Ergonomics and Design

- Fundamental role in design
- Any designs where humans play an active part
- Human sizes, reaches, movement patterns, biomechanical and physiological aspects
- Human psychology, cognitive capacities
- Ergonomic data can take out some of the mystery/uncertainty re humans

What is an Ergonomist?

Ergonomists **contribute to the design and evaluation** of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people.

IEA Definition

Professional Memberships

- M.H.F.E.S.A  Member of the Human Factors and Ergonomics Society of Australia
- C.P. Erg.  Certified Professional Ergonomist
Ergonomists – in practice

• Address real world problems
• Seek the best compromise under difficult circumstances
• Aim to offer most cost-effective solutions
• Develop prototypes
• Analyse and evaluate effects of change
• Develop benchmarks for best practice
• Communicate to interested parties

Stanton et al

Other Goals

• Find and apply relevant data in regard to human performance
• Assist the designer/engineer by way of ergonomic specifications
• Assess risk quantitatively, comparing current and intended designs
• Provide a standards based solution which seeks to accommodate desires of all stakeholders and is seen as more neutral or objective

Control Room: Operators not happy with architect

Time spent leaning forward over desk: ~60%
Selection vs Ergonomics

Neck pain from unhealthy neck or from looking up at 30-40° repetitively over 12 hours

Outcomes: Miner Modifications

- Floor raised 200mm
- Floor extended forwards 200mm closer to bolters
KEY AREAS IN ERGONOMICS

- Anthropometry
- Musculoskeletal ergonomics
- Tribology
- Equipment interface design
- Accident analysis
- Human-computer interaction
- Cognitive ergonomics
**Lge Forklift:**
- Pedals too far fwd relative to steering wheel
- If move seat fwd – legs too cramped over pedals
- Limited adjustment of SW
- Seat height fixed

**Shuttle Car & Short Male**
- Fixed pedals
- Fixed controls
- Poor seat adjustment
- Obstacles to vision
Shuttle Car & Tall Male

Key Factors

• Dimensions
• Clearances
• Posture stress
• Movement demands
• Forces
• Sight lines
• The above often combined with vibration/jolting

Simple (?) example: Dragline controls

• Drag and hoist levers
• Single plane
• >300mm range
• Light constant resistance
• Up to 80° shoulder elevation
• High wrist supports
• No forearm support
Possible Solution

Possible Issues

- Wrist action versus shoulder action
- Forearm slide versus wrist-rest slide
- Limited wrist range vs optimal range for control
- Backward shoulder movement obstructed by backrest
- Single axis/multi axis versus level of control

Points to Consider

- Forearm support takes ~38% of stress off spinal discs compared to no armrests
- Shoulder movements are less precise than wrist or finger movements especially if friction under the forearms
- Even wrist movements may not be precise enough given the speed, power and mass of the equipment being controlled
- The range of lever motion must not result in excessive joint postures or cramped positions or static muscle load
Type of handle

- Joystick: requires all movement to arise from wrist action and some shoulder
- Cylinder handle: palm inwards requires all movement via wrist, shoulder, elbow – some finger flex/extend;
- Ball-grip: palm down, palm inwards, finger-tips, finger-thumb tips – slide through hand with finger flexing contributes to range

FIGURE 9-14
Directions and planes of arm movements with stylus as used in study of hand steadiness, with direction of hand tremor and number of "errors" (number of times the stylus touched the side of the groove) for each condition. (Source: Adapted from Mead and Sampson, 1972, Fig. 1 and Table 1.)
Solution Goals

- Allow a variety of grips
- Allow a variety of joints to contribute to movement to allow variety of actions
- Support forearms
- Allow optimal posture of near vertical upper arms (10-20° fwd/back), squared shoulders, solid lumbar support
- Support side of hand

Musculoskeletal

- Functional anatomy
- Strength data
- Physiology
- Biomechanics

Range of Motion
Posture Stress

- Gravity
- Position
- Static
- Effort

Gravity

Mine Control Room
Shuttle Car Refit

Goals:
- Eye height
- Seat support
- Pedal reach
- Steering wheel reach
- Access/egress

Figure 5: Steering wheel position
Biomechanical Analysis

- Range, frequency, % of cycle
- Forces applied
- Space vs anthropometry
Human Tribology

Study of friction in relation to human locomotion
Includes analysis of underfoot surfaces
Relates to biomechanics and design of accesses

Cont Miner Access

Existing Miner:

Access on Miner

- Numerous incidents
- Excessive rises
- Incompatible rises and goings
- No handholds
- Small surfaces for tail access
- Large gaps to cross
- Poor slip resistance
- Excessive bottom step height
Common Tasks in Development Mining (sample = 27)

<table>
<thead>
<tr>
<th>Task</th>
<th>%</th>
<th>Body Part</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof bolting and handling bolts</td>
<td>52</td>
<td>Neck (3) Back (4) Wrist (1) Shoulder (1) Elbow (1)</td>
</tr>
<tr>
<td>Mesh handling</td>
<td>26</td>
<td>Back (5) Shoulder (2)</td>
</tr>
<tr>
<td>Accessing or egressing miner or tail</td>
<td>22</td>
<td>Legs/knees (5) Wrist (1)</td>
</tr>
</tbody>
</table>

Refurbished Miner

2600 class
1700 class access

New Miner Project

• New miner on order
• Potential issues related to monorail for flexiduct, mesh on top of miner, work heights, cassette access, access/egress, rib bolter controls, roof bolter controls
• Consultation day with operators, suppliers, engineer and OHS personnel – task analysis, application of ergonomic principles
• Report prepared - specifications

Specifications related to:

• Floor height;
• Monorail storage and handling;
• Mesh handling;
• Cassette storage and handling;
• Roof bolting;
• Rib bolting;
• Access/egress;
• Guarding and mechanical safety issues.
Scope

To provide ergonomic specifications in regard to:
- Dimensions
- Clearances
- Postures/reaches/movements
- Forces
- Controls/displays

Working Height

- Intended floor height: 993mm
- Roof ht: 2300mm above floor of miner
- Relevant to monorail hanging, pulling flexiduct, roof bolting
- Possible need to reach roof for monorail
- Need to reach to 300mm below roof for resin insertion

Required reach for monorail is near to 2300mm

<table>
<thead>
<tr>
<th>Vertical Height of Males with Shoes and Helmet Worn</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th percentile: 1720mm</td>
</tr>
<tr>
<td>50th percentile: 1835mm</td>
</tr>
<tr>
<td>95th percentile: 1950mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vertical Reach Capacity for Gripping</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th percentile: 1980mm</td>
</tr>
<tr>
<td>50th percentile: 2110mm</td>
</tr>
<tr>
<td>95th percentile: 2240mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vertical Reach Capacity for Gripping Standing on Tip-Toes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5th percentile: 2055mm</td>
</tr>
<tr>
<td>50th percentile: 2185mm</td>
</tr>
<tr>
<td>95th percentile: 2315mm</td>
</tr>
</tbody>
</table>

Relevant anthropometric data:
Vertical grip reach
Shoulder grip length
Reach fwds from chest
Fwd reach in front of toes
Stature of clothed workers
Implications

- Roof is out of reach of 5th and 50th percentile males
- Method for monorails needs to extend reach by 250mm for small males
- Force applied will determine actual reach needed
- Possibilities: raise floor or design guardrail as ladder
- Recommendation: 100-200mm floor rise

Roof Bolting

- Fwd reach to bolters: 550mm
- Reach capacity at 550mm fwd of shoulders:
  - 5th: 1635mm
  - 50th: 1852mm
  - 95th: 2052mm
- Required reach: 2000mm
- Tip-toes: add ~ 75mm
- Lean and reach: add about 150mm

Viewing Angles

- Allow for 500mm forwards of eyes and 2300mm ht
- 39-53° viewing angle
- Optimum angle for brief exposures is 40° made up of 15° upward eye angle and 25° neck extension
- 38° or more neck extension likely with short workers
- To limit neck extension to ~25° for short workers would require floor rise of 200mm
**Recommended Specs**

**Recommendation**
Raising the floor height will reduce stretching when inserting resin and roof bolt

**Recommendation**
Limiting the distance from platform to roof bolting rigs to 450mm or less will minimise shoulder stresses

**Recommendation:**
100-200mm rise in floor height or ladder built into guardrail (less preferable).

**Recommendation**
Minimum gap of 550mm between control consoles and adjacent structures to allow 2 arm access to bolters

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**Monorail Wt and Force Recommendations**

**General Shoulder Strength for Most Males**

<table>
<thead>
<tr>
<th>Static:</th>
<th>65Nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brisk:</td>
<td>41Nm</td>
</tr>
</tbody>
</table>

**Recommendations:**
- Monorail attachments weight limit: 10kg;
- Force to slide one section onto another: 12kg;
- Force to attach support to mesh: 10 – 12kg (fore–aft) and 8–9kg (side to side)

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**Mesh**

Ht to top of pack of mesh: 1925mm

% reach capacity at 300mm fwd of shoulders:

5th: 110%  
50th: 92%  
95th: 75%
Recommended Specs

Raise floor height
Limit slide force to 10kg

Other Recommendations

• Stairway configuration with handrail
• Slip resistant nosings
• Fold up stairs for travel
• Slip resistant nosings
• Primary levers 1050-1150mm ht
• Guard levers
• Angle rib bolter console more toward worker
Steps Required in the Design of New or Major Overhaul of Equipment

- Determine Objectives/Purpose
- Determine all functions to be performed (by machine, human software)
- Identify functions to be allocated to humans
- Perform in depth task analysis and workflow
  Identify relevant human performance data, outlining specific limitations and capacities
- Lay down design specifications based on human performance and Ergonomic Criteria
- Determine the viability or feasibility of ensuring design meets specifications, if not, reallocate functions and revise design

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Ergonomics Loop

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Ergonomics Design Process Std

Applicable to:
- New or overhauled heavy equipment
- Design of accesses, auxiliary equipment
- Design of control panels, controls, valve layout, workspaces, handtools & furniture
- Design or selection of handtools, PPE
- Design of work methods & techniques
Basic Principles

- Assign functions appropriately
- Determine the human demands and exposures for proposed functions
- Identify excessive or harmful demands or exposures based on human performance & ergonomic data
- Alter the design so as to alter the demands/set specifications or reallocate certain functions or sub-functions

Ergo Taskforce Charter

- Keep a focus on ergonomic factors
- Be a resource for assessments and audits
- Assist with incident analysis
- Assist with practical training
- Collect and pass on ergonomic concerns from employees
- Assist in the design process by being a channel for coordinated user feedback

Task Design Standards

- All tasks/exposures to be within human performance limits/guidelines
- Standards cover design, techniques and maintenance tasks
- Policies include processes for utilising standards in the purchasing, procuring, designing processes
- Evaluations and audits are based on criteria in the standards