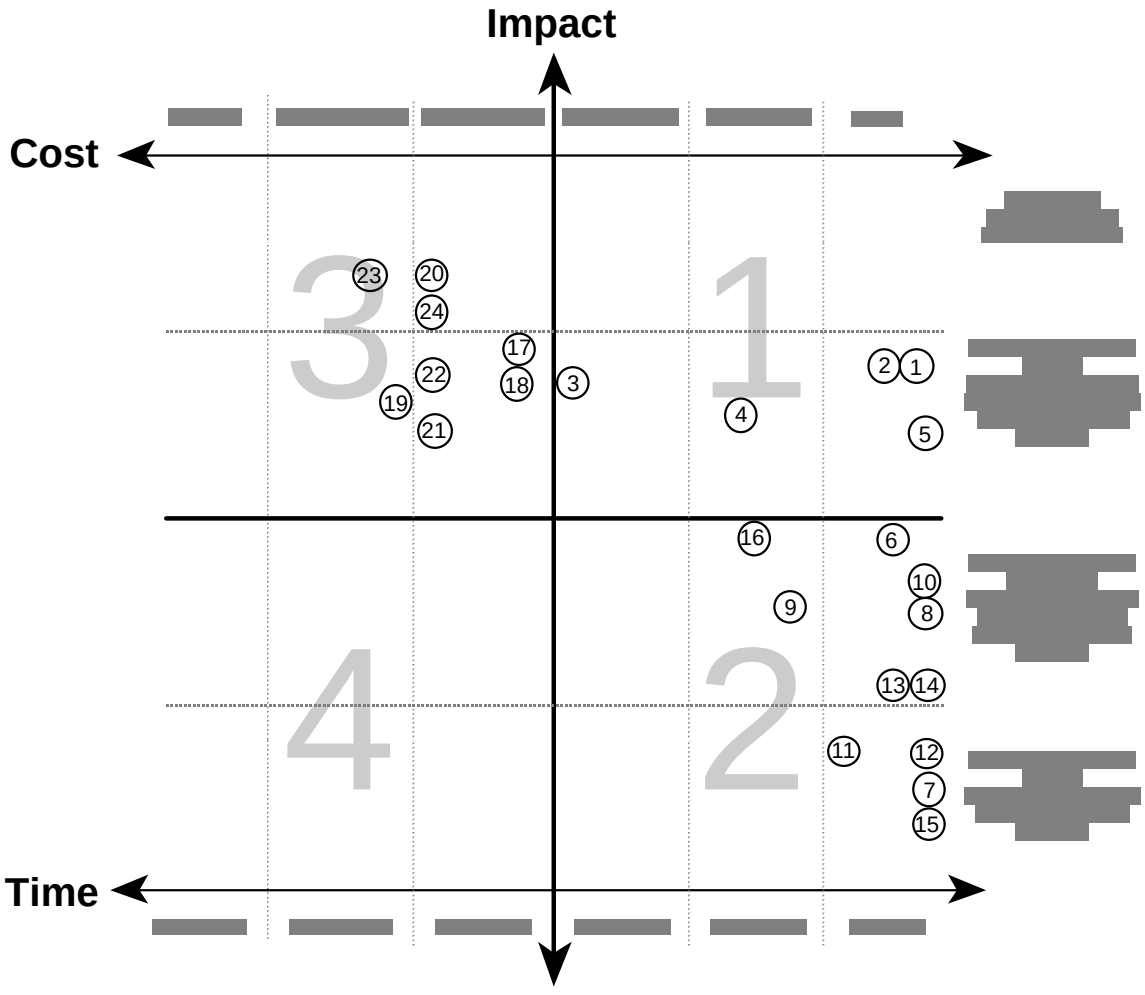

Figure 6. Sample of Impact versus Difficulty Plot of Ergonomic Countermeasures

Step 7 - Implement Solutions and Track Projects to Completion

Use existing project management systems to follow these projects through to completion. Document the process for future reference. Recommendations need to track whom, what and when. Failure to address any one of these three areas can lead to missed expectations. Integrate the improvements into new process engineering projects to avoid design amnesia.

Step 8 - Measure Progress

Track the project progress using the performance measures agreed on in Step 4. Additional measures to track are the number of job improvements completed, percentage of jobs improved, number of injuries/illnesses, and percentage of employees experiencing pain and discomfort from their job tasks.

Step 9 - Reward and Recognize

Tremendous benefits in the areas of improved employee morale, productivity gains, and improved product quality can result from the application of ergonomic principles. Recognizing the contributions of teams with public praise and appropriate rewards can maintain the momentum and keep the continuous improvement process going.

Does it work?

Redefining how and where we work sounds good, but does it work? The answer is "yes". There are hundreds of success stories from which to choose globally. One particular success story is that of a petro-chemical refinery based in the Midwest.

Substantial effort was put into developing an educated engineering and maintenance team to lead the ergonomics efforts. Members attended a two-day focused skill building course on applied ergonomics that supported the recognition, evaluation and control or work-related musculo-skeletal factors.

Teams proceeded to investigate possible issues at the refinery and gather information on possible risks. Problems were quantified and outcome goals were set before corrective measures were proposed. Recommendations were evaluated for feasibility and the selected work improvements were made. Results were communicated through the maintenance department (e.g., instead of the engineering function) using a monthly newsletter format entitled Dan's Den. Each month Dan would highlight, through digital pictures, the ergonomic issues and the improvement made. Success was shared by all that were involved and ergonomics was considered everyone's job. Over 100 improvements have been made and the overwhelming majority of these corrective actions have been handled internally by the maintenance staff with their internal resources.

Results after three years indicate that employee acceptance of ergonomics has been tremendous and the site recently received their VPP Star status on the first attempt. Personnel there indicated that they feel their ergonomic process played a significant factor in achieving this prestigious designation.

Focusing on past paradigms in the process based engineering will not help us deal with the future. Redefining our work setting and prudently investing in enhanced work environments that support human performance will help you into the next millennia. The choice is simple. Reinvent your process-based facility in terms of human interaction and you will be successful. Remain stagnant, and you will remain behind.

Author Biography

JOSH KERST, B.S.E. CPE, CIE

Josh Kerst is a Vice President and Ergonomics Engineer for Humantech, Inc. of Ann Arbor, Michigan. He has performed ergonomic risk assessments, training classes, and productivity/ergonomics analyses in the pharmaceutical, petro-chemical, electronics, health care, consumer products, automotive and steel industries.

Josh received his B.S.E. degree in Industrial and Operations Engineering from the University of Michigan and worked as an assistant research scientist with the University of Michigan Transportation Research Institute (UMTRI). He has over 10 years experience in the field of occupational ergonomics and is a member of the Human Factors Association of Canada (HFAC).

Josh has worked closely with new product/facility design teams. He has helped develop new laboratory designs, chemical handling systems, waste/recycling collection vehicles, petroleum transportation tankers, and new car development.

Josh has gained professional recognition as a Board Certified Professional Ergonomist (CPE) and a Certified Industrial Ergonomist (CIE). Josh also serves on the ANSI Z.245-4 ergonomics committee for solid waste handling.

Humantech is a full service ergonomics consulting firm specializing in optimizing human performance since 1979.
900 Victors Way - Suite 220
Ann Arbor, MI 48108
(734) 663-6707

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