EVALUATION OF ERGONOMICS IN A BASE METAL REFINERY

MIRANDA RECHINAH MELK

BSC HONOURS: PHYSIOLOGY

DISSERTATION SUBMITTED IN PARTIAL FULLFILMENT OF THE REQUIREMENTS FOR MSC IN OCCUPATIONAL HYGIENE IN THE DEPARTMENT OF PHYSIOLOGY AT NORTH WEST UNIVERSITY

SUPERVISOR: MR M.N. VAN AARDE

POTCHEFSTROOM
2005

TABLE OF CONTENTS

Page no

CHAPTER 1

CHAPTER 3

CHAPTER 4

RESULTS

CHAPTER 5

CHAPTER 6

LIST OF TABLES

APPENDICES

ANNEXURES

HOOFSTUK 1

OPSOMMING

Die doel van die studie was om die ergonomika van 'n Basis Metal Rafineeraanleg (BMR) te evalueer. Die hipotese wat getoets is, was dat die masjienerie en toerusting wat gebruik word, die liggaamsposisies van die werkers inneem, asook die ladings wat hanteer word nie voldoen aan ergonomiese standaarde en praktyk nie.

Antropometriese opnames is gemaak van 111 werkers inaggenome die lading wat hulle hanteer het en die ligaamsposisies wat hulle ingeneem het terwyl hulle hul werk uitgevoer het op werksbanke van verskeie hoogtes. Vraelyste is deur al die werkers voltooi om te bepaal hoe hulle voel oor hulle werksopset en werksomgewing. Die waargenome data is vasgelê om gebruik te word om te bepaal hoe die werk uitgevoer was Die antropometriese data wat geneem is sluit die volgende in: houding, gewig, vertikale reikafstand, voorwaartse reikafstand, skouer reiklengte en skouerhoogte/heuphoogte. Verskeie ander veranderlikes is ook gemeet waaronder die volgende: hoogte van werksbanke, gewig wat hanteer is, soort werk wat verrig is en die tussenposes van hantering. Mediese verslae en onveilige werksvoorvalle verslae is ook deursoek om vas te stel of hierdie verslae die hipotese ondersteun.

Die meerderheid van die werksbanke was nie ergonomies korrek ontwerp nie en die werk is uitgevoer in 'n staande posisie wat herhaal is vir die meerderheid van die werkskofte. Die antropometriese opnames wat versamel is, is gebruik om te vergelyk of die werk deur die werkers uitgevoer asook die werksbankontwerp, by die werkers aangepas is. Die werkers in die BMR is blootgestel aan die hantering van swaarder ladings as die 23 kg wat aanbeveel word deur NIOSH. Die werk is hoogs herhalend van aard en die werkers moes op 'n ongemaklike wyse buig om die werk te doen. Dit is onversoenbaar met die hipotese wat konstateer dat masjienerie en toerusting wat gebruik word en die liggaamshouding van werkers asook die ladings deur hulle hanteer nie voldoen aan goeie ergonomiese standaarde en praktyk nie.

Hierdie verklaring is ook ondersteun deur die mediese en onveilige werksvoorvalle verslae wat aandui dat meeste werkers vir lang tye afgelê word as gevolg van pyn in die lae rug. Ook was daar meer voorvalle ten opsigte van die hantering van swaar ladings as ander onveilige werksvoorvalle. By die BMR kom die meeste onveilige werksvoorvalle, ongelukke en siekgevalle voor onder "cell" werkers as enige van die ander beroepe in die BMR industrie. Die hoë getal onveilige werksvoorvalle en afwesigheid as gevolg van rugpyn kan direk toegeskryf word aan die soort werk wat uitgevoer word en die gewig van die ladings wat hanteer word.

Die oorgrote meerderheid van die werksbanke is te hoog of te laag wat die werkers forseer om sy/haar rug of nek te buig om sodoende die werkstuk behoorlik waar te neem. Dit bewys dat die BMR nie die werksplek ontwerp het om aan te pas by die werker, die wyse waarop die werk uitgevoer word, die liggaamshouding wat die werker inneem, die herhalende aard van die werk en die gewig wat hanteer moet word nie, aangesien al die bogenoemde faktore alle ergonomiese standaarde en praktyksreëls oorskrei.

CHAPTER 1

SUMMARY

The aim of the study was to evaluate ergonomics in a Base Metal Refinery (BMR). The hypothesis tested was that the machinery and equipment used and the postures of the workers and the load handled are not in line with good ergonomic standards and practices.

Anthropometrical measurements were taken from 111 workers and the loads they handled, their posture while performing the work and the heights of different workstations. Self administered questionnaires were completed by all the workers so as to determine how the feel about their work and an observational data was recorded in order to observe the way the work was performed.

Different anthropometrical measurements taken included stature, weight, vertical grip reach, forward grip reach, shoulder grip length, shoulder height/hip height. Different variables including height of the workstation, weight handled, type of work done and frequency of handling were also measured. Evaluation of medical records and incident reports were also carried out to determine whether these records support the hypothesis to be tested or not.

Most of the workstations were not ergonomically designed and the work performed in the Base Metal Refinery was done in a standing position and repeated for most of the work shifts.

Anthropometrical data was collected so as it can be compared with the type of work performed the duration of the work and whether the workstations were designed to fit the workers. Workers in the BMR were exposed to handling loads which were higher than the NIOSH recommended weight of 23kg, the work was highly repetitive and the workers had to bend awkwardly while performing the work. Therefore this disagrees with the hypothesis which states that the machinery and equipment used and the postures of the workers and the load handled was not in line with good ergonomic standards and practices.

This statement was also supported by the incidents reports and the medical records which showed that most workers were booked for a long time due to lower back pain, and more incidents occurred due to handling loads. In BMR most incidents, injuries and illnesses were common amongst cell workers than any occupation within the industry. High incidents and absenteeism due to lower back related illnesses can be directly associated to the type of work performed and the amount of load handled.

Most of the workstations were either too high or too low therefore forcing the workers to bend at the waist or his neck so as to properly observe the task, and this proves that BMR was not designed to fit the workers, the way the work was performed, the posture of the worker, the repetitive nature of the work and the weight handled were exceeding the ergonomic standards and practices.

1. INTRODUTION

The Rustenburg Base Metal Refiners forms part of the Rustenburg Anglo Platinum and is responsible mainly for producing nickel; copper, cobalt and sodium sulphate crystal. Waterval Converter Matte is delivered to MC Plant (Matte Concentration) where the magnetic material (MEC) is separated from the non-magnetic material. The latter is then transferred to the Base Metal Refinery (BMR) as NCM (Nickel-Copper Matte. The remaining base metals are leached out of the Platinum Group Metals in the PV's (Pressure vessels in the MC Plants) and pumped to the BMR as PVL (Pressure vessel liquor). The main objective of the BMR is to produce nickel, copper, cobalt sulphate and sodium sulphate.

During walk-through survey, the investigator identified that during their shift production time, BMR workers are engaged in the, lifting and carrying of heavy loads, and that is usually done for a prolonged period of time and in bad working posture. These factors are subjecting to the workers stress and pressure. The equipment and the workstations are thought not to be ergonomically designed and could play a very significant role in the health and safety of the workers.

1.1. BMR PROCESS FLOW (COMBINED)

1.1.1 TANK HOUSE LAYOUT

Nickel tank house consists of 168 cells of which 164 are normally in circuit at any one time, the remainder being off for maintenance. There are 90 cells on the east bay (all production) and 78 in centre bay, of which 46 are production and 32 are starters.

Copper tank house consists of 116 cells, normally 84 production cells and 20 starter cells are in line in any one time, with 12 off for maintenance.

Drop-out wells are situated on the north and the south sides of the tank house in order to lower the cathode to the basement for production management. Two boric cells in each bay are for the storage of treated starter sheets. These boric cells are situated next to the cathode wash tank.

The tank house is divided into six distinct areas namely: east bay (north), east bay (south), centre bay (production), centre bay (starter), copper bay (production), and copper bay (starter). The east bay (north and south), which are production cells consisting of 44 cells each of which 7 cells are pulled per day after 6 day cycle.

The centre bay which is a production cell consists of 46 cells of which 7 cells are pulled per day after 6 day cycle.

Centre bay which is a starter cell consists of 32 cells of which 17 cells are pulled per day after 2 day cycle.

Copper bay which is a production cell consists of 96 cells of which 12 cells are pulled after 7 day cycle.

Copper bay which is a starter cell consists of 20 cells of which 12 are pulled per day after 2 day cycle.

This work shift is operational on the morning shift only and is referred to as a pulling shift. They are responsible for ensuring the required production is pulled for the day.

1.1.2. STARTER SHEET PREPARATION

The aim of this process is to prepare starter for copper or nickel electrowinning.

1.1.2. a. Nickel starter sheet preparation

The starter sheets to be trimmed can either be double or single sheets, depending on how they are stripped. The scrap sheet is placed on a scrap pallet next to the machine. The double sheeting is then inserted into the guillotine, leaving the top part nearest to the operator, overlapping slightly over the dimensional guide of the bench. The sheet is cut once by pressing the foot operation lever down and two sheets are curt at one time. The sheet is swung by 90 ^{0} and insert the side to be cut squarely into the cutting machine with the side nearest to the operator once again overlapping the dimensional guide. Cut once, extract and swing the sheet by 90 ^{0} for the third cut. The sheet is inserted again and this time the edge of the sheet nearest to the operator is rested inside and surely against the dimensional guide to obtain the desired size of the sheet

After the third cut the sheet is swung by 45 ^{0} and the corner inserted in the position on the dimensional guide and the corners cut and this procedure is repeated until all the corners are cut. All trimmed sheets are placed on a pallet and moved with a forklift to storage area or to spot welder receiving table. For a good commercial production it is essential that all starter sheets be trimmed to exactly the same size.

1.1.2. b. Cutting starter sheets suspension straps (loops)

50mm wide strips are cut until the sheet nearly fits into 600 mm dimensional guide. The sheet is extracted and swung 180 ^{0} in the anticlockwise direction then inserted into the guillotine and this time the edge of the sheet rested nearest to the operator on the marks provided on the left and the right hand side of the dimensional guide. These marks are 600 mm from the blade which is the correct length of the strap.

The sheet is cut once and swung clockwise by 90 ^{0} and inserted squarely against the dimensional stop plate 5 mm behind the plate. After the sheets are cut down to 600mm length they are removed to the loop forming table.

1.1.2. c. Folding suspension strips

The folding press is operated manually by lifting and lowering the lever and the strap is placed on the bench in the holding jig that is at right angle to the operating lever travel. The operating lever is lowered until it rests on the strap and then pressed down firmly. Bent straps are placed on a table or storage pallets and then later moved from the table or pallets to the spot-welder.

1.1.2. d. Spot-welding straps to starter sheets

Two operators are required to perform this task. One operator selects a sheet from the pile and places it inside the guides on the bench while the second operator selects two straps and wets these in a drum of water (for better electrical contact) located next to the spot-welder. The straps are then fitted into a jig to straddle the starter sheet. The strap will overlap the sheet by approximately 50 mm. By operating the foot control the electrodes of the spot-welder move downward to make contact and effect spot-welding.

The straps are spot-welded 5 times (to ensure good attachment) once moved into position by the second operator. Air and water supply to the machine must be on at all times when spot-welding. After spot-welding the sheets are stacked neatly into pallets with the straps facing one way. When spot-welding of all the sheets are completed they are transferred to the ridgidiser.

1.1.2e. Ridgidising of the starter sheets

Starter sheets are ridgidised to strengthen the sheet preventing it from bending thus causing short circuits in the cell. The chamber of the ridgidiser must be cleaned before inserting the starter sheet by flushing the end of the chamber with the straps towards the operator. Once the sheet is correctly in position the ridgidiser controls are operated. The bottom part of the chamber will move upwards and force the sheet against the upper stationery part of the chamber. The pressure will be released automatically after a short pause.

After the pressure has been removed the starter sheet is removed and placed neatly on a wooden pallet (200 sheets per pallet). When all the sheets had been ridgidised the pallets are first weighed.

1.1.3 Copper starter sheet preparation

1.1.3a. Copper starter sheet trimming

The starter sheet is positioned squarely on the guillotine allowing the edge nearest to the operator to fit into the outside dimensional guide. The foot control operated and one cut will be made. Again the sheet is turned 90 ^{0} and inserted, this time to fit into the inside dimensional guide and the third cut is made. For the final cut the sheet must also fit into the inside dimensional guide. The sheet is then placed on a wooden pallet to be transported to the stidgidising area at the end of the shift. All trimmings from the above operation are to be placed in the designated trimming bag and all mossy copper and sweepings to be placed into a wooden pallet.

1.1.3b. Cutting 10 mm suspension straps

Scrap starter sheet is cut by making the first cut with the sheet overlapping the 600 mm dimensional guide. The sheet is then turned at 90 ^{0} for the second cut overlapping the 600 mm dimensional guide. This process is repeated until all the three cuts are made, and thereafter the sheet is inserted between the blades squarely against the dimensional guide at the back of the guillotine blade. The guide is 100 mm wide to give the correct strap width. After the strap cutting operation is completed all the straps are collected and stacked neatly on the strap forming table.

1.1.3c. Folding suspension straps

The folding gig is manually operated by lifting and lowering the lever. The lever is lifted and the strap placed down flat inside the retaining area which is at right angles to the operating lever travel. The lever is then lowered and pressed down firmly to fold the strap. It is important that only one strap is folded at a time in order to obtain square corners for better electrical contact. The folded straps are then transported to the stidgidising area.

1.1.3d. Copper stidgidiser

Three operators are required to perform this task. The oil pumps and the cooling fan are started. The first operator place one starter sheet onto the bed plate and push it into the machine and push down both hand buttons. The second operator positions the straps and presses the operating buttons on his side. Two hand switches are kept down and the upper part of the chamber will press downwards to ridgidise and at the same time stitch the straps onto the sheet. The sheet is then repositioned for the second punch.

1.1.3e. Copper toks machine

Two operators are required to perform this task. The machine is set on and the starter sheet is placed onto the bedplate and then pushed into the machine with the moving bedplate. The hand buttons are pushed down and the second operator position the straps and press the buttons on his side. The sheet is removed when the sequence is completed.

1.1.4. NICKEL CIRCUIT

1.1.4a. NCM and copper removal

Nickel- Copper slurry is received and stored in the NCM storage tank. If the MC plant is unable to supply NCM slurry, dry NCM from the stockpile can be repulped in the NCP repulpers. The copper removal reactors receive feed from the NCM storage and PLS mix wed with nickel dissolution takes place. The overflow solution or CPR (copper removal solution) containing Co and Ni are transferred via the CRS tanks, to the lead removal section.

The underflow pulp or CRR (copper removal residue) containing Co, Ni, Cu is transferred to the primary leach section via the CRR storage tank.

1.1.4b. Primary leach

The CRR of copper removal thickeners is mixed with various other solutions, including PVL from MC plant and copper spent from the tank house, before being pumped into the primary autoclaves where Co and Ni as well as small amount of Cu are leached out. The discharge from the primary autoclaves is received in the primary flash tank receiver, which feeds the primary thickener. Liquid-solid separation is received in the primary tank thickeners. The overflow solution or PLS (Primary Leach Solution) is pumped to the copper removal reactors.

-The underflow pulp, called PLR (Primary Leach Residue) is washed on the PLR belt filter, before being pumped to the secondary leach section via PLR storage tank. The filtrate from the belt joins the PLS flow to the Cu removal section.

1.1.4c. Lead removal-CRS

From the CRS storage tank is pumped to the lead removal section. Barium hydroxide is added to precipitate the lead in the solution. The precipitated lead is retained in the filter presses and transported to waterfall smelters. The filtrate (Ni and Co) is pumped to the cobalt precipitation reactors via the cobalt feed heat exchanger.

1.1.4d. Cobalt precipitation

The cobalt in the solution is precipitated by nickel addition, which is produced in the nickel electrowinning section. The precipitated cobalt is retained in the cobalt precipitation filter presses and is transferred to the cobalt treatment section. The filtrate (nickel feed) is pumped to the Ni feed storage tanks

1.1.4e. Nickel funda filters

Ni feed from the Ni filters is pumped through the Ni funda filters where it is clarified (serves as a polishing filter). The clean Ni filtrate passes through the pH adjustment pump box and temperature adjustments stage before the electrowinning process. The sludge from the Ni funda filters is pumped back to the cobalt precipitation lead reactor.

1.1.4f. Nickel electrowinning

Nickel feed solution flows through the nickel cells where the Nickel ions are plated out by an electrowinning process. The nickel cathodes are removed and transported to packaging and transport where they are prepared for marketing.

The Nickel spent electrolyte from the nickel cells is pumped to the sulphur removal via the nickel spent storage tanks. Nickel feed is also supplied to the nickel make-up section from where nickel Ni^{3+} is generated and supplied to the cobalt precipitation.

1.1.5. COPPER CIRCUIT

1.1.5a. Secondary leach

PRL from the PRL storage is mixed with the copper spent and spillage before being pumped into the autoclaves where copper is leached. The discharge from the autoclaves is received in the secondary flash tanks receiver, which feeds the SLR filter presses.

The copper filtrate or SLS (Secondary Leach Solution) from the presses is pumped to the SLS storage tanks. The filter press cake or (Secondary Leach Residue), containing iron is transferred to the MC plant (SLR) or is stockpiled.

1.1.5b. Selenium removal (copper purification)

During the secondary leach process, approximately 85% of the selenium received at the SLR, is transferred to the MC plant. The remaining 15% of the selenium in the copper solution must be removed to prevent contamination of the final copper cathode. Selenium is precipitated in the selenium section by Na_2SO_3 (Sodium sulphite) addition.

The precipitated selenium or copper selenide is retained in the copper funda filters. The sludge from the funda filters is transferred to the secondary flash tank receiver from where it is transferred with the SLR, via SLR presses, to the MC plant or SLR stockpile.

The filtrate from the copper funda filters, copper feed, is pumped to the copper feed storage tanks from where it is transferred, via the temperature adjustment unit, to the copper electrowinning section (tank house).

1.1.5c. Copper electrowinning

Copper solution (feed) flows through the copper cells where copper ions are plated out by an electrowinning process. The copper cathodes, removed from the cells are transported to packing and transport where they are prepared for marketing.

The solution from the copper cells, copper spent, is transferred to the copper spent storage tanks, from where it is distributed to the primary and secondary leach section, where its high acid content is made use of as a source of acid to leach the nickel and copper from sulphide matte.

1.1.6. SODIUM SULPHATE CIRCUIT

1.1.6a. Nickel precipitation

Ni spent electrolyte is pumped to the Sodium Carbonate Plant. The soda carbonate plant comprises of two sections namely: liquid sodium carbonate make-up section and the acid neutralisation section.

The solid sodium carbonate is added to neutralise the free acid in the spent solution. Liquid soda carbonate is then added on ratio to flow of NiS to the neutralisation reactor, this serves to precipitate some of the nickel as $NiCO_3$ (Nickel Carbonate).

The solution is then pumped to the Nickel precipitation reactors. Sodium Hydroxide (NaOH) is then added to precipitate the remaining nickel in the spent solution as nickel hydroxide. The nickel hydroxide and nickel carbonate is filtered-off on the Eimco drum filters.

The nickel hydroxide and nickel carbonate solid from the Eimco filters is transferred to the Ni dissolution reactors as a slurry where it is dissolved with Ni spent before being pumped to the Cu removal section (PLS and CSR storage tanks). The filtrate (sodium sulphate solution) from the Eimco Filters flows to the sodium sulphate press feed.

1.1.6b. Sodium sulphate section

The sodium sulphate filtrate from the Eimco filters is further treated with NaOH to increase the pH and precipitate the remaining small quantities of Ni as $Ni(OH)_3$. The filtrate is filtered through the presses.

The clean filtrate is transferred to RPMCD, via heat exchangers, where Na_2SO_4 is crystallised. This is the major outlet of sulphur from the BMR circuit. The filter press cake is transferred to the nickel precipitation spillage tank where it is mixed with the spillage and raffinate (from the cobalt plant) before being pumped to the Ni spent storage tanks.

1.1.7. COBALT CIRCUIT

1.1.7a. Cobalt treatment and wash section

The press cake retained in the Co precipitation is transferred to the cobalt treatment reactors. Ni spent is added to dissolve any nickel hydroxide entrained in the cobalt hydroxide press cake. Filtration then takes place in the Co treatment presses.

Filtrate from these presses is pumped to the Cu removal section. The press cake, retained in the treatment presses is transferred to the Co wash section where it is washed with demineralised water and filtered in three wash presses. The filtrate from the wash presses is transferred to the primary leach section as spillage and the press cake from the presses is transferred to the cobalt sulphate plant.

1.1.7b. Cobalt sulphate plant

The pulp from the presses is mixed with the spillage and filtrate from the manganese press in the Co dissolution reactors. The pulp is treated with acid formalin and caustic to dissolve the cobalt and to precipitate iron. Before filtration in the Co dissolution presses, copper is precipitated in the cobalt dissolution press feed tank, by adding BaS (barium sulphide).

The press cake retained in the press is repulped in the CDR (cobalt dissolution residue) repulper and transferred to the secondary leach section. The filtrate from the presses passes through the final Cu and Fe reactors where it can be treated with BaS, NaOH or air for final removal of Cu and Fe if necessary.

The filtrate from the funda filter flow through the solvent extraction where Cu is separated from the impurities present in the solution. The cobalt product solution is transferred to the crystalliser section from where the Co crystals are transported to packing and transport for marketing.

The Ni (plus other impurities) from the solvent extraction is pumped to the Ni precipitation section as raffinate.

Manganese (impurities) is removed by bleeding off the 20% acid, treating it with NaOH and sodium persulphate before filtering it through the Mn filter press. The filtrate from the press is used in the Co dissolution reactors while the press cake is sent to Waterval Smelters.

Ergonomics as defined by the board of certification for professional ergonomists (BCPE) "is body knowledge about human abilities, human limitations and human characteristics that are relevant to design. Ergonomics is the tailoring of products so that the human user involved is as comfortable as possible, and stress and fatigue are minimised. Health, safety and productivity often result from this worker-friendly approach.

Poor ergonomics results in causing cumulative trauma disorder due to repetitive motion, awkward posture, forceful exertion, contact stresses, vibration and other environmental factors such as vibration, heat/cold, illumination and the environment can act synergistically with the level of noise workers are exposed to, increase the effect of noise on the body of the workers (NPC Library, 3).

1.2 STATEMENT OF THE PROBLEM

1.2.1. Specific research questions

1.2.1. Are the workstations ergonomically designed to fit the workers?

1.2.2. Are the machinery and equipment and the posture of the workers in line with good ergonomic standards and practices?

1.2.3. Are there hazards associated with the way in which the work is conducted.

1.2.4. Is the height of the work surfaces determined in relation to the physical work to be performed, the dimensions of the work piece itself, and on the need to observe the work done?

CHAPTER 2

2. LITERATURE REVIEW

2.1 INTRODUCTION

2.1.1. Defining ergonomics

According to the Occupational Safety and Health Administration (OSHA), ergonomics is a science of fitting jobs to people. Ergonomics encompasses the body of knowledge about physical abilities and limitations as well as other human characteristics that are relevant to job design (Ergonomics in the workplace, 1).

Ergonomics is the fundamental basis of design. Ergonomics provides information and means by which we can make essential changes in our thinking about the relationship between people and machines (Kompendier, 1).

A more comprehensive definition of ergonomics is provided by Christensen, Topmiller and Gill (1988:7) "ergonomics is that branch of science that includes what is known and theorised about human behavioural and biological characteristics that can be validly applied to the specification, design, evaluation, operation and maintenance of products and systems to enhance safe, effective and satisfying use by individuals, groups and organisations", (Safety in Mines Research Advisory Committee, 20).

The term ergonomics is derived from the Greek word ergos meaning "work" and nomos meaning "natural laws of" or "study of" The profession has two major branches which considerable overlaps. One discipline, sometimes referred to as "industrial ergonomics" or "occupational biomechanics", concentrates on the physical aspects of work and human capabilities such as force, posture and repetition. A second branch, sometimes referred to as: human factors" is oriented to the psychological Factors aspects of work such as mental loading and decision-making. Further discussions will focus more on industrial ergonomics (ErgoWeb, 1).

Essentially, ergonomics is the relationship between the worker and the job, which focuses on the design of systems to meet certain goals of human performance. Without these, workers can become injured or incur permanent disability from work related stressors. With insurance and litigation cost soaring throughout the nineties, many employers implemented ergonomics programmes. Over the past few years, OSHA issued citations for ergonomic hazards. Occupational Health Safety Act 1993 (Act no. 85 of 1993) section 8(1) and section 5(a) 1 under the Occupational Safety and Health Administration Act (1970) OSHA say that a place of employment must be free from recognized hazards that are causing or are likely to cause death or serious physical harm to employees(Ergonomics in the workplace, 2).

According to OSHA, "Work related MSD's (Muscular skeletal disorders) currently account for one third of all occupational injuries and illnesses reported to the bureau of labour statistics (BLS) by employers every year. These disorders constitute the largest job related injury and illness problem in the US today. Companies in South Africa especially the mining industry are also experiencing financial claims from former employees as a result of occupational injuries and illnesses, (Ergonomics in the workplace, 2).

2.1.2. The focus of ergonomics

2.1.2a. Ergonomics focuses on the interaction between humans and:

1. product
2. equipment
3. facilities
4. procedures
5. physical environment
6. psychological environment

Used at work and in every day living, the emphasis is on humans and how the design and layout of the above influences them, (Safety in Mines adversary Committee, 20).

2.1.2b. The objectives of ergonomics

The main objective of ergonomics is to change the things people used and the environments in which they use them to correspond with their capabilities, limitation and needs. Two clear sub-objectives of ergonomics can be distinguished.

a. The first objective is to increase the efficiency and effectiveness with which work and other activities are performed.

b. The second objective is to enhance certain desirable human values. Examples of these are improved safety, reduced fatigue, increased effort, greater user acceptance; increases job satisfaction and improved quality of life, (Safety in Mines adversary Committee, 21).

2.1.2. c. Goals of ergonomics

The goals of ergonomics are to reduce occupational injury and illness, to contain workers' compensation costs, improve production and work quality, reduction of absenteeism and to comply with government regulations requirements (ErgoWeb, 1).

The ultimate goal of ergonomics is to improve and maintain the well being of the individual worker. At the same time the well being of the organisation will also be improved and maintained. The application of ergonomics has certain advantages for the individual worker such as an improvement in the following:

- health
- safety
- comfort
- satisfaction
- convenience

For the organisation, on the other hand, there will be improvement in the following:

- performance
- productivity
- effectiveness
- efficiency
- quality of product and service

in the process, there will be a resultant drop in absenteeism and labour turnover, and increase in worker involvement, more commitment to change, as well as an increase in worker motivation and the purchase of the company's products or services,(Safety in Mines adversary Committee, 21).

2.1.3 Ergonomics and design

2.1.3a. Workplace description

There are certain basic principles that apply to all workstations in any work environment. The work setting is characterised by the interaction between the following parameters; a worker with attributes of size, strength, and range of motion, intellect, education, expectations and other physical/mental capacity. A work setting comprise of parts, tools, furniture, controls/display panels and other physical objects and a work environment created by climate, lighting, noise, vibration and other atmospheric quality. The interaction of these parameters determines the manner by which a task is performed and the physical demands of the task. When the physical demand increases, the risk of injuries increases. When the physical demand of a task exceeds the physiological capabilities of a worker, an injury will likely occur (ErgoWeb, 2).

2.1.3b Work risk factors

Certain characteristics of the work setting have been associated with injury. These work characteristics are called risk factors and include: task physical characteristics (primarily interaction between the worker and the work setting); posture, force, velocity/acceleration, repetition, duration, recovery time, heavy dynamic exertion, segmental vibration.

Environmental characteristics (primarily the interaction between the worker and the work environment) include heat stress, cold stress, whole body vibration, lighting and noise (ErgoWeb, 2).

i). Posture

Is a position of the body while performing activities? Awkward posture is associated with the increased risk of injury. It is generally considered that the more a joint deviates from the neutral (natural) position, the greater the risk of injury. Posture issues can be created by work methods (bending and twisting to pick up a box; bending the wrist to assemble the part) or workplace dimensions (extended reach to obtain a part from a bin at a high location; kneeling in the storage bay because of a confined space while handling luggage). Specific posture has been associated with injuries of the wrist, shoulder, the neck and lower back (ErgoWeb, 2).

ii). Force

Task forces can be viewed as the effect of the exertion on internal body tissues, (e.g. compression on the spinal disc from lifting, tension within a muscle/tendon unit from a pinch grasp), or the physical characteristics associated with an object (external to the body). Generally the greater the force the greater the degree of risk. High force has been associated with risk of injury at the shoulder/neck, low back and the forearm/wrist/hand. It is important to know that the relationship between force and the degree of injury risk is modified by other work risk factors such as posture, acceleration, repetition and duration (ErgoWeb, 3).

iii). Repetition

Repetition is the time quantification of a similar exertion performed during a task. Repetitive motion has been associated with injury and worker discomfort. Generally, the greater the number of repletion, the greater the degree of risk. However, the relationship between the repetition and the degree of injury risk is modified by other risk factors such as force, posture, duration and recovery time. No specific threshold values (cycle/unit of time, movements/unit of time) are associated with injury (ErgoWeb, 4).

iv). Duration

Duration is the time quantification of exposure to the risk factor. Duration can be viewed as the minutes or hours per day the workers are exposed to the risk. Duration also can be viewed as the years of exposure to a risk factor or a job characterised by a risk factor. In general, the greater the duration of exposure to a risk factor, the greater the degree of risk (ErgoWeb, 5).

v). Recovery time

Recovery time is the time quantification of rests, performance of low stress activity or performance of an activity that allows a strain body area to rest. The recovery time needed to reduce the risk of injury increases as the duration of the risk factor increases. Specific minimum for recovery times for risk factors has not been established (ErgoWeb, 5).

vi). Heavy dynamic exertion

The cardiovascular system provides oxygen and metabolites and muscle tissue. Some tasks require long term/repetitive muscle contraction such as walking great distances, heavy carrying and repeat lifting. As the activity increases, muscle demands more oxygen and metabolites. The body respond by increasing the breathing rate and the heart rate. When muscle demand from metabolite cannot be met (metabolic energy expenditure rate exceed the body's energy producing and lactic acid removal rate) physical fatigue occurs. When this happens in a specific area of the body (shoulder muscle from repeat or long term shoulder abduction), it is termed localised fatigue and is characterised by tired/sore muscles. When this happens to the body in general (from climbing stairs and long term heavy carrying/lifting), it is termed whole body fatigue and may produce cardiovascular incidents. Also, high heat from the environment can cause an increase in heart rate through body cooling mechanisms, therefore for a given task; metabolic stress can be influenced by environmental heat (ErgoWeb, 5)

vii). Handling loads

Material handling is one of the most frequent and the most severe causes of injury all over the world. Exerting force in lifting an object with hands, strains hands, arms, shoulders, the trunk, and, if one stands, also the legs. The same parts of the muscular-skeletal systems are under stress in lowering, in pushing and pulling, but direction and magnitude of the external and internal force and torque vector are different. The primary physiological and biomechanical concern has been the low back, particularly the disc of the lumber spine, (Kroemer and Kroemer, 1994).

If the human must lift material over many hours in repetitive activities involving the whole body (or large section thereof) then the ability to do so is limited by metabolic and circulatory capabilities. Given the energetic in efficiency of the body, moving the body in this way taxes body abilities usually to such an extent that fairly little external load may be moved, and (Kroemer and Kroemer, 1994).

On the other hand, if very high force must be exerted just once, such as in lifting heavy object, then indeed the ability to generate large force once is a limited factor. This experience was apparently the reason why, in the past, guidelines were used that tried to determine the acceptable lifting task by establishing an upper weight limit. Of course, to set a weight limit for objects to be handled is not reasonable and prudent, because one may exert a large force even to a fairly small mass, if much acceleration is applied (Newton second law). Generating one-time upward force a needed to lift a heavy object does strain many musculo-skeletal components of the body, (Kroemer and Kroemer, 1994).

viii). Segmental vibration

Vibration applied to the hand can cause a vascular insufficiency of the hands/fingers (Raynaud's disease or vibration white fingers). Also, it can interfere with sensory receptor feedback leading to increased hand grip force to hold the tool. Further, a strong association between carpal tunnel syndrome and segmental vibration (ErgoWeb, 6)

2.1.4. Work Station Design

Body size is important in design of workstations, the enormous variation in body among individuals pose a great challenge for a designer of equipments and workstation. Often extreme body sizes are disregarded and the most striking differences in body sizes are related to ethnic diversity, gender and age. As a whole, females are smaller than men except in hip dimensions.

With increasing age, many adults become shorter but heavier, therefore workplaces should allow for the bodily dimensions of all users, females or male, between about 20-65 years of age, (Grandjean, 1997).

According to Grandjean (1997), optimum work surface height for a standing workstation upon which handwork is performed is dependent on the elbow height of the worker and the nature of the work.

For precision work, work surface height should be 5-10 cm above the elbow height, which allow for arm support to reduce static loads in the shoulders. For light work, work surface height should be from 10-16cm below the elbow height for space for small bins, tools, and materials. For heavy work, work surface height should be from 16-40 cm below elbow height to allow for muscular advantage of the upper extremity.

Ergonomically speaking, it is desirable to adjust the working height to suit the individual. Instead of improvisation such as foot supporters or lengthening the legs of the worktable, a fully adjustable bench is recommended (Grandjean, 1997).

2.2. ERGONOMICS IN THE SOUTH AFRICAN MINING INDUSTRY

The interaction between human, machine and environment results in many risks to workers while performing tasks in their work environment. In recent industry-wide risk assessment conducted by Ergotech on behalf of the safety in Mines Research Advisory Committee (SIMRAC), it was pointed out that poor ergonomics design and a lack of a strategy for introducing ergonomics into the South African mining sectors was a major contributing factor to poor worker heath and safety, (Safety in Mines adversary Committee, 11).

A lack of ergonomics research pertaining to the local mining industry was also identified as a major shortcoming and contributing factor. Basic ergonomics is currently applied to a limited extent in the South African mining industry. There is however no structure or co-ordination in this effort and as a result of no strategy. The science of ergonomics can make a contribution to the management of significant risks in mines if applied in a co-ordinated and integrated manner. The main purpose of an ergonomic strategy would be to focus and align the application of ergonomics in the local mining industry, (Safety in Mines adversary Committee, 11).

As a result of above-mentioned findings the need for a comprehensive ergonomics strategy for the South African mining industry was identified and it was decided by SIMRAC to approve a research project to satisfy the need. The research project to develop a comprehensive ergonomics strategy for the local mining industry was awarded to Ergotech, (Safety in Mines adversary Committee, 11).

The main objective of Ergotech study was the development of the comprehensive ergonomics strategy for the South African mining industry. This would facilitate the introduction and implementation of ergonomics in the local mining industry on integrated bases, thereby contributing to initiatives aimed at the management of health and safety risks in mines to the mutual benefit of all role players, (Safety in Mines adversary Committee, 11).

2.3. LEGISLATION

The Mine Health and Safety Act (act No. 29 of 1996) is the only legislation in South Africa that specifically addresses ergonomics or mention the term "ergonomics". According to Section 21(1) (c): "Any person, who designs, manufactures, erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that ergonomic principles are considered and implemented during design, manufacture, erection or installation".

This section of the act only implies to the duties for health and safety (and ergonomics) of manufacturers and supplier. Louw (1999) maintains that a court of law will be very reluctant to institute prosecution due to the fact that there are currently no regulations to provide the manufacturers of mining equipment with more specific guidance on ergonomic principles and how to apply them, (Safety in Mines adversary Committee, 33). Furthermore, section 21(1) (c) applies only to manufacturers and suppliers of mining equipment. What about the employer's duty to provide a work environment that conforms to good ergonomic principles.

Section 2(1) of the Act stipulates the following:

"The employer of every mine that is being worked must:

(a) ensure, as far as reasonably practicable, that the working environment is designed, constructed and equipped:

  i. to provide conditions for safe operation and a healthy working environment; and
  ii. with a communication system and with electrical, mechanical and other equipment to achieve those conditions;

(b) ensure, as far as reasonably practicable, that the mine is commissioned, operated, maintained and decommissioned in such a way that the employees can perform their work without endangering the health and safety of themselves or of any other person"

Although the term "ergonomics" does not appear in the above-mentioned article, ergonomics could be read into it as objectives similar to those of ergonomics are contained therein.

Article 5 and 11 of the Act stipulate the duties of the employer with regard to health and safety risks and hazards, and the identification, assessment and recording thereof. Therefore ergonomics could also be read into article 5 and 11 of the Act.

The main objectives of this Act are:

(a) to protect the health and safety of persons at mines,

(b) to require the employers and the employees to identify hazards and eliminate, control and minimise the risks relating to health and safety at mines,

(c) to give effect to the public international law obligations of the Republic that concerns the health and safety at mines,

(d) to provide for employee participation in matters in matters of health and safety through health and safety representatives and health and safety committees at mines,

(e) to provide effective monitoring of health and safety conditions at mines,

(f) to provide for the enforcement of health and safety measures at mines,

(g) to provide investigations and enquiries to improve health and safety at mines; and to promote:

- a culture of health and safety in the mining industry;
- training health and safety in the mining industry, and
- co-operation and consultation on health and safety between the State, employers, employees and their representatives.

The number of the above objectives of this Act is very similar to the objectives of ergonomics and an ergonomic strategy for the implementation of ergonomics in the local mining industry will facilitate the fulfilment of the main objectives of the Act. The ergonomic strategy could also provide guidance in the development of a code of practice for occupational hygiene as well as the drafting of ergonomics regulations for the Act and ergonomics standards for the South African Mining, (Safety in Mines adversary Committee, 34).

2.4. ADVERSE EFFECTS OF POOR ERGONOMICS

2.4.1. Back injury and pain

Injury occurs if the limits of maximal strain of the tissues (bone, cartilage, ligaments, and muscles) are exceeded. This may happen in a single strenuous effort, an accidental trauma. However, often repeated loading add up to cumulative overloading. In this case, the person repeatedly insulting the back does not have to disrupt the normal pattern of work until finally onset of pain signals the accumulated injury, (Kroemer and Kroemer, 1994).

The major difficulty in recognising and analysing the cause of a back injury is that it may happen without generating any pain. This is so because neither the facet of the apophyseal joint nor the intervetebral disks seem to have pain-sensitive nerves. The three-load bearing elements (two facet joint and one disc) of each spinal unit can indeed be injured without pain sensation. Clinical evidence shows that old but stable fractures are commonly found in people who have no recorded history of injury, (Kroemer and Kroemer, 1994).

2.4.2. Human body

The spine is the only "stiff" connection between the upper and lower parts of the body. It carries information from the brain to the functional systems. It is essential that we take care of it. Back problems account for more industrial days lost than any other cause, and they are often the most difficult to substantiate, or disprove. The spine has a series of normal curves called lordosis (curved towards the front) and kyphosis (curved towards the back). These may become excessively or wrongly curved. Basic mechanisms show that the part most vulnerable is the lumber section. Badly organised lifting is especially dangerous. Workplaces and work practises should be designed to eliminate unnecessary bending or stretching, especially the moving of heavy objects when twisting and off-balance. Loading and lifting design can play an important role in preventing problems here.

2.4.3. Effects of repeated heavy work on specific muscles

2.4.3. a. Fatigue

If the energetic work demands exceeded about half the person's maximal uptake capacity, anaerobic energy-yielding metabolic processes play increasing roles. This results in the accumulation of potassium and lactic acid, which are believed to be the primary reasons for 'muscle fatigue", forcing the stoppage of muscle work. The length of time during which a person performs this work depends on the subject's motivation and the will to overcome the feeling of fatigue, which usually coincide with depletion of glycogen deposits in the working muscle, drop in blood glucose, and increase in blood lactate. However, the processes involved are not fully understood, and highly motivated subjects may maintain work that requires very high oxygen uptake for many minutes, while other persons feel that they must stop after just a brief effort, (Kroemer and Kroemer, 1994, 120).

2.4.3. b. Musculoskeletal Disorders

Work-related Musculoskeletal Disorders (MSD's) are the disorders of the Musculo-tendonousosseous-nervous system that is caused precipitated or aggravated by repeated exertions or movements of the body. MSD's are caused by wear and tear on tendons, muscles, and sensitive nerve tissue caused by continuous use or pressure over an extended period of time. Most common parts of the body that are affected by poor work habits and workstation design are the wrist, hands, shoulders, back, neck, and the eyes. MSD's are groups of disorders with similar characteristics and may be referred to as: cumulative trauma disorders or repetitive trauma disorders (Ergonomics in the workplace, 8).

2.4.3. c. Examples of MSD's are:

i). Bursitis

It is the inflammation of the bursae, which are closed sacs that contain fluid and are located at points of friction in joints. Bursitis can occur in several joints, but the shoulder and the knee joints are the most common. The inflammation is attributed in some cases to excessive use of joints. The build-up of calcium deposit on tendons associated with the joint is frequent precipitating cause. The calcium deposit triggers an inflammatory reaction that can spread to a nearby bursa and even rapture it. Bursitis may be acute or chronic (Ergonomics in the workplace, 9).

ii). Carpal Tunnel Syndrome (CTS)

CTS is a disorder that causes a prickling or numbness in the hand. It can cause burning pain, decreased hand dexterity, and, in some cases, paralysis. CTS is caused by compression of the median nerve, which runs through a bracelet like bone structure in the wrist, the carpal tunnel, and branches to the thumb and first three fingers. Tendons in the carpal tunnel may swell and pinch the nerve. Compression and entrapment of the nerve may be accompanied by changes in elecromyographic (EMG) patterns and nerve conduction velocities, indicating a pressure block of the nerve (Ergonomics in the workplace, 9).

iii). DeQuervain's disease

In DeQuervain's disease, pain results from the tendons (and the covering of the tendons called the tynosynovium) becoming inflamed on the side of the wrist and forearm just above the thumb.

iv). Epicondylitis

Lateral epicondylitis, sometimes referred to as tennis elbow, can results from excessive activities such as painting with a brush or roller, running a chain saw, and using many types of hand tools continuously. Medial epicondylitis, sometimes referred to as Golfer's Elbow can results from activities such as chopping wood with the axe, running a chain saw, and using many types of hand tools continuously.

v. Cubital Tunnel Syndrome

Similar to the pain that comes from hitting the funny bone, cubital tunnel syndrome affects the ulna nerve where it crosses the elbow. The funny bone is actually the ulnar nerve on the inside of the elbow that runs in a passage called cubital syndrome (Ergonomics in the workplace, 9).

vi. Tendonitis

An inflammation of the tendon. Often associated with repeated tension, motion, bending, being in contact with a hard surface, vibration. The tendon becomes thickened, bumpy, and irregular in its surface. Tendon fibres may be frayed or torn apart. In tendon without sheaths, such as within the elbow and shoulder, the injured area may calcify, (Kroemer and Kroemer, 1994, 469).

vii. Thoracic Outlet syndrome.

A disorder resulting from compression of nerves and vessels between clavicle and first and second ribs, at the brachial plexus. If this neurovascular bundle is compressed by the pectoralis minor muscles, blood flow to and from the arm is reduced. This ischeamic condition makes the arm numb and limits muscular activities, (Kroemer and Kroemer, 1994, 469).

2.5. INTRODUCTION OF ANTHROPOMETRY

2.5.1. Anthropometry defined

Anthropometry (an-throh-pah'-uh-tree) is a field of science concerned with the measurement of the size and shape of the human body or skeleton. Humans have long been measured for both scientific and practical purposes. Artist and markers of clothing and other forms of personal equipment were probably the first practical anthropometrists. Physical anthropology use anthropometry to chart relationships between populations in terms of physical adaptations to environmental factors. Today, engineers use anthropometric measurements design workplace, tools, and other products, (Biomechanics/Anthropometry, 1)

Engineering anthropometry is a subfield of anthropometry that is specifically concerned with the measurement and application of numerical data concerning sizes, shapes, and other physical characteristics of humans in engineering design and evaluation. The principal thesis of engineering anthropometry is that objects or spaces intended for human use should conform to the form and dimensions of the human user population, (Biomechanics/Anthropometry, 1).

Anthropology, the study of mankind, was primarily philosophical and esthetical in nature until about the middle 19th century. Yet, the size and proportions of human body have always been of interest to artists, warriors, and physicians. Physical anthropology is that scientific subgroup in which the body, particularly bones, is measured and compared. In the middle of the nineteenth century, the Belgian statistitian Adolphe Quetelet first applied statistics to anthropological data, (Kroemer and Kroemer, 1994, 15).

This was the beginning of modern anthropometry, the measurement of the human body. By the end of nineteenth century, anthropometry was a widely applied scientific discipline, used in both measuring the bones of early people and in the assessing of the body sizes and proportions of contemporaries. A new offspring, biomechanics, had already developed. Engineers have become highly interested in the application of anthropometric and biomechanical information, (Kroemer and Kroemer, 1994, 15).

2.5.2. HISTORICAL INTEREST IN ANTHROPOMETRY

Vitruvius, an architect in ancient Rome (active between 46 and 30 BC) was first to describe the importance of designing buildings to fit citizens. He argued that buildings should be utilitas (useful), firmitas (strong), venustas (pleasing); in other words the structures should not only be strong, but fit and serve the needs of their users. Along the same lines, Le Corbuseir (1887-1965) published his treaties in 1961 entitled, The Modulator: A Harmonious Measure to the human Scale Universally applicable to Architecture and mechanics. Le Corbusier advorcated harmony between structures, their function, and the human form, ((Biomechanics/Anthropometry, 1)

Ancient mathematicians, and artists in the Gothic and Renaissance periods, found that human's dimensions and other natural forms appeared to follow certain ratios. Leonardo Pisano (1170-1240), also known as Leonardo of Pisa and Leonardo Fibonacci, found that certain numeric sequences, or proportions referred to as Fibonacci, numbers proved useful not only in number theory, but could be used to account for, or to predict, pleasing anatomical proportions, the spiral arrangement of petals and branches on certain types of flowers and trees, and other geometric relationship. One of the classic icons of ergonomics is Leonardo da Vinci's (1452-1519) human body, with extended limbs, inscribed within a circle and square. Today, artists continue to draw, paint, and sculpt the human form using ratios between body segments published by Albert Durer (1471-1528) in Four books of human proportions, (Biomechanics/Anthropometry,1).

Thus, ancient builders, mathematicians, and artisans were equally aware that failure to consider human dimension when designing structures, workspace, objects to be used by humans, or representing the human form to others resulted in undesirable consequences, (Biomechanics/Anthropometry, 2)

2.5.3. Consequences of ignoring Anthropometry in workplace or equipment design

If the workspace or equipment is not designed to fit the size, shape, and strength capabilities of the worker, then one or more of the following may occur:

a. **Inadequate clearance for larger workers**

Passageways and opening may not be large enough to safely accommodate the large worker. In extreme cases, the worker is simply unable to enter the workspace to perform maintenance, use of chairs provided, wear protective clothing, or effectively operate tools and machinery. More often, the large worker will be able to traverse passageways and openings, but not without significant effort, contortions, and frequent contact injuries, (Biomechanics/Anthropometry, 2).

In the case of protective clothing, too much clearance produces poor fits with smaller workers significantly diminishing or eliminating the protective value of the clothing and equipment. Inadequate clearance may require greater levels of force produced to accomplish the same task (e.g., tight- fitting gloves required gripping efforts to accomplish grasps, (Biomechanics/Anthropometry, 2).

b. Shorter worker may be unable to reach controls, tools, or objects

Placing controls, tools, or objects that must be grasped outside the functional reach envelop of shorter workers either prevents the worker from performing their job, and forces the workers to device some method, usually unacceptable from a safety or performance standpoint, to perform the task

> Locating controls, or requiring manual work, near or slightly beyond the extremes of the functional reach envelop of the small worker can produce sustained postural stress, quickens onset of fatigue, and usually places severe limits upon the worker's performance capabilities, (Biomechanics/Anthropometry, 2).

c. If reachable, controls, tools, or movement of objects may still exceed worker's strength capabilities

Placing controls, tool operations, or movement of objects within the reach envelop of the worker may not be adequate. Strength capability is posture-dependent and may vary significantly within the grasp envelop. Strength capability usually declines as workers must reach further away from the body and muscles, tendons, and ligaments are made taut.

> Strength may be further compromised when workers assume awkward postures to reach controls, to forcefully apply a tool to a surface or object, or to manipulate an object. For example, a large worker, forced to bend down to lift a heavy part out of storage bin, may not have sufficient strength to perform the task. Although this worker may be able to lift more than the shorter worker assuming the same posture, the shorter worker, not having to stoop over to perform a lift, may be able to accomplish the task. Tools handles that are too large or too small

in diameter can severely affect grasp strength and, subsequently, tool control and performance, (Biomechanics/Anthropometry, 3).

d. Unnecessary increase in biomechanical stress to the body

Although a worker may have the capacity to reach and exert the proper amount of the force on the control, tool, or object, locating controls, tools, or object closure to the body and improving body alignment can significantly reduces risks of musculoskeletal injury. Worker anthropometry dictates working posture when workspace or task layout cannot be adjusted to the worker's geometry and range of motion. Posture is a significant determinant of biomechanical stress and risk of injury in the low back, shoulder, hands and wrists, and other regions of the body, (Biomechanics/Anthropometry, 3).

e. Visibility is influenced by workers size

Workspace layout, viewport, and placement position of visual signs and other indicators play important roles in determining whether or not a worker can see importer information. Worker height determines their line-of-sight and, thus, display visibility. Tall workers can bend down, and short workers can stand on toes, boxes, or ladders, but in each case, the capacity for and frequency of observing important visual information will decline dramatically. If a worker's line of sight differs significantly from that intended, then performance and safety may be compromised, (Biomechanics/Anthropometry, 3).

2.5.4. Anthropometric fallacies: why do we often encounter inadequate use of anthropometric information in design?

1. "Feels alright to me"

In most cases no effort has been made to fit the workspace, tool, or product to the user population. Unfortunately most designers, or installers of equipment, feel that they represent the average person, and use their body-fit as a test of design acceptability. In short, the "fees right to me" design concept is not acceptable to the majority of the user population. In some cases the original workspace was well designed, but adding additional equipment, or replacing equipment, is done without anthropometric considerations, and a good design is then compromised, (Biomechanics/Anthropometry, 4).

2. “Humans can adapt”

Most workspace designers and installer of equipment realize that “some” people will have difficulty using the workspace, tool, or product. However, there is a very strong belief that “humans can adapt”. This belief is, for most part, true. However, requiring a user to adapt to a poor fitting workspace, tool, or product is not without its performance, safety, health, and with product marketing consequences, (Biomechanics/Anthropometry, 4).

3. “Average person”- Misuse of 50th Percentile Measurement

There is also an erroneous tendency to consider 50th percentile dimensional data as sufficient to accommodate the majority of users. This is not true. The 50th percentile dimensions will accommodate only the narrow portion of the population, not the majority of the users, (Biomechanics/Anthropometry, 4).

4. Source of variation in anthropometric datasets

Finally, anthropometric datasets are not available for all user population, metric of principal interest may not be included within an appropriate dataset, or dataset may be outdated. Selection of an inappropriate datasets, inappropriate methods used to derive needed information from an appropriate dataset, and secular trends in population anthropometry, can produce unacceptable anthropometric specifications used for workspace, tool, or product design, (Biomechanics/Anthropometry, 4).

CHAPTER 3
RESEARCH DESIGN AND METHODOLOGY

3.1 Type of the study

This is an Analytical Cross-Sectional study

3.2. Research methodology

The research focused on ergonomics which includes:

i). Anthropometrical measurements

ii). Design of workstation

iii). The posture of the workers and the way the work was performed

i. Anthropometrical measurements were taken from 111 workers, which include the following:

- The age
- Ethnic group
- The stature
- Body weight
- Vertical grip reach
- Forward grip reach
- Shoulder grip length
- Shoulder/hip height

ii. Observation and recording

The following were measured on different workstations:

- The height of the workstation
- Type of work performed
- Weight handled
- Frequency of handling.

iii. Questionnaires and interviews

Both open-ended and close-ended questionnaires were issued to determine the level of knowledge of the workers and the effect and impact of the work done on their health and safety. Workers were interviewed individually in order to identify common medical problems workers were complaining of and to identify their level of knowledge relating to ergonomics.

iv. Reviewing of medical record

Medical records were reviewed in order to identify common medical problems workers are experiencing.

v. Reviewing of incident reports

Incident reports were reviewed to identify which incidents occurred regularly in the Base Metal Refinery.

vi. Photos were taken from different workstations to study the postures of workers in those workstations whilst performing different tasks were compared with the ergonomic standards or requirements.

3.3.3. Procedures

3.3.1. Methods

Anthropometrical measurements were taken on all 111 workers.

i. Stature

Method: the subject stands fully erect with the feet together. Head oriented in the Frankfort plane. The measurements were taken with the anthropometer.

ii. Body weight

Method: the subject stands on a weighing scale. The HL 120 Avery Berkel scale was used.

iii. Vertical grip reach

Method: The subject stands fully erect with shoulder blades and buttocks firmly against the vertical surface, arms fully extended vertically. The measurements were taken with an anthropometer.

iv. Forward grip reach

Method: Subject stands fully erect with shoulder blades and buttocks firmly against the vertical surface, arms fully extended horizontally. The measurements were taken with an anthropometer.

v. Shoulder grip reach

Method: Subject stands fully erect, with shoulder blades and buttocks firmly against the vertical surface; equal pressure of shoulders against the vertical surface, arms fully extended horizontal. The measurements were taken with an anthropometer.

vi. Shoulder height

Method: Subject stands fully erect with feet together. Shoulders are relaxed, with arms hanging freely. The measurements were taken with an anthropometer.

vii. The age and the ethnic group of all the workers were recorded

3.3.2. Parameters of the workstations:

i. The height of the workstations was measured using the 30 meters Webco steel measuring tape.

Method: the workstation was measured from the floor to the top of the working surface.

Weight handled.

i. the weight of the starter sheet, starter blanks, hanger bar, strapping bar, steel frame, wooden frame, and the cathode were measured using an Avery electronic scale provided in the workshop.

3.3.3. Observation and recording

The duration and repetition of the work done was observed. Three cycles of work were observed and the duration of the work performed recorded to ensure the standardisation of the procedures.

3.3.4. Questionnaires.

Workers were given questionnaires to complete on their own without assistance to ensure that they didn't influence each other.

3.3.5. Interviews

The researcher interviewed workers individually.

3.3.6. Reviewing of medical records.

The researcher reviewed all the medical records by using the workers employee numbers to ensure confidentiality. Medical records were grouped according to the different sections of the body affected and the duration of sick leave was also recorded.

3.3.7. Reviewing of incident reports

The researcher reviewed incident reports and the incidents were recorded including the part of the body affected and which type of work was performed when the incident occurred.

3.3.8. Taking of photo's

A Samsung digital camera was used to take photos of workstations and of workers whilst they perform their duties.

3.4 Ethical Consideration

The proposal will be submitted to the PUK Ethical community for their consent. Norms and values of the workers will be respected by telling everyone who is going to take part in the study about the whol project and give them the assurance that they are not going to be endangered.

No names will be attached to the medical record in order to ensure confidentiality. Alphabetical letters will be used in all medical records which will be analysed.

3.5. Data analysis

SAS Statistical program was used to analyse the data

CHAPTER 4
EXPERIMENTAL RESULTS AND DISCUSSION

4. RESULTS:

One of the important principles of ergonomics is that workplace dimensions should match the body dimensions of the expected users. A good match can be obtained if anthropometric data are applied. Incorrect workplace design where anthropometric data are ignored can cause psychological discomfort, physical fatigue and could be harmful and damaging in the long term. Therefore, anthropometric data are an essential condition to the design of safe, comfortable and effective machine, tools and workplace, (M. Mokdad, 2001, 1)

4.1 TABLE 1: SELECTED ANTHROPOMETRICAL DATA OF WORKERS IN BASE METAL REFINERY

Variable	Number	Min	Max	5th Percentile	50th Percentile	95th Percentile	Standard Deviation
Age (years)	111	20	60	23.0	35	50	8.93
Weight (kg)	111	48	108	54	72	96.5	12.96
Stature (m)	111	1.16	2	1.59	1.82	1.96	0.13
Vertical- grip reach (m)	111	1.94	2.75	2.01	2.17	2.36	0.12
Forward grip reach (m)	111	0.63	0.96	0.73	0.80	0.87	0.05
Shoulder grip reach (m)	111	0.56	6.56	0.60	0.66	0.76	0.56
Shoulder/hip height (m)	111	1.33	1.94	1.44	1.55	1.69	0.09

The table above represents anthropometrical data collected from all the employees working in BMR. The age groups of employees were ranging from 20 to 60 years, with the mean age of 35 years. 85 % of the employees were Tswana speaking, and the remainder 15 % were spread between the Sotho, Tsongas, Zulus and Pedi.

Workers up to the age of 50 fall under the 95th percentile. Therefore 95th percentile should always be considered when designing a workstation or equipment. The aging process influences the muscle mass wasting, recovery rates and stamina. Maximum strength is reached by the early 30's and then typically starts to decline, depending on the fitness level and genetic makeup of the individuals, (RMMS Document Issue 1, 11).

The weights of the workers were ranging from 48 kg to 108 kg with the mean weight of 72 kg. 95th percentile covers the weight of 96.5 kg. The difference in total body weight, lean body mass and stature influence the strength capabilities of all these factors. It should be noted that the stature and other body dimensions, such as arm or leg length, influence the body posture interrelation to the human interface contact point of force application, which will results in differences of muscle strength capabilities, (RMMS Document Issue 1, 10).

Anthropometrical measurements should be used to design workstations that can adjust to fit the smallest member of the population (the 5th percentiles of females) and the largest members of the population (95th percentile male). However, a majority of those left outside of this range are people with disabilities. This means that designing for ergonomics is situational and case-by –case

The body posture adopted by the individual is the result of the human-machine interface and is strongly influenced by the anthropometry of the person. The correct postural alignment can positively affect the strength capabilities of the human, just as a poor posture can adversely affect the strength capabilities. Arm length is most efficient when working between the level of shoulders and elbows, and when the arms are held closer to the body, (RMMS Document Issue 1, 11).

Arm forces must be designed for application in the forward direction. Outward angles of up to 30 ^{0} are acceptable. Design for working above the shoulder, particularly for sustained repetitive tasks, must be avoided. The capability to move levers horizontally is stronger when pushing in towards the middle to the body than away from the body, (RMMS Document Issue 1, 11).

All applications where biomechanical force designs are an important consideration, supportive structures must always be supplied, in order to allow for the most efficient utilisation of biomechanical forces. A supported upright trunk will assist in producing better strength capabilities for both arm and leg strength forces, (RMMS Document Issue 1, 11).

This data above aims, therefore to provide anthropometric data which can be used in design or redesign, description, comparison, and evaluation purposes. It should be noted that body measurements were taken when the body was in static posture. Therefore they should not be used directly in the design or redesign of equipment, tools, and workplaces as they require functional body dimensions which are more representative of human activities, as suggested by Kroemer and Kroemer (Kroemer 1983). He suggested that all heights are decreased by 0.3% of their values except elbow heights which are increased by 0.5% of its value, and knee height which is left as it is (i.e., with no change); reaches particularly forward reach, are decreased by 30%; and if extensive shoulder and trunk movements are involved, the reach is increased by 20%, (Kroemer and Kroemer, 1983).

4.2. TABLE 2: COMPARISON OF THE WEIGHT HANDLED BY WORKERS BY MAKING USE OF THE CALCULATION METHOD IN APPENDIX A

Workstation	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Step 5**	**Step 6**
	W/kg	**Origin of lift in kg**	**No/duration of lift**	**Twisting *0.85**	**Lifting limit**	**Weight in 1 < weight in 5**
Ridgidiser	60	18.14	0.65	N/A	11.79	No
Spot welder	30	24.94	0.65	13.78	13.78	No
Nickel cutter	60	22.68	0.75	N/a	17.01	No
Copper cutter	30	22.68	0.75	N/a	17.01	No
Stidgidiser	30	22.68	0.65	N/a	14.74	No
Loop cutter	23	18.14	0.75	N/a	13.60	No
Stripping starter Blanks	30	22.68	0.75	N/a	17.04	No
Handling of anodes	95	31.75	0.65	N/a	20.64	No
Copper production Sorting	68	24.94	0.65	N/a	16.24	No
14-day production Pulling	108	31.75	0.65	N/a	20.64	No
Nickel Treatment	30	22.68	0.65	N/a	14.74	No
Nickel production Sorting	45.8	24.94	0.65	N/a	16.21	No

Table 4.2 presents the amount of weight handled by the worker at different workstations in kg in relation to the origin of the lift and the duration of the work performed. The allowable weight is calculated by using appendix b: Calculator for analysing lifting operation adapted from Department of Labour and Industries of the State of Washington. See attached annexure 1 (Note that all the weight represented in lb has been converted to kg).

In order to determine the allowable weight to be handled by workers, comparison between the calculated weight limit and the actual weight lifted must be done and if the actual weight lifted is higher than the calculated weight limit, the job concerned is a hazard.

When comparing the amount of weight handled by the workers and the type of the work they perform and the origin of the object from where the load is handled; it is clear that weight handled in the Base Metal refinery while performing work is excessively high. Heavy work is any activity that calls for great physical exertion, and is characterised by a high-energy consumption and severe stresses on the heart and lungs, (Kroemer and Kroemer, 1994).

Recommended weight limit is defined for a specific sets of tasks conditions as the weight of the load that nearly all healthy workers could perform over a substantial period of time (e.g., up to 8 hours) without an increased risks of developing lifting –related lower back pain. The load constant (23kg) refers to the maximum recommended weight for lifting at a standard lifting location under optimal condition (i.e. sagittal position, occasional lifting, good coupling, 25 cm vertical displacement etc), (Ergonomics 1993, 762).

When taking this statement into consideration it is clear that BMR workers are handling loads higher than recommended value, as most workstation heights are too low and uneven (handling and bending with loads on top of the cells). The minimum weight handled is 23 kg and the maximum is 108 kg either by one worker or with assistance. These values show that the weight handled by workers is very high.
The above table disagree with the hypothesis as this proves the workstations were not ergonomically designed to fit the worker.

4.3. INTERPRETATION OF QUESTIONNAIRES.

TABLE 3: SUMMARY OF THE SELF ADMINISTERED QUESTIONNAIRES (REFER TO ANNEXURE 2)

Q-Number			Mean response	Q-Number	Mean response	Q-Number	Mean response
A1	1	2					
	79	19					
A2	1	2		A		B	
	88	10					
B1			3	C1	2	C1	2
B2			4	C2	3	C2	2
B3			3	C3	3	C3	2
B4			4	C4	3	C4	2
B5			3	C5	3	C5	2
B6			3	C6	2	C6	2
B7			3	C7	2	C7	2
B8			3	C8	2	C8	2
B9			3	C9	2	C9	2
B10			3	C10	2	C10	2
				C11	2	C11	2

The above table summarise the responses of the workers about experiencing discomfort or pain in any part of the body as a result of their day to day work activities presented on a scale from 1-5 whereby 1 represents no or less discomfort and 5 represents the worst discomfort. For question B the mean values for the response were ranging from 3 to 4; this clearly shows that this was not ergonomically designed as most of the workers experience discomfort while performing their day to day work, (refer to annexure 2).

Questions C1-10 asked the workers to indicate at different body parts how often they experience discomfort, numbness or pain. This information was ranged between the scale of 1 to 4, and four being the worst. The mean response of the workers was ranging at 2; which indicate that they sometimes feel discomfort, numbness or pain; and the severity of the feeling was moderate. This response could indicate that after a certain period of time the workers become acclimatised to the type of work performed, (refer to annexure 2).

On the self- administered question which analyse how worker lift an object, (question A1), 88% of workers were bending at the waist when lifting an object, and only 18% were bending at the knees. On the question which analyse how the load was handled (question A2), 98% of workers were handling loads close to the body. This response could have occurred due to guessing as sometimes it was difficult to handle the load close to the body when considering how the work was performed (refer to annexure 2).

4.4. SUMMARY OF OBSERVATIONAL DATA QUESTIONNAIRES

TABLE 4: REPRESENT THE RESPONSE OF WORKERS OBSERVED WHILE PERFORMING DIFFERENT TASKS (REFER TO ANNEXURE 3)

Question number	Response in %		Question number	Response in %		Question number	Response in %	
	YES	**NO**		**YES**	**NO**		**YES**	**NO**
1	41	59	15C	95	5	17I	64	36
2	74	26	15D	95	5	17J	87	13
3	61	39	15E	92	8	18A	96	4
4	77	23	16A	83	17	18B	99	1
5	9	91	16B	78	22	18C	90	10
6	24	76	16C	14	86	18D	91	9
7	64	36	16D	90	10	18E	83	17
8	78	22	16E	94	6	18F	32	68
9	80	20	17A	82	18	18G	89	11
10	52	48	17B	41	59	19A	61	39
11	37	63	17C	84	16	19B	42	58
12	87	13	17D	78	22	19C	35	65
13	16	84	17E	45	56	19D	23	77
14	63	37	17F	9	91	19E	62	38
15A	95	5	17G	23	77			
5B	96	4	17H	13	87			

From the table presented above, it clearly shows that the work performed by the workers was not ergonomically design to fit the workers as it involves handling of loads in an awkward position (posture). This table also shows that the workers had to perform the work while bending either the neck or at the waist without the ability to vary posture and the work is highly repetitive, (see response for question 7-10). The posture of the workers were also so bad that they had to use the same motion with little and no variation (see response for question 15A-E)

i. Manual material handling

On the question analysing manual material handling 83% of the workers were handling weight. About 78% of the work needed lowering of the load, and 90% of the work needed workers to bend on the waist and 94% answered yes to twisting of the waist while performing the work. This also shows that the workers were performing heavy work while handling loads. Only 14% of the workers were exposed to "over the head" reaching.

ii. Physical energy demand

On the question which analyse whether the weight handled was more than 23 kg, 84% of the work involved handling of weight. And on whether bending, stooping, or squatting a primary task activity 84% positive respond was recorded.

About 78% of the work involves lifting and lowering of loads and 87% of the workers complain that the rest breaks and fatigue was insufficient.

iii. Other musculoskeletal demand

The work performed very high muscular demand on the body as the workers had to handle loads, the work postures also require frequent bending either on the neck or waist and the work was also highly repetitive, (see response to question 18A-G in table 4) .

iv. General workplace

The workers were complaining about the kind of shoes provided as most experience athlete foot and sores especially during summer. 70% of the workers complained about the shoes provided. Rubber shoes were worn throughout the workstation and when it is too hot most of the workers were treated for athlete foot. In order to reduce these condition workers may be supplied with socks.

4.5. REVIEWING OF MEDICAL RECORDS

Medical records were reviewed and grouped according to different parts of the body affected and the time lost due to sick leave. The graph represented in appendix 3 shows that prevalence of low back pain was the highest and most time was lost due to this problem. This supports that handling of loads is the contributory factor to this problem.

The medical records a period of 1 year (May 2002-2003) was also analysed, and this graph (appendix 2) also shows that most employees were booked off due to lower back problems and more time is lost due to this problem. This could have occurred because workers had to handle loads while performing different tasks.

4.6. REVIEWING OF INCIDENTS REPORTS

i. Comparison of number of injuries which occurred in relation to the type of work/task performed

When comparing the data presented in appendix 3, it is clearly visible that more incidents occur due to handling load, and is followed by slipping and falling. Handling of starter sheets, starter blanks and cathodes which are more than 23kg could be the contributory factor to these high incidents. The second highest incidents occurred due to slipping and falling, and this also holds true as the work surface is very slippery and always wet. The results presented in this graph (refer to appendix 3) also shows that height of the work surface is not determined in relation to the physical work to be performed, the dimensions of the work piece itself, and on the need to observe the work done.

ii. Comparison of number of incidents which occurred in relation to different types of occupation

When comparing number of incidents occurring in relation to the type of work done. It is clearly visible that more incidents occur among cell workers than in other occupations. This graph also shows that the workstations which are not ergonomically designed to fit the worker and the machinery and equipment and the posture of the workers are not in line with good ergonomic standards and practice, (see appendix 4).

iii. Comparison of number of incidents that occurred in relation to the type of work done

When comparing the number of incidents which occurred with the type of work done, it clearly shows that stacking and handling of metals has the highest number of incidents which occurred. The workers are involved in handling and stacking of heavy materials therefore the amount of weight handled is higher than the NIOSH recommended weight limit of 23kg as shown in table 2, (see appendix 5).

4.7. COMPARISON OF DIFFERENT ERGONOMIC PRACTICES AT BMR WITH THE REQUIRED AND RECCOMMENDED ERGONOMIC PRACTICE.

Different ergonomic practices were observed at all workstations to compare whether the way the work is performed and the design of the workstations are in such a way that it is designed to fit the workers.

4.7.1. STARTER SHEET PREPARATION

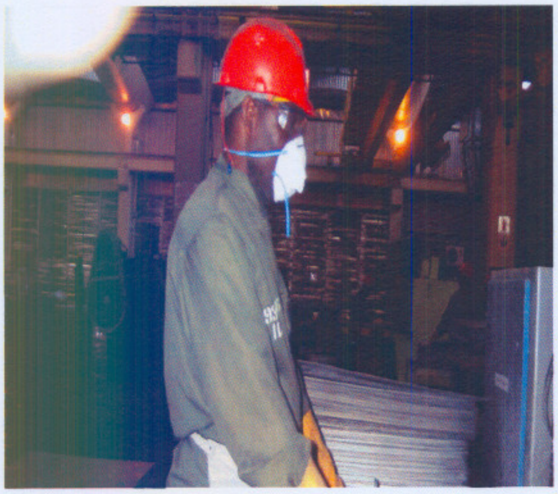
i. Ridgidising of starter sheets

Picture-1: Worker operating the ridgidiser

Starter sheets are ridgidised to strengthen the sheet preventing it from bending thus causing short circuit in the cell. The ridgidiser which was 1.08 meters away from the floor with the side bay which was 0.6 meters high which was used for handling the starter sheets (see picture 1 above). The worker had to lift two starter sheets weighing 20 kg (two starter sheets) both from the side bay into the ridgidiser in order to ridgidise them. The whole process was repeated every 19 seconds for

8 hours. During this process the worker was handling the load higher than the recommended load and the work was performed while standing and it was repetitive. After ridgidising the starter sheet it was then dropped on the floor and then the worker bend at the waist to properly pack them into a batch of 10.

i. Nickel starter sheet trimming



Picture-2: Worker trimming the starter sheet

Two starter sheets were put into the cutter, cut once by pressing the foot operated lever down, swung 90 ° and insert the side to be cut squarely into the cutting machine with the side nearest to the operator once again overlapping the dimensional guide. Three cuts were made.

The nickel cutter's height was 0.89 meters high and the side bay 1.5 meters high without loads and 1.2 meters high with the loads. The worker was lifting two starter sheets from the side bay put it into the nickel cutter and cut it and drop it on the floor bend for 5 seconds to straighten them up (see picture 3 below). The whole process was repeated every 31 seconds for a period of 8 hours with a lunch break in between.

Picture-3: The worker dropping and straightening the starter sheet on the floor

Picture 4a: Worker spot welding straps to starter sheets

At the spot welder which was 1meter high with the side bay of 0.88 meters high. The worker was lifting the load from the side bay into the spot welder to weld in the handles; and after that the other worker bend at the waist and drop the load on the floor and bend for 5 seconds to straighten the loads (see picture 4c below)

Picture-4b: The worker spotwelding the handles

Picture-4c: The worker dropping the starter sheet on the floor after welding

Damaged starter sheet are used for loops, and during the process of loop bending the side station which was 0.88 meters high was use to hold the starter sheet and put into the loop cutter which was 0.97 meters high for cutting then slide them onto the packaging bay which was 0.5 meters high. This process was repeated every 18 seconds for 8 hours excluding breaks.

At the copper cutter which was 0.96 meters high with the side bay which was 0.85 meters high without loads and 0.5 meters more with the loads? The worker had to hit the starter sheets with a hanger bar which weighed 8 kg to straighten them before putting them into the cutter for cutting then dropped them on the floor.

At the copper stidgidiser which was 0.92 meters high with the side station which was 1 meter high without the load and 1.29 meters high with the load (see picture 5a and 5b). The machine was operated by three workers. The plate was picked up from the side bay and put into the machine to be stidgidised and then the other worker drops and straighten the starter sheet while bending on the waist (see picture 5c below).

Picture-5a: Worker operating the stidgidiser

Picture-5b: The worker operating the stidgidiser

Picture-5c: The worker dropping and straightening the starter sheets

During the whole procedures the workers had to stand for 8 hours. Standing for a long period of time on the hard surfaces causes physical fatigue. Leg muscles are totally static, and constricted as they work overtime to keep that person in an upright position. Blood flow is greatly reduced causing pain and discomfort.

4.7.2. COPPER ELECTROWINING

i. Copper starter cell pulling

During starter cell pulling a ten- fold bailer to the crane hook, the crane transport the bailer to the cell to be pulled, the crane lowers the bailer to just above the cell top. The bailer hooks are lowered in between the starter blanks hanger bars, the cell worker properly hook the hanger bar onto the bailer while bending at the waist until all 10 starter blanks are attached to the bailer hooks (see picture 6a below).

Picture-6a: Worker properly hooking the bailer onto the hanger bars and properly fitting the hooks onto the hanger bar.

The crane then lifts the starter blanks to the cell wash located next to the stripping rack, for washing. During this process the worker had to pick up and remove the starter blank from the crane bailer into the wash cells, bend over to check that the starter sheets are properly immersed into the water. During this process the worker bended at the waist (see picture 6a above)

When the blanks are clean, they are then removed and transported to the stripping rack which is 1.35 meters from the ground, to be stripped.

ii. Stripping of copper starter sheets

The starter blanks are moved to one side of the stripping rack, one blank is moved away from the rest allowing a safe working space. The corners of the starter sheet are removed by using a paint scraper. The worker then removes the side holder from the blank, hit with a hanging bar weighing 8 kg, to loosen and peel the sheet away from the starter blank on both side then drop it on the floor (see picture 7a and 7b below). After stripping the starter sheet the worker picked it up and stack the sheet onto the wooden pallets located next to the stripping rack (see picture 7c below). The same process is repeated until 10 starter blanks are striped.

Picture- 7a. Worker stripping the starter blanks

Picture- 7b: The worker pulling and stripping the starter blanks

Picture 7c: The worker lifting and packing the starter sheet

After all the starter blanks are stripped the crane lowers the bailer hooks above the starter blanks, attach the hanger bars to the bailer hooks by hand, then the crane hoist the load the starter blanks to the cell being pulled, the crane lowers the starter blank to directly above the cell top. The worker lifts the starter blank from the crane above shoulder height into the cell. The worker then bends at the waist for 5 seconds to ensure that edging strips stays in position. The same process is repeated until 40 starter blanks are pulled, stripped and replaced in the cell.

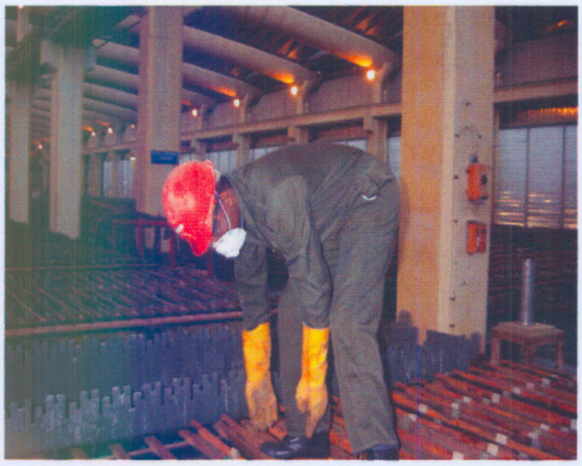
iii. Copper production pulling

The cathodes are removed and extracted from the cell. The worker bends at the waist to check whether the bailers are properly fitted into the hanger bar. The cathodes are then extracted from the cell and transported to the copper cathode wash tank.

After dislodging the cathodes in the wash tank. The workers then lift the starter sheet from the starter sheet storing rack, walk for 1.5 meters with the load, lifted it to above shoulder height, and handed the starter sheets to the worker standing on top of the cell (see picture 8a below). The worker then takes the starter sheet, lifts it to above shoulder height to put it into the cell. The worker then bend at the waist every eight seconds to ensure that the starter sheet is properly fitted into the cell (see picture 8b and 8c below). Above steps are repeated until 40 cathodes are loaded to the wash tank.

Picture- 8a: The worker lifting the starter sheet

Picture- 8b: Worker properly fitting the starter sheet into the cell



Picture-8c: The worker checking whether the sheets are properly fitted into the cell

The crane then removes the cathodes from the wash tank, using a ten –fold bailer, and lowers them to the basement floor onto the roller frame, 10 at a time. The cell worker then remove the hanger bars from the cathodes and loads them into the hanger bar basket. Two workers then pull and roll the cathodes over the roller frame (see picture 9a below); and dropped them on the floor and packed into pallets (see picture 9b below) which are then transported to product management by the fork lift. The cathodes are then sorted, stacked and stored.

Picture -9a: The worker pulling and rolling production

Picture -9b: Worker packing production

4.7.3. NICKEL ELECTROWINING

i. Nickel starter cell pulling

During starter cell pulling a tenfold bailer to the crane hook, the crane transport the bailer to the cell to be pulled, the crane lowers the bailer to just above the cell top. The bailer hooks are lowered in between the starter blanks hanger bars, the cell worker who is standing on top of the cell, and then bend at the waist for 5 seconds to properly attach 10 starter blanks to the bailer hooks. The worker had to bend at the waist to check whether the bailer had been properly fitted onto the hanger bar. This practice force the worker to work while bending at the waist (refer to picture 8c).

The crane then lifts the starter blanks to the cell wash located next to the stripping rack, for washing. During this process the worker had to pick up and remove the starter blank from the crane bailer into the wash cells, bend over for 3 seconds to ensure that they are properly immersed into the water (refer to picture 8b). And again if there are blanks that stick to the bag frame the worker had to manually pried the frame loose with a tommy bar. Therefore the worker had to bend at the waist to loosen the frame and is exposed to handling more weight, which had to be picked up above shoulder height, to properly remove it from the cell.

The blanks are then transported to the wash cell and when the blanks are clean; they are then removed and transported to the stripping rack which is 1.35 meters from the ground.

ii. Nickel starter sheet stripping.

After the blanks are safely dislodged onto the stripping rack, the worker then pushed all the starter blanks to one side of the strapping rack, and then slide one starter blank away from the rest. The worker loosens the bottom corner of the plastic strips by hand or by hitting with a screwdriver where the strips were removed (refer to picture 7a). The sheet is removed by forcefully pulling it from the starter blank (refer to 7b). The same process is repeated until all ten starter blanks are stripped and starter sheets are packed onto the wooden pallets. During the stripping process the worker had to forcefully strip starter sheet, lifting it up and bend at the waist to properly straighten it up on top of the pallet (refer to picture 7c).

After all ten starter blanks are stripped the worker had to check whether the starter blanks are packed correctly, pieces of nickel crystal where present are removed by paint scrappers, and whether the hanger bars are in place, he then attaches the crane bailer hooks onto the hanger bars. The starter blanks are then transported to the wash cell.

From the wash cell the crane then moves the starter banks to the cell they will be put on, lowers the starter blanks to just above the cell, then worker had to manually remove the starter blank from the crane, and put it into the bag frames and then lowered into the cell, (refer to picture 8b).The same process is repeated until 40 starter blanks have been stripped and replaced.

iii. Nickel starter sheet anodic and boric treatment.

The nickel starter sheets had to be placed into the anodic and boric treatment cell and treated with reverse current in an acidic solution, because if they are stored in the open for the extended period the surface becomes passive and will not readily accept metal being plated, or they get covered with various dirt.

The starter sheets are removed manually from the starter sheet rack, and hanger bars are inserted into the straps. After this the worker then lifts the starter sheet from the straightening board, walk for 1, 5 meters with the load, lift it to above shoulder height, handed it to the worker standing on top of the cell (refer to picture 8a), who also lifted the starter sheet above shoulder height to properly insert it into the cell between the cathode, bend at the waist to check whether the nickel spent supply hand valve is open and the spent solution is overflowing at the cell overflow weir box (refer to picture 8b). The same process is repeated until 40 starter sheets are put into the anodic cell.

The crane then lowers a 40-fold bailer hooks in between the starter sheet hanger bars, then the workers attaches the hanger bars to the bailer hooks, while bending at the waist (refer to picture 8c). The crane then lifts starter sheets and transports them to the boric holding cell, just above the cell top, and then the workers lifts the starter sheet and carefully insert them into the cell.

The process is repeated until 3 batches of 40 starter sheets are treated and stored in the boric cell, 120 sheets per cell.

iv. Nickel production pulling

During production pulling a ten- fold bailer is attached to the crane hook, the crane transport the bailer to the cell to be pulled, the crane lowers the bailer to just above the cell top. The bailer hooks are lowered in between the cathodes hanger bars, the cell worker who is standing on top of the cell, bend at the waist for 5 seconds to properly attach 10 cathodes to the bailer hooks (refer to picture 8c).

The crane then lifts the cathodes to the cell wash located next to the drop out well, for washing. The crane then lowered the cathodes into the wash cell. The worker bends at the waist to check whether the cathodes are fully submerged under the hot water (refer to picture 6a).

After the cathodes are dropped into the wash cell a ten-fold bailer is lowered by the crane just above the boric holding cell, the worker then attaches ten starter sheets to the bailer hooks by hand, whilst bending at the waist (refer to picture 8c). Then the crane transported the starter sheets to the cell being pulled, lower the starter sheet just above the cell top, then the workers insert the starter sheets into the empty bag frames from which the cathodes have been pulled.

From there the crane travel to the wash tank, lowers the bailers, then the worker ensures that the bailer are properly fitted into the hanger bars, then the crane lifts the cathodes, to the drop out well and lowers it to the basement. The cathodes are then lowered onto the duckboard on the basement floor, dislodges the hanger bars from the bailer hooks. The operator extracts the hanger bars from the cathode loops and places them into the hanger bar basket. The same process is repeated until 40 production cathodes had been pulled, and 40 starter sheets are put into production cells.

v. Resorking

If the cathode bags are not tied properly to the steel supporting bar, the bag will drop down below the cell level, and the spent will flow into the bag, causing pitting of the cathode.

In the case of loose bags, the complete frame (wood frame-weighing 16 kg and steel frame weighing 18 kg) must be removed from the cell using the fold bailer, the nylon strings retied properly and the bag and the cathode replaced in the cell.

Picture- 10a: worker resorking damaged bag

During the resorking process the workers had to retie the bags while bending at the waist or while squatting (see picture 10b below)

Picture-10b: worker resorking damaged bags

vi. Operation of the crane

During the removal of copper and nickel production and removal and insertion of starter sheets and starter blank in and out of the cells, the driver of the crane had to look down to see whether the crane bailer was properly hooked onto the hanger bar. This practise put strain on the operator's neck as he had to bend it more than 90^{0} until 10 or more starter blanks or starter sheets are properly hooked.

Vii. 14 day production

In order to ensure that copper and nickel are plated correctly, a 14 day production test cell is then used for this purpose. After every 14 days cathode weighing 108 kg are removed from the test cell by the crane and when stuck onto the cells workers had to manually remove them from the cell and hang them on the stripping bay. Ten cathodes are then stripped for about 30-35 minutes. A hanger bar weighing 8 kg is used to hit the cathode to loosen the plated sheets from the starter blanks. After stripping the final product is then packed onto 10 pallets. The 14 day production exposed workers to handling loads which could affect their health and wellbeing.

CHAPTER 5

5. DISCUSSION

Since it is clear that the work performed at BMR is a heavy work which involves handling of loads, awkward posture and is repetitive in nature, it is recommended that all workers must undergo fitness tests to determine whether they are fit to perform strenuous work. A fitness test will ensure that the best worker who has the ability and strength to do the work is selected.

Overall physical fitness is a prerequisite in numerous industries: apart from improved productivity and, as direct consequences, improved profitability, it remains fundamental with regard to the maintenance of good health and safety. The South African mining industry is a prime example of an industry relying extensively on physically demanding work, often complicated by hostile environments. Quite clearly, therefore, work fitness must be regarded as an integral component of any realistic health and safety strategy.

Employees should be assessed for functional work capacity tests which embraces mobility, work position and effort in both restricted and unrestricted work environment, as well as the dexterity in different work positions. In addition, overall work capacity is also assessed. "Overall fitness' must be seen as an essential adjunct towards achieving high level of productivity, including health and safety. (Obviously, any such concept should be extended to include mental wellbeing as an equally important parameter of fitness).

5.1.2. Handling of load

In many years traditional guidance on manual handling have concentrated on the weight of the load. It is now well established that the weight of the load is only one- and sometimes not the main- consideration affecting the risk of injury. Other features of the load such as its resistance to movement, its size, shape or rigidity must also be considered. Proper account must also be taken of the circumstances in which the load is handled.

5.1.3. Is the load bulky or unwieldy?

The shape of the load will affect the way in which the weight can be held. For example, the risk of injury will be increased if the load to be lifted from the ground is not small enough to pass between the knees, since its bulk will hinder a close approach. Similarly if the bottom front corners of the load are not within reach when carried at waist height a good grip will be harder to obtain. And if the load to be carried at the side of the body does not clear the ground without requiring the handler to lean away from the load in order to raise it high enough, the handler will be forced into unfavourable posture.

Low back pain has been a long –standing health problem in manual workers. The training of workers in the safe handling techniques is believed to constitute a preventative measure for reducing risk factors in the working environment. Even though a large consensus of opinions exists for the promotion of sound biomechanical principles, their applications in training programs does not appear simple. Training programs have met little success in reducing low back injuries and their effectiveness can be contested: the reason appear to be the lack of control conditions and appropriate measurement techniques, inadequate training methods, either for their lack of applicability or lack of rationale and the lack of consideration for the adaptability to suit variations in task, workplace and worker (M. Gargon, 2003, 1) .

5.2. GENERAL RECOMMENDATIONS

In order to realise optimum performance, it is necessary that the movements of the body members be such that a favourable load originates; fatiguing body motion have been avoided. According to the principle of motion economy, the motion should be confined to the lowest classification with which it is possible to perform the task satisfactorily. By moving body members in harmony, simple and logical results are obtained, (Unasylva- no 29-logging and concession-ergonomics in tropical agriculture, 2)

Attention should be paid to the following: (a) there should be good balance among bodily movements; (b) the amplitude, strength, speed and pace of movements should be mutually adjustable; and (c) movements with great accuracy requirements should not entail exertion of considerable muscular strength.

The working posture is largely determined by the layout and shaping of the tools, as well as by the location and displacement of the controls. The probable locations of pains or other symptoms, as a consequence of bad posture, have been described in current literature, (Unasylva- no 29-logging and concession-ergonomics in tropical agriculture, 2)

5.2.1. Handling of loads

The capacity for infrequent lift is a combined function of the individual's muscle strength and the strength of various body structures, particularly the lumber spine. Studies have confirmed that lifting under certain condition is limited more by the stresses on the lumber spine than by limitation of strengths. Moreover, when manual lifting is modelled, large momentum are created in the trunk area, especially when the load cannot be held close to the body. (Revised NIOSH equation, 753).

During lifting, three types of stresses are transmitted through the spinal musculoskeletal tissue to the L5/S1; compressive force, shear force, and torsional force. The relative importance of each stress vector is not well understood. Disc compression is believed to be largely responsible for vertebral end-plate fracture, disc herniation and resulting nerve root irritation.
Moreover, large compression forces at the L5/S1 spinal disc can be produced by muscular exertion, especially during lifting (ergonomics, 1993, revised NIOSH equation, 753).

The load constant (23 kg or 51 lbs) was recommended by NIOSH and it refers to the maximum recommended weight for lifting at a standard lifting location under optimal condition (i.e. sagittal position, occasional lifting, good coupling, equals or less than 25 cm vertical displacement) (ergonomics, 1993, revised NIOSH equation, 753). Since the work performed at BMR is repetitive with awkward posture and with workstations which are not ergonomically designed, therefore it does not support the above-mentioned statement.

It is recommended that the loads handled by the worker should be reduced to less than 23 kg or the lifting process should be mechanised; and management should also ensure that the workers follow work procedures as stipulated to avoid handling more weight than required.

5.2.2. Workstation design

Using an old rule-of- thumb, if we try to design something that everyone can use, no one will be able to use it. The same principal hold true with ergonomic workstation design. The idea of workstation design is to make it fit the user. It will have to be adjustable for many body heights, sizes, weights, and reaches whether sitting or standing, (Ergonomics Information, 2).

One of the first principals in workstation design is to consider the tallest employee and the employee with a shortest reach. The reason being is that we cannot raise the shorter employee or lengthen the employee's reach. Platforms can be used to raise shorter employee to a proper working height. Either sitting or standing, the employee should be comfortable at his work station. The arms should rest at the employee's sides and the employee's back/neck should be kept straight; therefore the work level must be waist high (Ergonomics Information, 2).

Standing in one place for prolonged period of time may lead to a host of injuries. Sit/stand workstation should be considered. If the employee has to stand, providing something to lean on so that the employee will have the opportunity to rest. Also providing a heavy rubber pad to stand on will help relieve neck, shoulder, back, and leg stress. With the causal observation of workstation, each of the prone positions can be eliminated.

Another area of workstation design is product flow. One simple question is "how many times does an employee have to pick up and carry materials or the process before it is completed?" Each time the product is moved from one work level to another, the chances of back, neck and shoulder injuries and the host of repetitive motion disorder are greatly increased, (Ergonomics Information, 3).

Tools should be designed, modified or used in a manner to rest in a near neutral position. The handles of the tools should extend the full length of the palm, be soft/shock- resistant and large enough to be easily gripped, trigger activate tools should be modified to a full handgrip activation.

5.2.2a. Posture should be avoided where:

- the elbow is above mid torso,
- the hand is above the shoulder,
- the arms must reach behind the torso.

5.2.2b. Avoid wrist posture where there is:

- inward or outward rotation with bent wrist,
- excessive palmer flexion or extension,
- ulnar or radial deviation,
- pinching or high fingers forces with above torso.

Avoidance of mechanical stress concentration on elbows, base of palms and backs of fingers should be emphasised. Wooden pallets should be used to increase the height of the side bays to avoid unnecessary bending at the waist.

5.2.2c. General lifting guidelines include

- keeping the load to the body,
- using the most comfortable posture,
- lifting slowly and evenly (don't jerk),
- avoiding twisting the back,
- securely gripping the load,
- using the lifting aids or getting help.

5.3.1. Basic anthropometrical design guidelines

Equipment and the workplace must fit the user population. The user population will vary in size, and the equipment design must account for this range in size. There are three ways in which the design will fit the user.

5.3.2. i. Don't design for the average worker

In the past the tendency has been to design for the "average man". Unfortunately, no human is the average in all dimensions. If one examines anthropometric data for the middle 30 % of the large population (i.e. n=4000), less than 40 subject were found to be average in across five measurements. For this reason, we must rely upon the concept of "design limits", (Biomechanics/Anthropometry 1: 9).

5.3.2. ii. Design for population extreme

Design and sizing of objects or the workplace should ensure accommodation, compatibility, operability, and maintainability by the user population. Generally design limits are based on the range of the user population from the 5th percentile to the 95th percentile values for critical body dimension, as appropriate. The use of this range theoretically covers 90%.

Use the 5th percentile female limit when personnel must position their body to operate or maintain equipment. Use the 95th percentile male limit when designing to accommodate a full range of unrestricted movement.

Accommodate 100% of the population's dimensions and strength capability safety devices and systems, (Biomechanics/Anthropometry 1: 9-10).

5.3.2. iii. Provide adjustability

Even when an anthropometric design parameter is acceptable to the vast majority of the working population (i.e. 5th through the 95th percentile), providing adjustability in the parameter can accommodate a larger segment of the population and allows the worker to make adjustment to enhance strength, capability and comfort. Adjustable chair geometry, variable desk top height, adjustable vehicle seat , and providing the ability to elevate or lower the standing platforms are examples of design adjustability that help very large or small workers to accommodate to their workspace, furniture, and tools, (Biomechanics/Anthropometry 1: 10).

5.3.2. iv. Provide several sizes

Several sizes of equipment may be required to accommodate the full population size-range. This is usually necessary for equipment or personal gear that must closely conform to the body such as clothing, (Biomechanics/Anthropometry 1: 10).

5.3.3. Human Body

The spine is the only stiff connection between the upper and the lower part of the body. It carries information from the brain to the functional systems of the body. It is essentially that we take care of it. Back problems account for more industrial days lost than any other cause, and they are often the most difficult to substantiate, or disprove, (Kompendier, 5).

The spine has a series of normal curves called lordosis (curved towards the front) and kyphosis (curved towards the back). These may become excessively or wrongly curved. Basic mechanics show that the part most vulnerable is the lumbar section. Badly organised lifting is especially dangerous, (Kompendier, 5).

CHAPTER 6

6. CONCLUSION

In conclusion, this study showed that the machinery and the equipment used and the posture of the workers and the load handled were not in line with good ergonomic standards and practice. These findings were also supported by medical records which proofed that employees were booked off due to musculoskeletal diseases, more especially lower back pain. According to NIOSH recommended weight limit a worker had to handle is 23 kg, and the results presented in table 2 clearly showed that the minimum weight handled was above the 23 kg limit with the maximum of 108 kg.

6.1. Training

The work practice of the workers showed that their level of knowledge in relation to ergonomics were limited. Workers didn't know the importance of good lifting practice and its impact on their health. Incident reports also showed that most incidents occurred in BMR in relation to all other working places, and most incidents occurred during metal handling (as shown in appendix 3).

Ergonomic training programmes must be developed and implemented, to ensure that workers are properly trained and become aware of good ergonomic practice and standards.

6.2. Selection of workers

Since the work in BMR is a physically demanding one, overall 'physical work fitness' must be a prerequisite, as apart from improved productivity and, as a direct consequence, improved profitability, it remains fundamental with regard to the maintenance of good health and safety. Functional work capacity as a tool to assess employees physical abilities to undertake a variety of job-related tasks should be developed to ensure that the best employees are placed in a specific type of work, which he is capable of performing.

6.3. Assessment of overall fitness

The term overall fitness embraces both medical and physical fitness. The physical fitness consists of age consideration, anthropometry and physique and heat tolerance (where necessary); and medical fitness consist of satisfactory health, as determined by the general medical examination, and the absence of critical contra-indication or impairments as determined by a risk base medical examination, i.e. medical surveillance. These requirements can be coupled with mental wellbeing and aptitude, which can be determined through psychometric tests.

6.4. Work procedures

Employer has to ensure that there are working procedures developed for each task to be performed and also ensure that it is followed. It was established that BMR had working procedures which were not implemented and monitored. This resulted in unnecessary handling of weight, as in many cases two starter sheets were handled instead of one. Measures should be taken to train workers and make them aware of all procedures in place and the importance of following them.

Properly implemented and monitored work procedures will insure the decrease in incidents and injury occurrence which are unnecessary.

6.5. Manual material handling

Employer should ensure that their employees understand clearly how manual handling operations have been designed to ensure their safety. Employees, their safety representatives and safety committee should be involved in the development and implementation of manual handling training and the monitoring of its effectiveness.

An employer has to provide training to employees which is supplemented with job specific information on manual handling injury risk and prevention as part to reduce the risk. Employees to be trained to recognise the loads whose weight, in conjunction with their shape and other features, and the circumstances in which they are handled, might cause injury.

6.6. ANTHROPOMETRICS

Anthropometrical data can be used to determine whether the worker is fit to work or perform a specific task. Anthropometrical data is most helpful when conducting fitness tests as it could guide us in selection of the proper man for a job. This will safe the company money lost on absenteeism due to people who are always booked off as a result of not coping with the work. Since BMR requires healthy and fit person who can perform optimally without being always sick. It is recommended that all workers in BMR should undergo fitness tests to determine whether they are fit to work in a highly physical demanding work. Anthropometrical data such as body weight and height of the worker can be used to determine if he is fit by exposing him to a moderate exercise and then record his heart rate.

Workplace and work practice should be designed to eliminate unnecessary bending or stretching, especially the moving of heavy objects when twisting or off balance. The height of the work surfaces should be adjusted to the type of work being done. Lifting and handling are the major causes of incidents. Great care must be taken with the design of workplaces. Most ergonomic failures derive from the inability or unwillingness of the designer to incorporate known information into the design process.

CHAPTER 7

7.1. REFERENCES

Biomechanics/Anthropometry- introduction to anthropometry [Web]
http://www/asi.or/msis/:1-4,9,10p

Diversified Ergonomics Ergonomic Data. [Web:]
http://www.diversergo.com/data.html: 2

Ergonomics information
http://www.okhighered.org/training-centre/trnresources/docu.../ergonomic_information.ht: 2-3p.

Ergonomics in the workplace: A resource Guide [Web]
http://janweb.icdi.wvu.edu/media/ergo.html. 1, 8-10p

Ergonomics in the workplace: is it time for an OSHA Standard?[Web]
http://www.policyalmanac.org/economic/archive/csr_ergonomics.shtml: 2, 8-9p

ErgoWeb. Ergonomics Concepts. [Web]
http://www.ergoweb.com/resources/fag/concepts.ctm: 1-6p

Grandjean, E. 1997. Fitting the task to the Man. A textbook of occupational ergonomics. 4th ed. Philadelphia: Taylor & Francis. 363 p.

Kompendier. Ergonomics & Design. [Web:]
http://www.ddc.dk/UK/Laes_om_design/kompendier/grundbegr/gree.html:5p

1999 OSHA Ergonomic Guidelines- 7 of 31 files. [Web]
http://www.afscme1185.org/ergonomics-0/htm

Tennessee Mat Company Rental Mats. Html [Web]
http://64.1/6.23.101/making_ergonomics_work.html: 2p

Revised NIOSH Equation. Application Manual for the revised NIOSH Lifting Equation. [Web] http://www.cdc.gov/niosh/homepage.html: 753p.

OR-OSHA (Online Course 202: Module 3) [Web]
http://www.cbs.state.or.us/external/osha/educate/training/pages/202m3.html: 4-6p

Safety in Mines Research Advisory Committee- A comprehensive ergonomic strategy for the South African mining industry, (Final project Report) [Web]
www.simrac.co.za/newsletter.199.pdf : 11, 20-21p

Unasylva-No. 29 Logging concession – Ergonomics in tropical agriculture and forest workers. Web]
http://www.fao.org/docrep/n9800e05.htm: 2 p

Gargon, M. 2003. The efficacy of training for three manual handling strategies based on the observation of expert and novice workers. Clinical Biomechanics, 18: p, May.

International Standard (ISO7250) - Basic human measurements for technological design.

Kroemer, K. H. E. and Grandjean, E.1997. Fitting the Task to the Human, A Textbook of Occupational Ergonomics.5th ed. Philadelphia:Taylor & Francis. 416 p.

Kroemer K, Kroemer H, Kroemer-Elbert K 1994. Ergonomics- How to design for ease and efficiency. Prentice Hall: Fabrycky and Mize: 120, 469, 473-474p

Mokdad, M 2002. Anthropometric study of Algerian farmers. International Journal of industrial Ergonomics, 1,29: p, May.

RMMS Document (Document issue: 1)- Ergonomic Design: Biomechanics- Specific Body Strength data, Standard for RSA-MIL-STD-127: Vol 5. 10-11p.

Rustenburg Base Metal Refiners: Work instruction –WI/BMR/17; Nickel Electrowinning.

Rustenburg Base Metal Refiners, Copper electrowinning, 2002. Work instruction.

Rustenburg Base Metal Refiners: Work Instruction- I/BMR/20; Starter Sheet Preparation

Rustenburg Base Metal Refiners: Work Instruction –WI/BMR/25; Process Flow

Rustenburg Base Metal Refiners: Procedure Manual- PM/BMR/01; Procedure Manual

SOUTH AFRICA. 1995. Occupational Health and Safety Act No 85 of 1995. Pretoria. Government Printers.

SOUTH AFRICA. 1996. Mine Health and Safety Act No. 29 of 1996. Pretoria: Government Printer

ANNEXURE 1

Appendix B: Calculator for analyzing lifting operations

Company

Evaluator

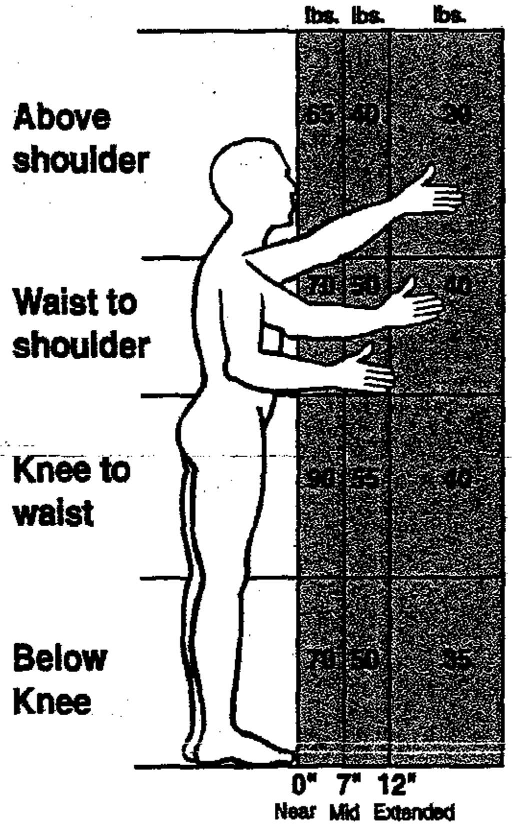
Job

Date

1 **Enter the weight of the object lifted.**

Weight Lifted
lbs.

2 **Circle the number on a rectangle below that corresponds to the position of the person's hands when they begin to lift or lower the objects.**



Department of LABOR AND INDUSTRIES

3 **Circle the number that corresponds to the times the person lifts per minute and the total number of hours per day spent lifting.**

Note: For lifting done less than once every five minutes, use **1.0**

How many lifts per minute?	**How many hours per day?**		
	1 hr or less	**1 hr to 2 hrs**	**2 hrs or more**
1 lift every 2-5 min	1.0	0.95	0.85
1 lift every min	0.95	0.9	0.75
2-3 lifts every min	0.9	0.85	0.65
4-5 lifts every min	0.85	0.7	0.45
6-7 lifts every min	0.75	0.5	0.25
8-9 lifts every min	0.6	0.35	0.15
10+ lifts every min	0.3	0.2	0.0

4 **Circle 0.85 if the person twists 45 degrees or more while lifting.** 0.85

Otherwise circle 1.0

5 **Copy below the numbers you have circled in steps 2, 3, and 4.**

____ **lbs.**	**X**	____	**X**	____	**=**	**Lifting Limit** ____ **lbs.**
Step 2		**Step 3**		**Step 4**		

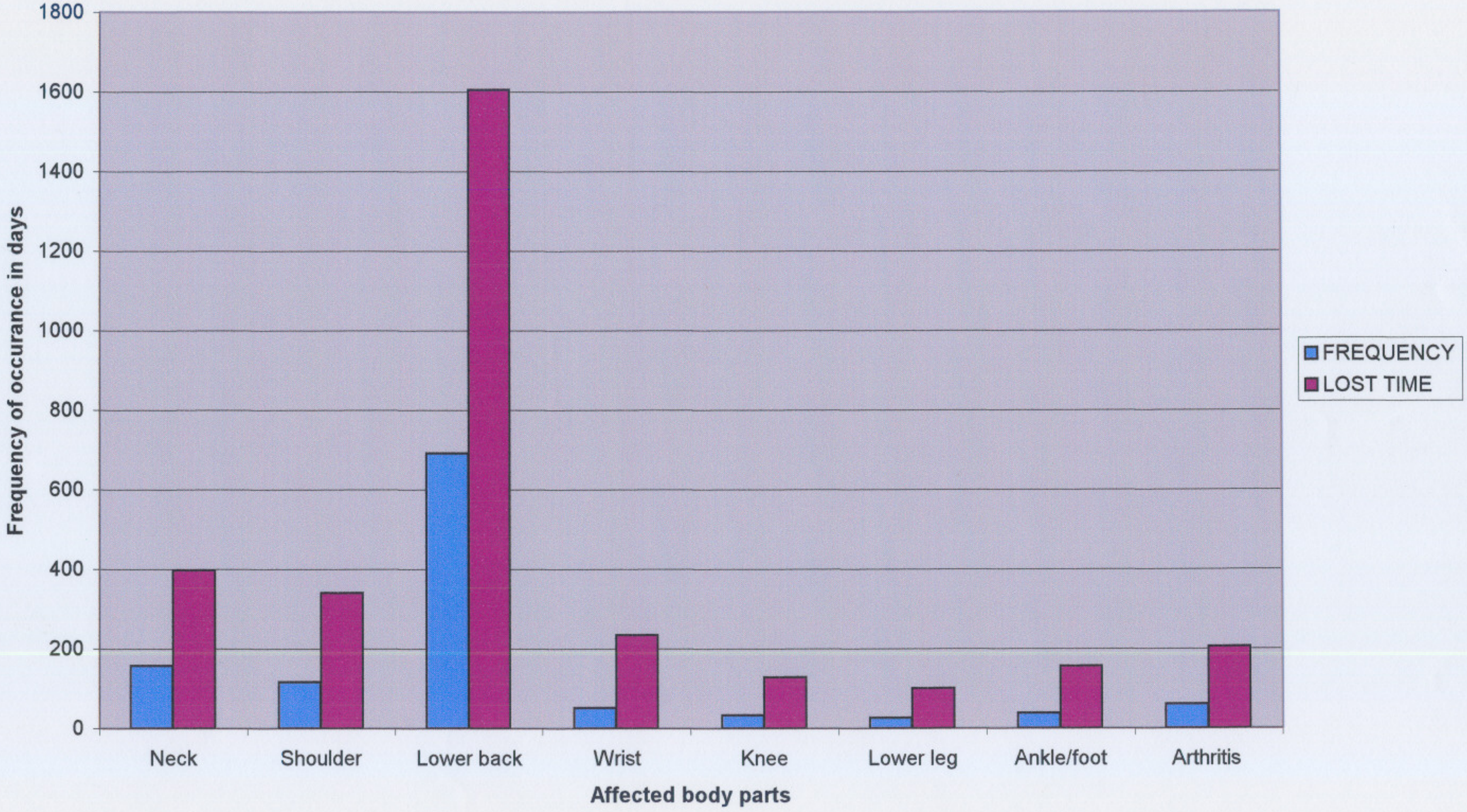
6 **Is the Weight Lifted (1) less than the Lifting Limit (5)**

Yes – OK
No – HAZARD

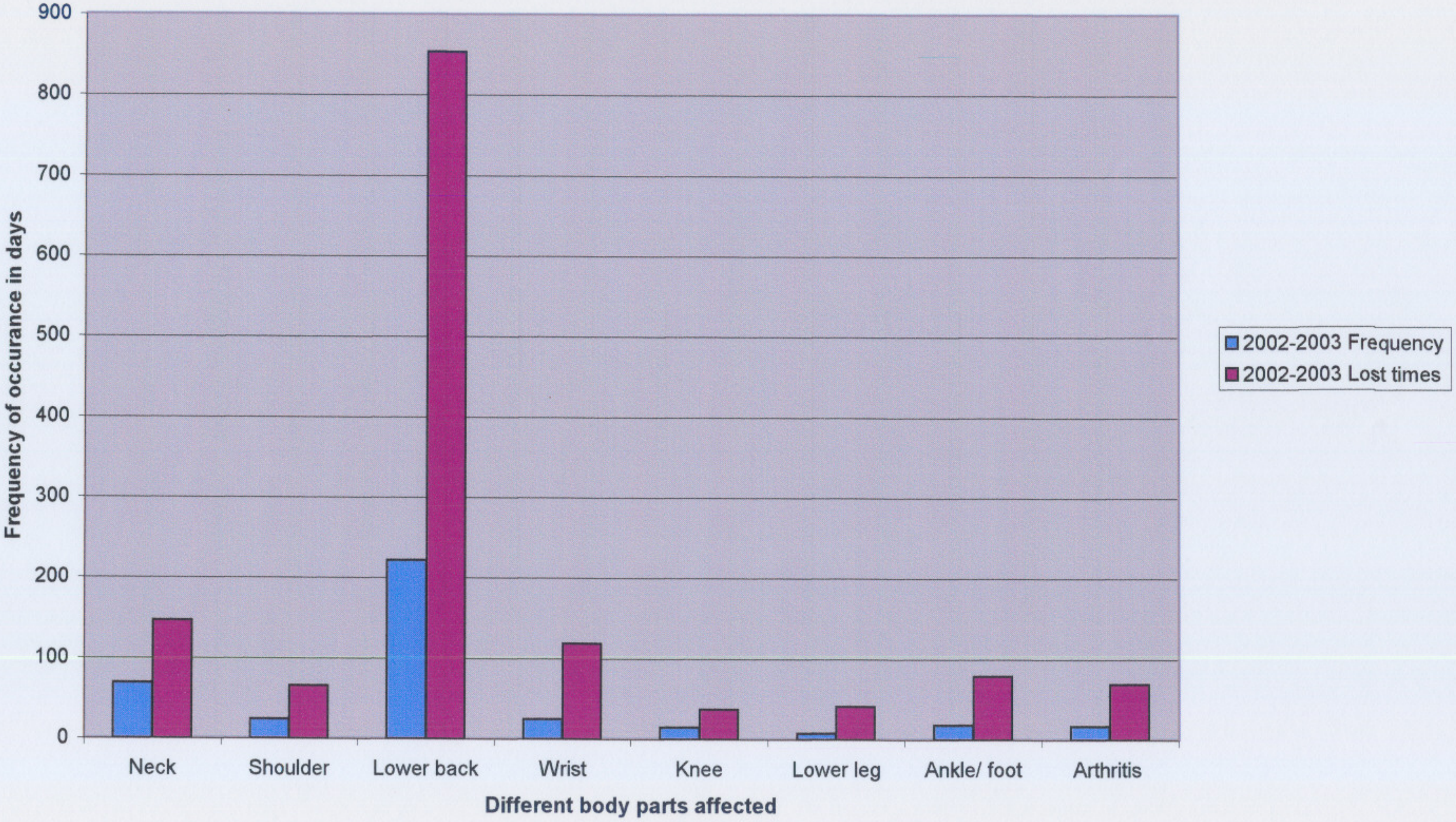
Note: If the job involves lifts of objects with a number of different weights and/or from a number of different locations, use Steps 1 through 5 above to:

1. Analyze the 2 worst-case lifts – the heaviest object lifted and the lift done in the most awkward posture.
2. Analyze the most commonly performed lift. In Step 3, use the frequency and duration for <u>all</u> the lifting done in a typical workday.

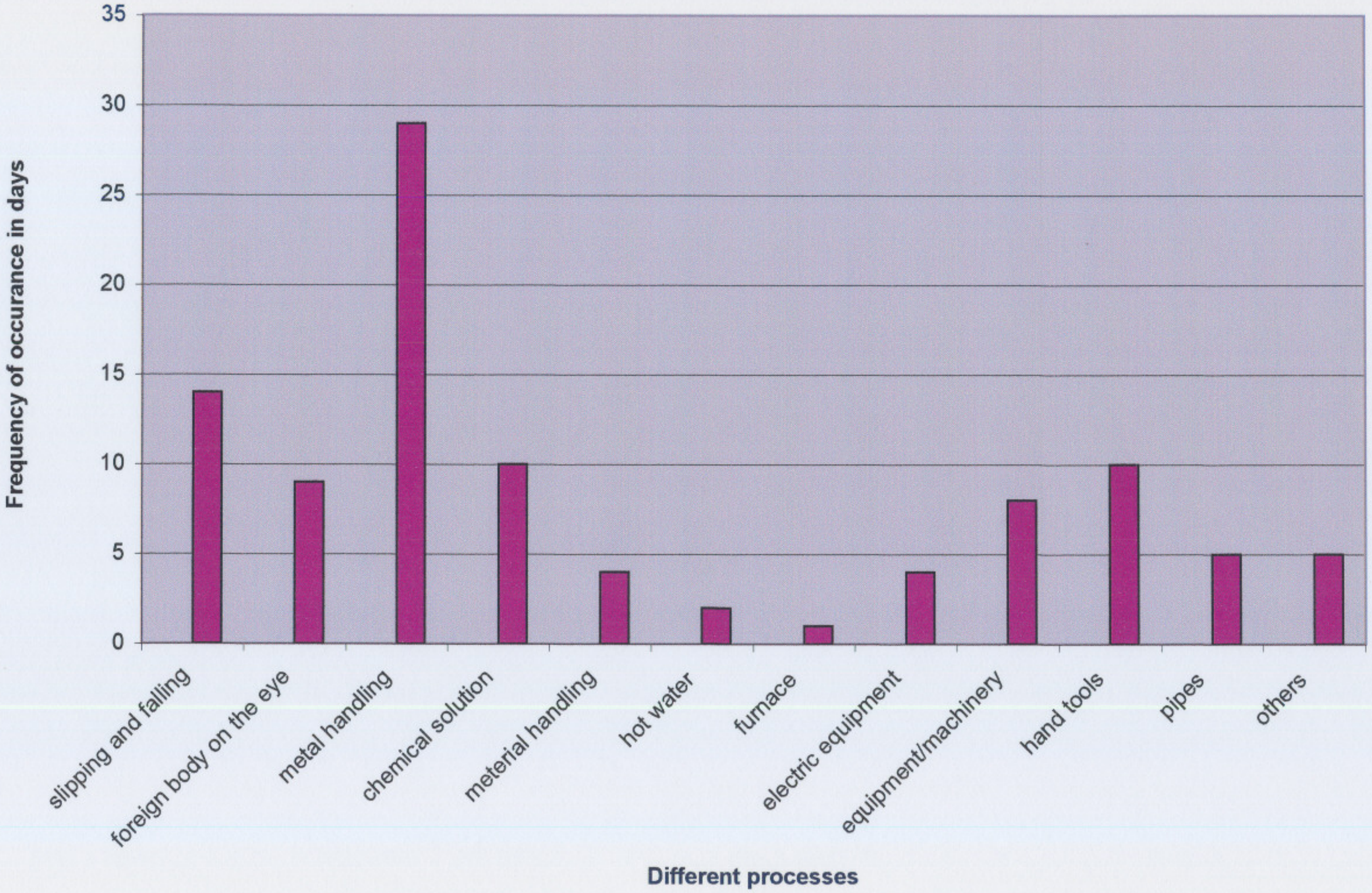
Appendix 1 : The graph represent medical records which shows different body parts affected and the time lost in days from 1994 to 2003 for 108 workers



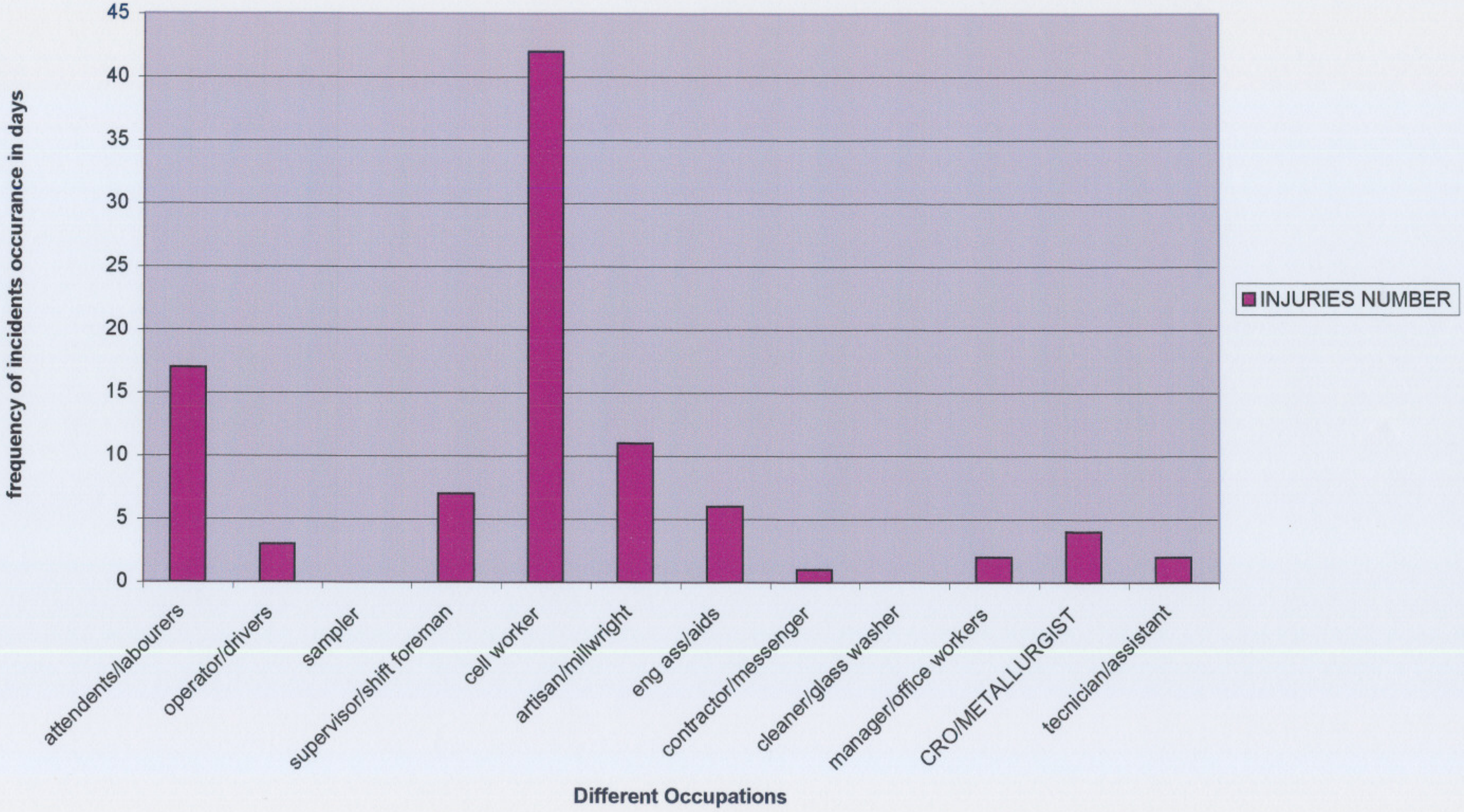
Appendix 2: The graph represent medical records which shows different body parts affected and lost days (sick leave) due to different illnessess and or medical conditions per year for 108 workers



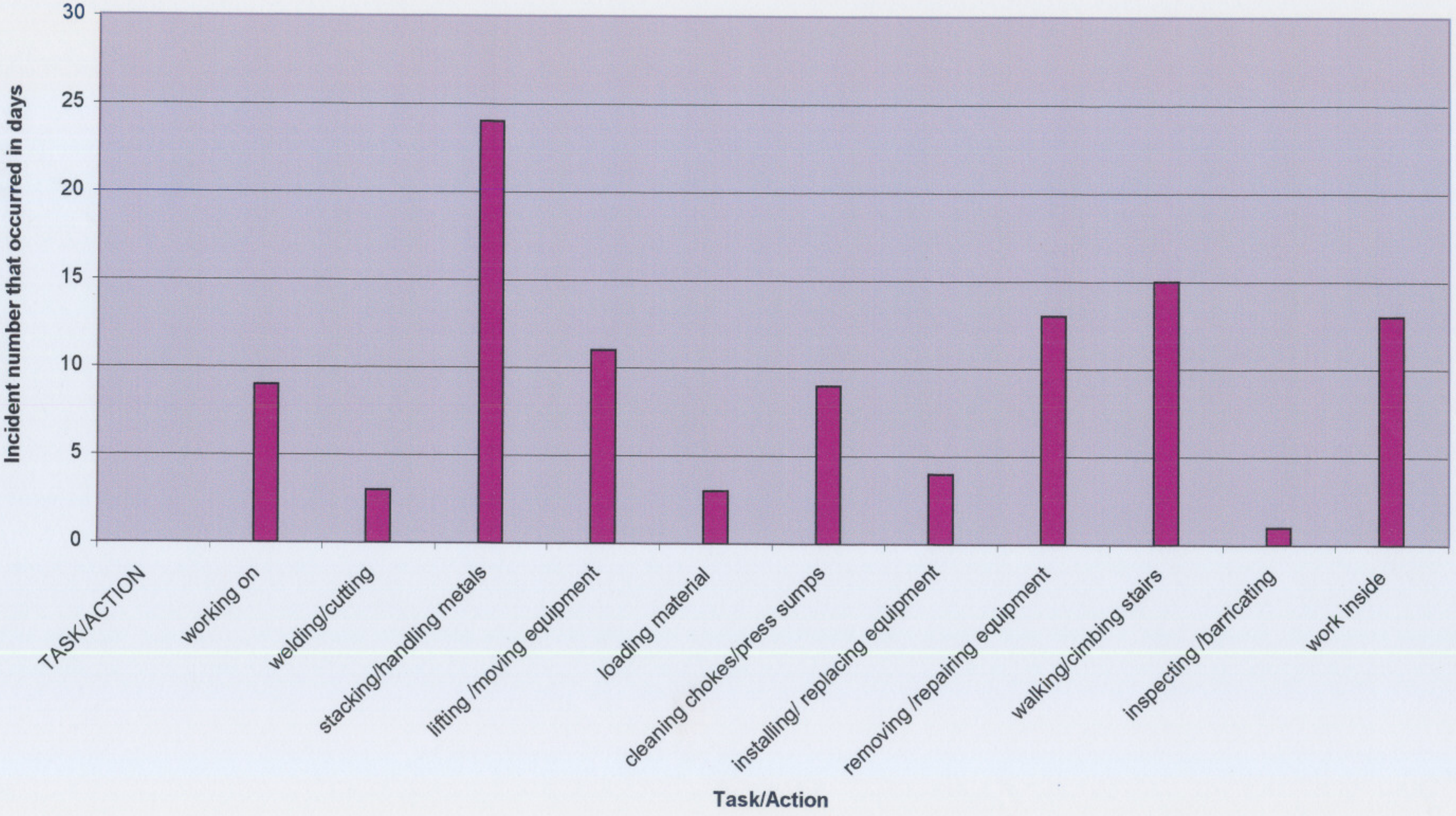
Appendix 3: The graph represent incident reports of different activities and the frequency of occurance per year for 108 workers



Appendix 4: The graph represent incident reports which shows different occupation and the number of incidents that occurred per year for 108 workers



Appendix 5: the graph represent incident report which shows different task performed and the number of incidents that occurred per year for 108 workers



ANNEXURE 2

SELF ADMINISTERED QUESTIONNAIRES:
(Circle the correct answer)

A1. When lifting an object, do you bent at your:

1. Waist
2. Knees
3. Squat
4. Kneel

A2. When handling load, do you handle it?

1. Close to your body
2. Further from your body
3. With stretch arms
4. Over your head

B. The following is a survey of how your body feels as a result of your job. Please complete the following to the best of you abilities.

Do you experience discomfort or pain in any part of your body as a result of you day to day work activities? For those body parts affected, please circle the score which you feel best describes your level of discomfort. 1 represents no or less discomfort whilst 5 represents the worst pain or discomfort. Circle the applicable

1. Neck	1	2	3	4	5
2. Shoulder	1	2	3	4	5
3. Elbows	1	2	3	4	5
4. Lower back	1	2	3	4	5
5. Forearm	1	2	3	4	5
6. Wrist/hands	1	2	3	4	5
7. Thighs	1	2	3	4	5
8. Knees	1	2	3	4	5
9. Lower legs	1	2	3	4	5
10. Foot/ankle	1	2	3	4	5

C. Do you experience discomfort, numbness, or pain in any part of your body at work or at home? For those parts affected, indicate how often and how much (typically), leave the blanks for those body parts not affected.

Body parts	**how often**				**how much**		
☐	**rarely**	**sometimes**	**always**	**often**	**mild**	**moderate**	**severe**
1. Neck.	○	○	○	○	○	○	○
2. Shoulders	○	○	○	○	○	○	○
3. Upper back	○	○	○	○	○	○	○
4. Elbows	○	○	○	○	○	○	○
5. Lower back	○	○	○	○	○	○	○
6. Forearm	○	○	○	○	○	○	○
7. Wrist/arm	○	○	○	○	○	○	○
8. Thighs	○	○	○	○	○	○	○
9. Knees	○	○	○	○	○	○	○
10. Lower leg	○	○	○	○	○	○	○
11. foot/ankles	○	○	○	○	○	○	○
					○	○	○

ANNEXURE 3

OBSERVATIONAL DATA COLLECTION

1. Handling of loads above the shoulder YES ☐ NO ☐

2. Handling of loads waist to shoulders YES ☐ NO ☐

3. Handling of loads from knees to waist YES ☐ NO ☐

4. Handling of loads below the knees YES ☐ NO ☐

5. Working with hands above the head or the elbow above the shoulder
YES ☐ NO☐

6. Repeatedly raising hands above the head or elbows above the shoulder
YES ☐ NO ☐

7. Working with the neck bent more than 45 degrees (without support or the ability to vary posture YES ☐ NO ☐

8. Working with the back bent forward more than 30 degrees (without support or the ability to vary posture YES ☐ NO ☐

9. Working with the back bent forward more than 45 degrees (without support or the ability to vary motion YES ☐ NO ☐

10. Squatting YES ☐ NO ☐

11. Kneeling YES ☐ NO ☐

12. Highly repetitive work-repeating the same motion with the neck; shoulder; elbow, wrist or hands with little or no variation every few seconds, more than 2 hours total per day YES ☐ NO ☐

13. Pinching an unsupported object weighing 2 or more pounds
YES ☐ NO ☐

14. Gripping an unsupported object weighing 10 or more pounds per hand
YES ☐ NO ☐

15. Using the same motion with little or no variation every few second

A. Neck	YES ☐	NO ☐
B. Shoulder	YES ☐	NO ☐
C. Elbows	YES ☐	NO ☐
D. Wrist	YES ☐	NO ☐
E. Hands	YES ☐	NO ☐

16. Manual material handling

A. Is there lifting of loads, tool or part	YES ☐	NO ☐
B. Is there lowering of tool, loads or part	YES☐	NO ☐
C. Is there overhead reaching of tools, loads or part	YES ☐	NO ☐
D. Is there bending at the waist to handle tool, loads	YES ☐	NO ☐
E. Is there twisting at the waist to handle tool or loads	YES ☐	NO ☐

17. Physical energy demands

A. Do tools and parts weigh more than 10lb	YES ☐	NO ☐
B. Is reaching greater than 20 inch	YES ☐	NO ☐
C. Is bending, stooping, or squatting a primary task activity	YES ☐	NO ☐
D. Is lifting or lowering of loads a primary task activity	YES ☐	NO ☐
E. Is walking or carrying loads a primary task activity	YES ☐	NO ☐
F. Is stair or ladder climbing with loads a primary activity	YES ☐	NO ☐
G. Is pushing or pulling loads a primary task activity	YES ☐	NO ☐
H. Is reaching overhead a primary task activity	YES ☐	NO ☐
I. Do any of the above task require five or more complete work cycles to be completed within a minute	YES ☐	NO ☐

J. Do workers complain that the rest breaks and fatigue are insufficient?

YES ☐ NO ☐

18. Other musculoskeletal demand

A. Do manual jobs require frequent, repetitive motion YES ☐ NO ☐

B. Do work posture require frequent bending of the neck, shoulder, elbow, wrist, or finger joint YES ☐ NO ☐

C. Is the worker unable to change his or her position often? YES ☐ NO ☐

D. Does the work involve forceful, quick or sudden motion YES ☐ NO ☐

E. Does the work involve shock or rapid build-up of forces? YES ☐ NO ☐

F. Is finger-pinch gripping used? YES ☐ NO ☐

G. Do job posture involve sustain muscle contraction of any limb YES ☐ NO ☐

19. General workplace

A. Are the walkways uneven, slippery or obstruction YES ☐ NO ☐

B. Is housekeeping poor YES ☐ NO ☐

C. Is there inadequate clearance or accessibility for performing task YES ☐ NO ☐

D. Are the stairs cluttered or lacking railings YES ☐ NO ☐

E. Is proper footwear worn YES ☐ NO ☐

ANNEXURE 5

VOCABLARY

Anthropometry: The study of the range of human physical dimensions such as size, breadth, and distance between anatomical points.

Abduction Motion away from the midline of the body that increases the angle between the limb and the sagittal plane.

Adduction Motion towards the midline of the body that decreases the angle between the limb and the sagittal plane.

Anthropometer: Is a specialised tool for measuring linear distances between points on the body and standard reference surface, such as the floor or a seat platform.

A tape measure: Is used for measuring body circumference. To determine the maximal posterior protrusion of a seated person, a measuring cube 200 mm on each side is used. To determine grip measurements, a rod of 20mm is used.

Ergonomics : A multidisciplinary activity dealing with the interactions between the worker and the working environment, plus such traditional and environmental aspects such as atmosphere, heat, light, and the sun, as well as of tools and equipment in the workplace.

Extension Movement involving the bending of a joint whereby the angle between the bones is increased.

Flexion Movement involving the bending of a joint whereby the angle between the bones is diminished.

Force: The effect of an exertion on internal body tissues or the physical characteristics associated with the object(s) external to the body.

Goniometre: A device that measures the angle and the range of angular movement between two body segments connected by the joint.

Posture The position of the body while performing work activities.

Repetition: The time quantification of a similar exertion performed during a task

Recovery time: The time quantification of rest, performance of low stress activity, or performance of an activity that allows a strain body area to rest.

Static exertion: The performance of a task fro one postural position foe an extended duration.

Kyphosis: The convexity of the spine that is normally observed in the thoracic region.

Lordosis The concave curvature of the spine that exists in the neck and in the lumber region.

Starter Sheet It is a 2-day-old Nickel or Copper sheet that has plated out on the starter blank to be used as a starter sheet in production cells.

Starter Blank- It is a titanium or stainless steel plate that is inserted in Nickel or Copper starter sheet. Two days to produce a starter sheet.

Hanger Bar- is a copper bar attached to starter blanks or inserted into the loops of the starter sheet to convey the electrical current to the starter blank or sheet

Cathode bag fame û Is a polypropylene frame, which fits into the cathode bag.