Developing and Implementing an Ergonomic Audit for Manufacturing

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The purpose of this paper is to develop and implement an ergonomic audit for use in a manufacturing environment. With the emergence of ergonomic-related disorders such as Cumulative Trauma Disorders (CTD) that include Carpel Tunnel Syndrome (CTS), Tendonitis, and Tension Neck Syndrome, appearing as a result of work activities, it is necessary for companies to consider any number of different methods to assist in preventing these disorders from occurring. 1 One method to help a company in reaching this goal is to develop and implement an audit specifically focused on ergonomic issues in the workplace.

An audit is defined by the American Society for Quality (ASQ) organization as "a planned, independent, and documented assessment to determine whether agreed-upon requirements are being met." 2 Put simply, it is a method for double-checking whether a company or its departments are following the procedures correctly. It is but one tool that a company can use to check for effectiveness – in this case, ergonomics within the workplace. A number of other tools exist for purposes related to ergonomic analysis and are listed in Appendix I. Suffice to say, an organization can help their workforce and also positively impact their bottom line by implementing any combination of these tools within their ergonomics program.

Concerning the topic of costs, an audit makes an impact in this fashion – it can be viewed as preventative in nature and with the time and effort spent early in the process, it can help identify problems while promoting problem assessment before they become severe. As seen in Appendix II, the dollars saved by investing in preventative activities such as education, audits, and exercises can be enormous in terms of reducing if not eliminating ergonomic injuries. As one recent report by the State of California indicated, the impact of ergonomic injuries to workers in California was conservatively estimated at $4 billion dollars and covering a third of all workplace injuries. 3

Where does one begin in establishing an audit for ergonomics? Especially for a company that does not have an established program for ergonomics, the minimum that a company can start is by reviewing existing injuries from the workplace. Either the OSHA log or any documented record that a company has on injuries will suffice – no injury should be dismissed as even near-miss accidents could be caused by an ergonomics-related situation. For a manufacturing company, the next item would be to separate the injuries into categories: office versus manufacturing floor, light work (inspection) versus heavy work (material handling), departments, body parts. Whichever category or categories are used to differentiate the injuries is acceptable as long as the company realizes it must be useful and meaningful. See Appendix III for one example of how this categorization is done. In this example, the Pareto Principle was applied (ie-

1 Kroemer, Karl H.E. (1997). Ergonomic Design of Material Handling Systems. Boca Raton: CRC Press LLC – Lewis Publishers. Table 2-2, pg. 15-17 and Table 2-3, pg. 23-24.
Cumulative Trauma Disorders in the Workplace Bibliography, Sep, 1995, retrieved on June 28, 2003, from http://www.cdc.gov/niosh/95-119.html, section on Management of Upper Extremity Cumulative Trauma Disorders, Table 1, pg.119.

2 Russell, J.P. editor (2000). The Quality Audit Handbook: Principles, Implementation, and Use (2nd ed). Milwaukee: ASQ Quality Press, pg. xxvi.

3 Ergonomic Injuries in California report dated March 31, 2001, retrieved on July 21, 2003, from http://www.house.gov/reform/min/pdfs/pdf_inves/_pdf_work_ca_rep.pdf, pg.i.

prioritizing the highest incidence of injuries) to determine where the company should focus their attention. In this case, strains were the major problem area since they comprised over 66% of the total injuries incurred at the workplace. In addition, attaching a dollar figure is meaningful to determine if the largest incidence of injuries also happens to be the costliest. In some situations, this may not happen so it is helpful to apply cost figures to check this correlation. For another example using the Pareto Principle, there is a report generated by the University of Maryland on OSHA statistics indicating the breakdown by injury condition and the associated insurance cost in reference to CTD's. 4

Here are a number of different work environments that the author has been exposed to over the years: extrusion and casting plant, a microelectronics facility, a mechanical and electrical assembly operation, packaging for a specialty clothing manufacturer, and screen printing operations. In each of these facilities, there were situations that exposed the employee to ergonomic-related problems (see Appendix IV). Here is a breakdown of common work areas within any manufacturing environment:

1) Office Administration/Computer Workstations
2) Quality Assurance Laboratory
3) Manufacturing/Production Floor
4) Inventory/Material Handling
5) Facilities/Maintenance

Here are groupings of areas that are common within a manufacturing facility and that have potential ergonomic impact to the employee: 5

1) Workstation design affected by such factors as reach, sitting, standing
2) Material Handling concerns such as lifting, carrying, and pulling/pushing
3) Sound issues such as noise and vibration
4) Illumination such as proper lighting
5) Climate such as temperature and air flow
6) Controls on machinery and equipment
7) Visual Information in text, signs, and labels
8) Chemical exposure and proper protective equipment availability

There cannot be one audit checklist that covers all situations so it is the goal of this report to identify the common areas and to build a checklist that can be used as a generic template. One can tailor this checklist to be more specific once it has been identified what type of industry this manufacturing facility exists and what type of priority problems they are faced with concerning ergonomic issues. This can be viewed as an entry level audit checklist for most companies who may not have such a list to begin with. Let us examine each of these key areas.

Workstation design includes a number of different items such as posture, sitting/standing, and hand/arm situations. Based on the US Army study conducted back in 1988 on service personnel, one can surmise that people come in different shapes

4 University of Maryland report on OSHA Statistics, retrieved on July 22, 2003, from http:///www.inform.umd.edu/CampusInfo/Departments/EnvirSafety/os/erg/stats/html

5 Dul, Jan & Weerdmeester, Bernard (2001). Ergonomics for Beginners: A Quick Reference Guide (2nd ed). London: Taylor & Francis. pg. 126-132.

and sizes. 6 There is no efficiency gained by designing for the "average person" because that person does not exist. The key before starting is to retrieve an ample amount of anthropometric data on characteristics that apply to the task at hand. For example, in reviewing a computer workstation design, either in an office setting or on the manufacturing floor, here are data that need to be collected:

a) Heights: stature, eye height, elbow height, thigh height (sitting), knee height (sitting), popliteal height (sitting), shoulder
b) Depths: forward reach, buttock-knee distance, buttock-popliteal distance
c) Breadths: forearm-forearm breadth
d) Hand Dimensions: hand length

Obviously, one workstation may not work for all personnel, especially if shared by many users. By retrieving the appropriate anthropometric data, a Human Factors Engineering (HFE) professional can determine what range of people to design for (ie-5th, 50th, 95th percentile). Included as part of this design is selecting the proper chair to use. Such ergonomic problems to avoid if the design has been properly managed are tendonitis, carpel tunnel syndrome, and stiff neck syndrome. Keys in the design criteria is keep the employee in a natural posture as well as put their limbs in neutral positions to avoid or reduce strains.

Material handling includes lifting, carrying, and pulling/pushing. This activity is a fairly broad region that can cover small and light items as well as large and heavy items. It could involve office personnel as well as manufacturing operators. Even in today's business climate that relies heavily on computer use and online transactions, many organizations still have a need to have material or information physically moved from one location to another. The key for a company is to find accessories like a lift, dolley, cart, or conveyor that can help assist on the movement of the item where applicable. In addition, design criteria such as using the NIOSH lifting equation to determine maximum allowable loads, incorporating suitable handles where necessary, and following proper lifting techniques can assist in reducing ergonomic risk to the employee.

Sound includes noise and vibration. Noise is certainly applicable to an environment that has many machines and equipment running. Is the threshold of 80 decibels exceeded at any time? Is machinery sound-proofed to reduce the noise? Is machine maintenance followed in a routine fashion to help reduce noise and vibration concerns? A key is to reduce exposure if design or process changes cannot eliminate the noise or vibration.

Illumination is a broad but an important area. This basically focuses on these questions: how much light is the workstation receiving? And is it adequate?

Climate covers environmental issues such as adequate temperature and proper air flow. Especially for workplaces that require a temperature-controlled cleanroom environment, having the proper temperature and air flow is important for the manufacturing process, product, and the employees who have to work in those conditions. Additional factors such as wearing cleanroom clothing only makes the challenges more difficult to maintain a balanced atmospheric condition to work in.

Controls refer to machinery and equipment. Almost all machinery and equipment have controls on their panels that need operator interface to allow them to

6 Kroemer, Karl, Kroemer, Henrike & Kroemer-Elbert, Katrin (2001). Ergonomics: How to Design for Ease and Efficiency (2nd ed). New Jersey: Prentice-Hall, Inc. Table 1-3, pg. 27

run or stop. Proper layout, sizing, and coding to avoid mix-ups are key factors to consider in the design review.

Visual information concerns text, sign, and label information. This is usually an understated area of concern for many companies. However, when one considers that visual writing in the form of text, signs, or labels is usually the primary means of communication, it is one area that needs more attention. Having the proper character sizing, emphasis, and legibility are important considerations for improved readability.

Chemical refers to having the proper information about the chemicals that many companies invariably deal with in their processes, even for simple items such as glue and cleaning solutions. The situation becomes complicated when more complex chemicals are used in the manufacturing process. In addition, proper storage and spill containment of these chemicals present challenges for the company in addition to material handling.

Remember, the focus should be on jobs and activities, not departments. Other methods, in addition to audits, are surveys, job evaluation, and job surveillance. Surveys given to employees can help provide another way to receive information about the job and if there are any pains and aches to report. Job evaluation should be conducted prior to starting any work to review the procedures and loads on an employee. Job surveillance is needed by the HFE professional to verify whether the job is going according to plan or whether there are any hidden problems that were not uncovered during the initial job evaluation.

The purpose in developing and implementing an audit checklist is to focus attention to the areas of ergonomic risk. The ones mentioned in this audit checklist are commonly found in many companies regardless of industry. It is not the intent of the author to suggest one checklist can cover all situations. One can refine this checklist to include more detailed questions about particularly areas where necessary. One does not wait to have a car accident to check your brakes. Or do you? If a company can perform this audit at a reasonable interval as suited to the business conditions (a minimum of one audit per month to get the program started is a suggestion while allowing time for corrective action and activities), a company can certainly move forward in preventing serious ergonomic injuries from occurring. A proactive company pursues vehicles like an audit checklist to supplement other activities like education, job analysis, and exercises as well as surveys, job evaluation, and job surveillance to help maintain the health and safety of the employee at an acceptable level while on the job. Or as one top executive puts it "…the cost of preventing problems is cheaper than correcting them" and "I want the plant managers to open up their plants to audits so that we can find the problem and fix it internally."7 Ultimately, this will be borne out in an employee's satisfaction as well as reduced medical and insurance costs to the company when an ergonomic stability level is maintained on the job.

7 Johnson, Dave, Siddiqi, Shahla & McClure, Jennifer Sr. (2000, May 11). Living in a World beyond OSHA, retrieved on July 22, 2003, from http://www.ishn.com/CDA/ArticleInformation/features/BNP_Features_Item/0,2162,2807,00.html

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http:///www.inform.umd.edu/CampusInfo/Departments/EnvirSafety/os/erg/stats/html

Appendix I

There are many ways to view ergonomic-related situations that occur in the workplace. Audits are certainly one method to check and review how processes are running in relationship to their impacts to the employees but it is certainly not the only tool available to the Human Factors Engineering (HFE) professional. Here is another way of viewing ergonomics from the perspective of Dr. Joseph Juran, who helped pioneer the area of costing as it relates to quality. Borrowing his template, ergonomics can be broken down into these main headings: Prevention, Appraisal, Internal Failure, and External Failure as it relates to the employee and the ergonomic situations at the workplace. Taking it a step further, one can view prevention and appraisal events as "proactive" activities with a focus on getting ahead on reducing potential ergonomic risks to the employee. On the other hand, internal and external failure events are viewed as "reactive" activities to ergonomic situations that have already occurred to the employee. These events differ in that external failure is the most severe situation where, for example, one requires surgery when all other remedies or treatments have proven to be unsatisfactory.

Proactive	**Reactive**
Prevention	Internal Failure
Education/Training Surveys/Questionnaires Audits Exercises Review of Statistics Job Analysis	OSHA log Medical treatment Rehabilitative treatment
Appraisal	External Failure
Medical Exams Complaints – document & follow-up Anthropometric dimensions Job Evaluation	Medical treatment that requires surgery Worker's compensation claim Employee released due to injuries

Juran, J.M. & Gryna, Frank M. (1980). Quality Planning and Analysis: From Product Development through Use. New York: McGraw-Hill, Inc., pg. 14-16.

Campanella, Jack (1999). Principles of Quality Costs: Principles, Implementation, and Use (3rd ed). Milwaukee: ASQ Quality Press Books, pg. 188-189.

Appendix II

$	$	$
Most costly	Less costly	Least costly
External failure	Appraisal, internal failure	Prevention
The employee requires surgery due to lack of progress from other methods	The employee has problem diagnosed and receives medical and rehab treatment	Education, training, and exercises help prevent any injury

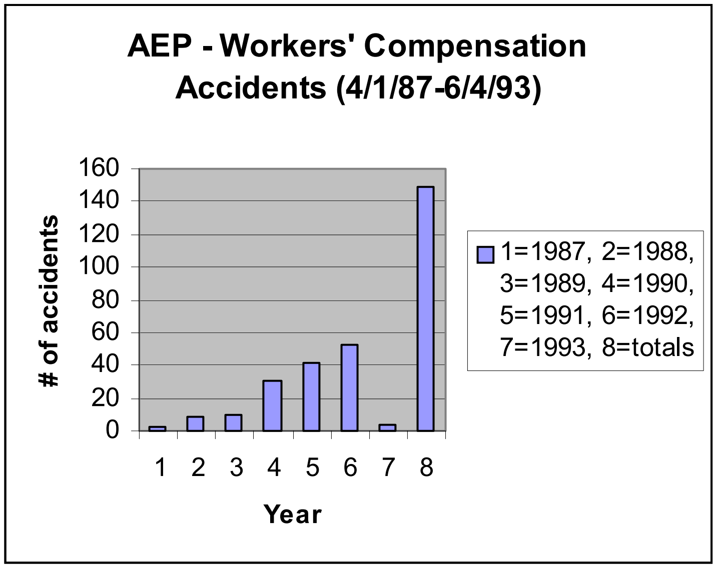
Adapted from Campanella, Jack (1999). Principles of Quality Costs: Principles, Implementation, and Use (3rd ed). Milwaukee: ASQ Quality Press Books, pg. 8, Fig.1.3 – comparative cost of quality.

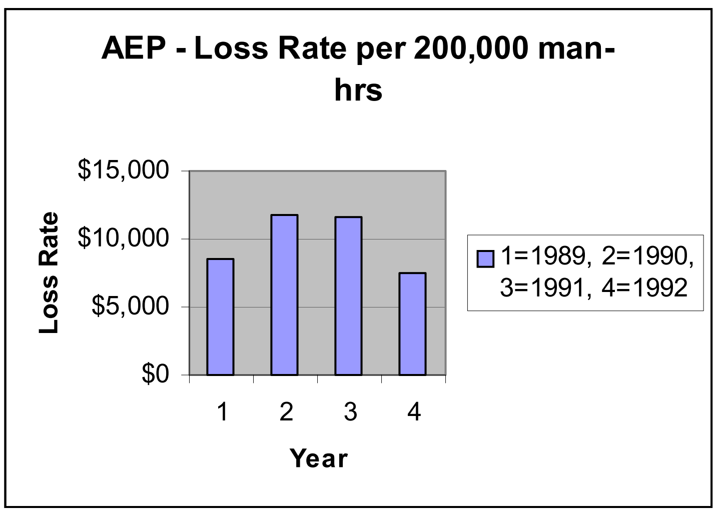
Appendix III

Alcoa Electronic Packaging, Inc. (AEP) in San Diego: Loss History from 1987 – 1993

1) About 150 accidents sustained over a six-year period.
2) Accident frequency & costs are growing at a steady rate during the six-year period.
3) Over 80% of the frequency & costs occurred during the last three years.
4) Per 200,000 man-hours (four years), the frequency of accidents is increasing but the loss rate remains the same during a four-year period.
5) 69 of the accidents were strain injuries (46%) and most occurred during the last three years.
6) 66% of the insurable costs (strains):
   a) Back Strains: 39 cases (26%); 36% of cost
   b) Upper Extremities: 15 cases (10%); 10% of cost
   c) Shoulder Strains: 9 cases (6%); 2% of cost
   d) Neck Strain: 1 case (1%); 14% of cost
   e) Lower Extremities: 5 cases (3%); 4% of cost
7) Over 80% of the strain injuries were sustained in the following departments:
   a) Greenline
   b) Punching
   c) Final Inspection
   d) Brazing
   e) Firing
   f) Plating
   g) Blanking (happens to be one of the departments that reported to the author at the time he was managing for AEP)

The following two charts show in graphical form what these numbers indicate: that there was a rise in strain injuries as a result of ergonomic issues and that medical costs, though dropping slightly, were still high.





Statistics and charts were reproduced from a company-sponsored ergonomics training seminar conducted by AEP and Liberty Mutual Insurance from June 29 through July 1, 1993 when the author was an employee of Alcoa. This plant was shut down in March, 1996.

Appendix IV

Various work experiences by author in relationship to ergonomic concerns –

Type of business	Job title	Key job duties	Ergonomic issues
Aluminum mfg'r - extrusions, drawn tube, cast plate	Industrial Engineer	Cost improvement Quality teams Time Studies Methods Analysis	Material handling Workstation design Sound Illumination Climate
Ceramic board mfg'r for electronics (cleanroom)	Sector Manager	Manage production processes and labor	Workstation design Material handling Illumination Climate Controls Visual information Chemical
Mechanical & electrical assembly of vending machines	Plant Manager	Manage assembly processes and labor, safety, facilities, and transportation	Workstation design Material handling Sound
Specialty clothing mfg'r	Packaging Manager	Manage packaging processes and labor	Material handling Workstation design
Electronic board mfg'r (cleanroom)	Production Manager	Manage production processes and labor	Workstation design Material handling Climate Chemical
	Production Planner/Scheduler	Planning using PC (SAP system)	Illumination Visual information

Appendix V

See attached Excel spreadsheet for a copy of the Ergonomic Audit Checklist (4 pages plus a back page).

Questions are grouped into the general areas common to a workplace for any industry. In addition, the rating scale is simple – answer with a “yes”, “no” or “n/a” plus there is a back page to be used for additional commentary if needed. The reason for this system, rather than using a Likert-point scale, is that this audit is intended for companies who do not have an existing audit program. It is quite possible that they may not have a safety audit as well as possibly a very scaled back EHS (Environmental, Health & Safety) department. Many small companies encountered by the author have limited resources and it is intended that this audit may help those companies that fit this description. For those companies with more resources available, a more detailed and sophisticated audit may be in order. Still, this audit can be used as a template to build that advanced form.

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Dul, Jan & Weerdmeester, Bernard (2001). Ergonomics for Beginners: A Quick Reference Guide (2nd ed). London: Taylor & Francis. pg. 126-132

Appendix VI

Here are some useful equations and guidelines to follow in reference to the audit sections:

1) Workstation Design: use 1988 US Army Survey of Service Personnel for anthropometric data 1

2) Material Handling: NIOSH Equation for calculating the recommended weight limit (RWL)

   RWL = LC x HM x VM x DM x AM x FM x CM 2

   Where: LC = Load Constant of 23 kg (51 lbs) and where each multiplier can assume a value between 0 and 1.

   HM = Horizontal Multiplier: H is the horizontal location (distance) of the hands from the midpoint between the ankles at the start and end points of the lift.
   VM = Vertical Multiplier: V is the vertical location (height) of the hands above the floor at the start of and end points of the lift.
   DM = Distance Multiplier: D is the vertical travel distance from the start to the end points of the lift.
   AM = Asymmetry Multiplier: A is the angle of asymmetry, ie – the angular displacement of the load from the medial (midsagittal plane) which forces the operator to twist the body. It is measured at the start and end points of the lift, projected onto the floor.
   FM = Frequency Multiplier: F is the frequency rate of lifting, expressed in lifts per minutes. It depends on the duration of the lifting task.
   CM = Coupling Multiplier: C indicates the quality of coupling between hand and load.

Proper Lifting Guidelines to follow:
a) Design manual lifting (and lowering) out of the task and workplace.
b) Be in good physical shape.
c) Think before acting.
d) Get a good grip on the load.
e) Get the load close to the body.
f) Involve primarily straightening of the legs in lifting.

Things to avoid:
a) Do not twist the back or bend sideways.
b) Do not lift or lower awkwardly.
c) Do not hesitate to get help, either mechanical or from another person.
d) Do not lift or lower with arms extended.
e) Do not continue heaving when the load is too heavy. 3

3) Sound: Noise measured in decibels (dB). Some examples of categories of sound intensity levels 4
   a) Deafening: 120 dBA, for example, jet engine, explosion, thunder, riveter
   b) Very loud: 100 dBA busy street, duplicating machine, mfg
   c) Loud: 80 dBA street activities, typewriting
   d) Moderate: 60 dBA conversation, radio, air conditioning
   e) Faint: 40 dBA soft background music at home
   f) Quiet: 20 dBA whisper in a soundproof room

   Audible noise greater than 85 dBA or greater is hazardous. Some preventative strategies to consider in countering the effects of noise: 5
   a) Avoid generation
   b) Impede transmission
   c) Leave the area

   Also, having adequate protective hearing devices such as sound-isolating helmets, caps, or plugs can be useful towards reducing the harmful effects of noise.

4) Illumination: three important design factors to consider 6
   a) Illumination: is the amount of the lighting falling on a surface.
   b) Luminance: is the amount of light reflected or emitted from a surface.
   c) Luminous contrast ratio: describes the difference between the luminance values of the adjacent areas, assuming that there is a defined boundary between them.

   Some guidelines to follow: 7
   a) Select a light intensity of 10-200 lux for orientation tasks
   b) Select a light intensity of 200-800 lux for normal activities
   c) Select a light intensity of 800-3000 lux for special applications

   Examples of luminance ratios and its effect on perception: 8

1 -	none
3 -	moderate
10 -	high
30 -	too high
100 -	far too high
300 -	extremely unpleasant

5) Climate: guidelines to use for acceptable air temperature ranges for tasks requiring different levels of physical effort 9
   a) Seated, thinking task 18-24 degree C
   b) Seated, light manual task 16-22
   c) Standing, light manual task 15-21
   d) Standing, heavy manual task 14-20
   e) Heavy work 13-19

6) Controls: some guidelines to consider 10
   a) Make controls distinguishable by touch
   b) Avoid unintentional operation
   c) Controls should be placed well within reach
   d) Think carefully before using labels and symbols
   e) Limit the use of color

7) Visual Information: some guidelines to consider 11
   a) Do not use text consisting entirely of capitals
   b) Do not justify text by inserting blank space
   c) Use a familiar typeface (like sans serif)
   d) Avoid confusion between similar characters
   e) Make sure that the characters are properly sized
   f) The longer the line, the greater the required line spacing
   g) Good contrast contributes to legibility

8) Chemical: the Threshold Limit Value (TLV) is an 8-hour weighted average concentration and should not be exceeded in any single day. 12

1 Kroemer, Karl, Kroemer, Henrike & Kroemer-Elbert, Katrin (2001). Ergonomics: How to Design for Ease and Efficiency (2nd ed). New Jersey: Prentice-Hall, Inc., pg. 27

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12 Dul, Jan & Weerdmeester, Bernard (2001). Ergonomics for Beginners: A Quick Reference Guide (2nd ed). London: Taylor & Francis, pg. 92