Development of Functional Fitness Measures Related to the Work Practices of Underground Coal Miners





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EXECUTIVE SUMMARY

In spite of increasing mechanisation, underground coal mining remains a physically demanding occupation that involves frequent manual handling often in confined spaces and hazardous environments. The tasks encountered during a particular shift, usually of 8 or 12 hours duration, may place high forces on the musculoskeletal system, often involving repetitive movements which commonly include lifting and manipulating objects overhead.

Nationally, the mining industry has a high injury incidence rate (89 per 1000 workers) compared to the national average of 49.3 per 1000 workers (ABS, 2002) and a high number of worker compensation claims relative to most other industries (Worksafe, 1999). A larger proportion of musculoskeletal injuries and disorders are associated with underground mining than with open-cut operations (Parker et al, 2006).

As such, the development and implementation of strategies to minimise worker injury and lost work-time is beneficial for both the miner and the mining company. The preferred injury prevention strategy is to reduce the physical demands of the job to suit the capabilities of the worker. This is commonly achieved by redesigning the task, reducing the loads handled and using equipment to eliminate heavy lifting. Educational programs designed to increase awareness of safe lifting techniques are also commonly used as an injury prevention strategy. Unfortunately, it has not been possible to eliminate all physically demanding tasks using these strategies and in work categories where demands remain high, it is important to ensure that the functional capacity of the individual is adequate to safely match these demands.

A broad range of protocols has been used to evaluate functional capacity in an attempt to match a workers capacity with job demands. In their most basic format, evaluation of suitability for a particular position involves a medical examination in which medical history and current health status is related to the perceived job demands. In the more comprehensive functional capacity evaluations (FCE's), the medical examination is complemented by objective measures of functional fitness and/or performance on tests designed to simulate work tasks.

It has been identified consistently throughout the literature and confirmed by legislation that tests designed to evaluate suitability for a particular position should be based upon the critical tasks of the job (Jamnik and Gledhill, 1992; Kuruganti and Rickards, 2004; Equal Opportunity Commission Victoria, 2006). A range of different types of evaluation are currently used in the mining industry, including a medical examination and evaluation of performance on functional tests, however there is a lack of published information related to their development, validation or efficacy.

In other occupations, the more successful protocols have involved a job demands analysis, functional testing and some general tests of physical capacity in addition to the medical examination. While some tests show evidence of reliability or validity, no test has presented evidence of an adequate level of reliability and validity in all aspects of the test, particularly for those tests used in physically demanding occupations. (Innes and Straker, 1999a; Innes and Straker, 1999b; Wind et al., 2005).

The application of screening protocols has been most frequently directed towards selection of applicants into physically demanding positions on the basis of their functional capacity, rather than utilising the information to inform the design, implementation, evaluation and monitoring of programs targeted at enhancing the physical capacity of workers to meet their job demands. Use of the evaluation as one part of a broader health surveillance program that addresses injury prevention, (including medical, drug, alcohol and psychological screening, education programs, job redesign, equipment changes, work scheduling and fatigue management issues) would appear to offer the best outcomes (Bennell, 1998; Parker et al., 2004).

The purpose of this project was to develop a functional capacity evaluation (FCE) that may be used to identify the functional capacity of individuals in relation to the specific physical work demands of underground coal mining. The test protocol aims to evaluate both general fitness and work-specific fitness of the individual. Information derived from the tool can be used as a basis for the design and evaluation of interventions targeted at enhancing workers' functional capacity and in the evaluation of changes in functional capacity with age or following injury.

In the development of the FCE, a range of techniques were used to characterise the work tasks of mineworkers across four underground coal mining operations participating in the project. Safety issues associated with more objective measurements of job demands, such as physiological or biomechanical analysis, limited the analysis to direct observation and photography, focus group discussions and surveys of workers. Considerable time was spent on day and night shifts monitoring, evaluating and recording work tasks in development, longwall and maintenance roles. Numerous discussions were also held with individual miners and groups of miners while at work or during crib breaks, to gain insight into the nature, frequency, intensity and duration of work tasks. An initial sixty-five tasks were identified across the work categories and were compared with any documentation of job descriptions held at the minesite. An evaluation of the weight and size of various pieces of equipment and other items commonly handled by the workers during execution of work tasks was also conducted to provide additional insight into the intensity of particular work tasks.

Further characterisation of the more commonly performed work tasks was obtained from the results of a survey of 196 workers across the different work categories. The questionnaire provided demographic and work specific information and the workers ratings of the intensity, frequency and duration of the work tasks.

These ratings and information from earlier focus group discussions were used to further characterise the work tasks and to exclude a number of tasks which were either performed too infrequently, were unsafe, or could be readily redesigned. Some tasks such as walking and carrying equipment could be combined thus reducing the number of individual tasks while at the same time representing different physical demands.

Following the characterisation phase, six tasks, or combinations of work-related tasks, were identified as being good simulations of key tasks in development, longwall and associated maintenance tasks. Each task was characterised as having relatively high frequency and intensity and requiring adequate levels of aerobic capacity, flexibility, strength and muscular endurance. Workers were consulted in the development of these simulations and specific equipment was designed and constructed to simulate conditions underground as closely as possible and to enable the tests to be conducted above ground.

The following tests were selected for evaluation and validation in a preliminary trial involving five miners:

1. Walking/carrying equipment
2. Lifting water pipe
3. Lifting/dragging cables
4. Lifting ventilation ducts
5. Coal shovelling
6. Lifting and handling mesh

In addition, a battery of health-related fitness tests were selected by the research team after consideration of the physical demands of the different work tasks. The research team has expertise in functional anatomy and exercise physiology and was competent to select tests designed to evaluate strength, muscular endurance, aerobic capacity and flexibility. These tests were also selected based on their reported validity, reliability and practicality. The tests were:

1. Back extensor strength
2. Knee extensor strength
3. Elbow flexor strength
4. Shoulder flexor strength
5. Abdominal strength
6. Abdominal endurance
7. 3-minute step test
8. Sit-and-reach

Following the preliminary trial some tests were eliminated or modified to improve the safety or reliability of the particular test and avoid redundancy where two tests were evaluating similar functions. The work-related tests showed high content validity with respect to the participants' perception of their realism and physical demand by comparison with performance during a normal shift.

The work-related tests were incorporated along with general, health-related fitness tests into the overall protocol. The revised protocol was evaluated in a trial involving 20 workers at two separate mine sites. The results confirmed the high validity in the work-related tests and allowed finalisation of procedures related to the administration of the test protocols.

RECOMMENDATIONS

The health and work-related screening protocols are developed for the guidance of employers and employees as one component in the evaluation of the functional fitness of employees to perform duties associated with underground coal mining with particular relevance to work in development, production/longwall and associated maintenance tasks. The tests may be used at various stages in the employment continuum and if applied prior to employment could be used as a basis for targeted intervention programs designed to improve the functional capacity of employees and potentially reduce injury risk.

Importantly, the tests are not meant to replace other strategies designed to reduce the physical demands of work, such as job redesign, but recognises that at this stage in the development of the industry, there remains a high component of physical work associated with underground coal mining. The extent and consequence of this physical demand is reflected in the high incidence of musculoskeletal injury and over exertion being identified as a major mechanism associated with these injuries. The predictive value of screening tools with respect to injury is inconclusive, but their importance has been recognised as a basis for ongoing interventions to enhance functional capacity in relation to work demands.

It is recognised that at this time the FCE developed in this project has been evaluated using a relatively small number of subjects. Although content validation was high, this should be re-evaluated over time following implementation of the FCE as additional data becomes available. With this additional data it will be possible to develop normative age related data for mineworkers for comparative purposes.

The FCE should be viewed as one component of a far broader strategy for injury prevention in the coal mining industry. Considerations should also be given to extending the typical physically oriented FCE to include measures of psychosocial status, which are critical to performance and to the injury and health profiles of workers. Job redesign is the preferred method to reduce mechanical load, and educational programs and participatory ergonomics are also useful in increasing awareness of injury risk factors and identifying solutions. However, knowledge of functional capacity relative to job demands is important and may identify deficiencies in fitness that may be improved through targeted interventions. Increased functional capacity may contribute not only to injury prevention but also to the general health of the individual.

Recommendation 1a

Functional capacity screening protocols be implemented as a component of the selection process for applicants to physically demanding occupations in underground coal mining.

The recommendation is based on:

- The perceived need for work-related test protocols in the underground coal mining sector.

- The need for a work-related assessment to determine:
  (1) suitability for a physically demanding position prior to starting, returning from injury, or as a function of age; and
  (2) appropriate interventions designed to enhance functional capacity.
- Evidence to suggest that implementation of a work-related functional capacity evaluation may reduce costs and lost work days associated with injury (Nassau, 1999; Gassoway and Flory, 2000; Harbin and Olson, 2005; Rosenblum and Shankar, 2006).

Recommendation 1b
The protocols developed and evaluated in this study represent a sound initial basis for the implementation of such functional capacity screening.

This recommendation is based on:
- The relevance of the protocols to underground coal mining as revealed by analysis of tasks and the high ratings of realism of these protocols provided by current mine workers;
- This recommendation is made with recognition of the limitations of any functional screening protocol, and of the need to assess, refine and update them on the basis of new information.

Recommendation 2
Data on the outcome of any testing implemented using the designed protocols should be used to provide an extensive set of normative data relative to age and occupational categories and to investigate the predictive value of the test protocols with respect to work-related musculoskeletal injury.
This recommendation is based on:
- The need to provide comparative data on the functional capacity of mineworkers for longitudinal analyses and to contrast with other population and industry norms;
- Inconclusive evidence concerning the predictive value of musculoskeletal screening protocols with respect to reducing injury.

Recommendation 3
The normative data enabled by further testing may be used to establish standards or criteria for purposes such as applicant screening, rehabilitation and return to work decisions, and on change of job or tasks.

The development and validation of tests reflecting the content of work is a process that is mostly objective and amenable to a scientific process. When put into practice, however, tests used for other than descriptive purposes often apply standards of performance, “pass/fail” or other criteria. These reflect a range of non-scientific factors and may include qualitative judgments. The test protocols developed in the current study have several potential uses ranging from screening new applicants, evaluating readiness to return to work following injury, to informing decisions about reassigning miners to new jobs and tasks. A single standard or criterion would be inappropriate for these diverse applications.

The test score procedure outlined in Appendix 5, includes advice about the use of both health-related and work-related test scores. This advice is based on the premise that since the sample included miners without injury and capable of undertaking all relevant underground mining tasks at the time of testing, scores on the test that are within the range obtained from this sample would suggest that a test-taker has comparable function to that of currently uninjured miners.

On the other hand, the sample is relatively small and its representativeness has not been established definitively. Moreover, the levels of performance from any group of workers does not necessarily represent optimal or, for some measures, even good levels of health and physical function. Finally, use of these tests for purposes such as rehabilitation and return to work should ideally make use of the individual's own data rather than a generic standard.

Recommendation 4

The efficacy and content of the test protocols should be assessed after a 12-month trial period.

This will enable any modifications to be made which may have arisen from a structured feedback process involving testers and participants.

This recommendation is based on:

- The need to constantly review the screening protocols with respect to any logistical or potential safety issues that may arise in their implementation.
- The potential development of new technology or equipment which may become available in the future that could replace or assist in the performance of these work tasks, therefore reducing the physical load on the worker.

Recommendation 5

To implement research concerning the role of psychosocial factors in the development of musculoskeletal disorders in mining and use the results to incorporate an evaluation tool designed to address psychosocial issues.

The functional capacity evaluation developed in this project is focused on the evaluation of physical capacity in relation to job demands. Consequently, as indicated earlier, the test protocol forms only one component of a more holistic evaluation process concerned with the health of individual workers. This recommendation is based on:

- Increasing recognition of the role of psychosocial factors in the incidence of musculoskeletal injury and disorder;
- The high levels of psychological disorders identified in the mining workforce;

- The significant social disruption and potential for psychological stress for some miners associated with working away from home and long working hours.

Recommendation 6

None of the tests described in this Report should be put into effect until the Report's findings and recommendations have been properly considered by Coal Services Health and Safety Trust. Such consideration should occur in the broader context of health surveillance, pre-employment screening, and medical and functional assessment issues, and should ideally allow any of the tests contained in this Report to be integrated appropriately with other assessment protocols.

Introduction

Traditionally, fitness for duty has been described as "the detection of medical problems that may compromise personal, co-worker, and/or public safety" (Kales et al. 1998). This view of work ability focuses solely on the identification of pre-existing medical conditions and the resultant risk of injury. Mining and some other hazardous industries have responded to legislation and increased awareness of risks by also testing employees for drug and alcohol intoxication, and in some instances, excessive fatigue. Thus, if a worker is found not to have either medical problems or impairments related to drugs, alcohol or fatigue, he or she is to be considered 'fit for work' – implicitly extending the concept of fitness for work beyond the absence of illness or injury. However, a broader view of this concept should consider the interaction and congruency between a worker's capacities and the demands posed by the job. It should also take a long-term view of how a worker's health and fitness status may change over their lifespan, the capacity for, and limits to physical adaptation, and cumulative effects of work demands. This more comprehensive concept of fitness for work is consistent with the goals of life-long health surveillance, and would allow interventions to preserve health and maintain work capacity to be implemented in a timely way, and tailored to the individual's needs.

Current outcome measures of fitness for duty indicate musculoskeletal health, not just the presence of a medical condition, contributes significantly to fitness for duty. Musculoskeletal injury and disease (including poisoning) has been identified as a major cause of work-related disorders and work loss, totalling 88.8% of all work-related injury cases in 2004 (NOHSC Database, 2004). Strains and sprains alone constituted 51.4% of these cases and 45.6% of all work-related injury cases (NOHSC Database, 2004). These values are congruent with other national and international sources of work-related injury statistics, which report that musculoskeletal injuries constitute approximately 50% of total work-related injuries (NOHSC Database, 2001; NOHSC Database, 2004; ABS, 2001; European Labour Force Survey, 1999). The total annual cost of work-related injury and disease in Australia has recently been estimated to be in excess of $31 billion (NOSHC Annual Report, 2002-3).

The frequency of lost-time due to injury is particularly high in underground coal mines, with an injury rate more than 3 times that seen in surface coal mines over the 2-year period from 2000-2002 (Queensland Mines & Quarries, 2002). Musculoskeletal injuries and disorders represent the highest category of injury in the coal mining industry with significant individual and corporate costs. Musculoskeletal injury is generally classified as acute or cumulative (chronic). An acute injury occurs as a result of a relatively short exposure to loads that exceed the physical capabilities of the individual, mechanisms of which are commonly manual handling and overexertion associated with the physical demands of work. In contrast more chronic injury occurs in response to exposure to lighter loads over longer time periods. Injury occurs when the micro damage to musculoskeletal tissues exceeds the capacity of the tissues to repair this damage. Other musculoskeletal disorders may include a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joints, peripheral nerves and supporting blood vessels (Punnett & Wegman, 2004). Based upon the personal and financial burden of musculoskeletal injury, there is a strong necessity for employers to provide interventions aimed at reducing the rate and cost of musculoskeletal injuries in underground coal miners.

A specific challenge in defining the musculoskeletal component of 'fitness for work' in mining is that the actual physical fitness requirements of many work-tasks have been under-emphasised in recent years and there is a lack of quantitative data defining specific physical demands of underground coal mining tasks. This reflects conflicting philosophies as well as major structural change. Historically, it has always been accepted that underground mining work imposes heavy physical demands on miners, and that not all are suited to this work. Mechanisation in general, and open-cut methods specifically, have reduced many physical demands, but in an inconsistent manner. For example, some manual tasks have disappeared completely, but mechanisation has itself created new physical demands, especially in maintenance, moving and set-up of equipment. The legal and philosophical background has also changed, with anti-discrimination and equal employment opportunity legislation leading to the onus being on the employer to make appropriate accommodations to provide equal employment for those of diverse age, gender or race, and that exceptions to this must be justified in terms of health and safety or unjustifiable financial hardship (Shephard and Bonneau, 2002; Equal Opportunity Commission Victoria, 2006). Finally, these changes have occurred against a background in which physical activity and fitness levels in the community have arguably declined, and levels of overweight and obesity have clearly increased (Cameron, 2003).

A significant component of an underground miner's work involves manual handling tasks that are often performed in a constrained working environment involving unusual postures. Each manual task performed in underground mining loads the skeletal system differentially, and the combination of both compression, torsional and shearing forces on the spine particularly when working in confined spaces presents significant risk of back injury, the most prevalent musculoskeletal injury. Underground miners working from a kneeling posture show increased muscle activity, quicker onset of fatigue and reduced lifting capacity (Gallagher et al, 1988). The high frequency of muscular sprain and strain injuries associated with these kinds of tasks suggests that the loads often exceed the capacity of the musculoskeletal structures under load.

The first approach to injury prevention is to redesign the task to suit the capacity of the worker. Other strategies include the training of workers in manual handling tasks and the raising of awareness of injury risk through educational programs and participatory ergonomics sessions. Each of these strategies has strengths and weaknesses and although job redesign is the preferred option this is not always feasible in every situation and other strategies are required. Safe lifting programs have also had only moderate success in some industries as workers taught safe lifting techniques do not always follow the designated methods and in some cases because it is harder and more difficult to lift by these methods (Snook, 1991).

Despite the implementation of one or more of these strategies many of the work tasks undertaken by underground miners still require significant manual handling, exertion of high forces, often with non-optimal postures in difficult environments. The physical work is of an intermittent nature and is not sufficient to enhance or maintain aerobic capacity, contrary to the perceptions of many workers. Demands on strength across a shift are also intermittent but in some tasks, such as bolting, lifting monorail and moving cable, require the generation of high peak forces or muscular endurance of the upper limb. The length of shift and design of rosters is also an important factor in the potential for fatigue and further reduction in functional capacity as a result. With some of these limitations there is a real danger that in trying to comply with the goals of equal employment opportunity, and the ergonomics credo that work should always be modified to fit the worker, the effects of those "irreducible" physically demanding work-tasks on miners will not be properly appreciated. Because of population-level health and fitness changes and the nature of underground coal mining jobs, the expectation that all members of the general workforce could perform all mining work-tasks with no risk of injury, may be increasingly unrealistic.

Strategies that have been used to increase the physical capacity of workers to meet their job demands include fitness training and the use of pre-employment tests to better match the capacity of the worker with physically demanding job tasks (Snook, 1991). Fitness level and exercise training may decrease the relative risk of injury, and high levels of aerobic fitness, strength, and flexibility have been shown to inversely relate to the workers' compensation costs of fire fighters (Cady et al., 1979; Cady et al., 1985) and line-workers (Doolittle et al., 1998). While these data suggest that fitness programs would likely reduce musculoskeletal injuries, lack of specificity in the design of the exercise program and poor compliance is often a major problem of this approach.

Functional capacity evaluation has been suggested as the preferred ergonomic approach for those physically demanding jobs that cannot be redesigned (Snook, 1991; Cole et al., 2004; Gledhill, 1992; Jackson, 1994; Nassau, 1999). This strategy is based on the assumption that injury risk can be reduced when only individuals who have the capacity to perform a given job without excessive risk are selected for a position (Ayoub, 1982; Snook, 1991).

Current methods of measuring physical capacity involve both general and functional tests. General 'physiological' tests measure conventional fitness components such as flexibility, muscular strength, aerobic capacity and muscular endurance (Kuruganti and Rickards, 2004). 'Functional' tests have been defined as task-specific or job related tests which duplicate the demands of the job and are utilised to measure the physical capacity of individuals with respect to specific activities (Jamnik and Gledhill, 1992; Tuckwell, Straker and Barrett, 2002).

Strength testing has been considered the most effective technique for stratifying applicants for materials-handling tasks (Snook, 1991) and strength as a component of fitness ability has been shown to be associated with low-back injury (Keyserling et al., 1980; Baumgartner et al., 1999). The relationship is not with absolute strength, but rather with strength in relation to the physical requirement of the task. The closer the lift demands are to 100% of the individual's maximum strength capacity, the higher the risk of injury.

A three year prospective study conducted on employees in a labour intensive company found that matching the physical capacity of employees to job demands through isokinetic pre-employment strength testing significantly reduced the frequency and severity of musculoskeletal disorder injuries (Rosenblum and Shankar, 2006). The particular isokinetic strength test utilised was not a work-simulation, but was more specific than a general test of muscle strength. The isokinetic screening protocol was developed through the conduct of a thorough job demands analysis in which the maximum force requirements (kg) in each task were determined and translated into an isokinetic test for each body region. Results of strength and agility based on push, pull, lift and carry forces required in each of the three different job types were interpreted with respect to the US Department of Labor's Dictionary of Occupational Titles (1991) standards to determine hire status. Through comparison of injury data on 503 screened and 1423 non-screened applicants over a 33- month period, the study found that non-screened applicants were 2.38 times more likely to experience a musculoskeletal disorder-related overexertion injury specific to the knees, shoulders, and back than screened applicants. These findings support the causal relationship between physical capability employment screening (using isokinetic technology) and a significant reduction in musculoskeletal disorders.

Rosenblum and Shankar's (2006) research is supported by a study into food production plant employees by Harbin and Olson (2005) who found that employees with adequate physical capacity to perform their job tasks had a significantly lower back injury rate than non-matched employees. The study, however, failed to find any predictive value of strength testing to injury incidence. This has been the case in several other studies which have failed to determine valid predictors of injury risk (Bigos et al., 1992; Gross and Battie, 2004).

In addition to the lack of evidence of the predictive ability of strength testing to determine injury risk, measurement of strength alone may not reflect the more specific requirements of particular work tasks, hence there is a need to develop testing protocols that better match the nature, type and intensity of work performed. General and functional test protocols each have inherent advantages and disadvantages with respect to their use in occupational screening. General tests are simple to administer and can be generalised across a range of jobs, however they have been criticised for their lack of similarity (and hence validity) to job tasks. Functional tests have higher content validity and assess aspects such as agility and posture, however they generally do not measure the maximal capacity of the musculoskeletal system, and therefore cannot determine the physical reserve an individual possesses during work tasks.

General and functional tests have been studied in the literature for evidence of attributes considered essential in the development of screening protocols: safety, reliability, validity, practicality and utility (Innes and Straker, 2003; Gross, 2004). Both general and functional test types have been studied in varying degrees for their reliability and validity in simulating the physical demands of various jobs and predicting injury. Results from these studies indicate that some tests show evidence of reliability or validity, however there is yet to be one test with evidence at a clinical level of reliability and validity in all aspects of the test, appropriate to all occupations (Innes and Straker, 1999a; Innes and Straker, 1999b; Wind et al., 2005). In particular, many tests have been unable to provide evidence of their ability to predict injury risk or decrease injury rates (Nassau, 1999). With respect to coal mining, published evidence of the reliability and validity of functional capacity evaluations currently in use within the mining industry is scarce.

While there is currently no consensus on the most appropriate physical capacity screening tool for underground coal mining, it has been identified consistently throughout the literature and confirmed by legislation that injury prevention tools used to assess physical capacity must be based upon the critical tasks of the job (Jamnik and Gledhill, 1992; Kuruganti and Rickards, 2004; Equal Opportunity Commission Victoria, 2006). To meet this need, functional capacity evaluations based on task analysis are replacing or supplementing the more traditional medical evaluations in a number of industries. This shift reflects concerns associated with the validity of traditional methods to evaluate the work capacity of the individual in relation to the tasks inherent in their work.

There is currently a lack of information regarding quantification of the physical demands of underground coal mining tasks. The limited evidence available has been derived from assessment of the heart rate of miners during underground coal mining tasks (Montoliu, Gonzalez and Palenciano, 1995; Abt and Tranter, 1999) and physiological responses of whole body vibration (Bobick, 1988). Information regarding the job demands, the physical capacity required to safely perform these tasks and appropriate methods to screen and match the physical capacity of workers to job demands is currently not available.

The purpose of this project was to develop a functional capacity evaluation tool that may be used to identify the functional capacity of individuals relative to specific physical work demands of underground coal mining. The test battery aims to evaluate both general fitness and work-specific fitness of the individual. Information derived from the tool can be used as a basis for the design and evaluation of interventions targeted at enhancing worker's functional capacity and in testing work-related changes in functional capacity with age or following injury.

Stage 1

Preliminary discussions and observation of work tasks



Stage 1 Preliminary discussions and observation of work tasks

The aim of this initial stage of the project was to develop a preliminary classification of work tasks with respect to the nature of tasks in four different occupational categories in underground mining and to derive information on the workers' perception of their duration, frequency and intensity. A sample of underground coal miners involved in physically demanding tasks were invited to take part in focus group discussions to assess work tasks. All project procedures in this and later stages of the project complied with the NH&MRC guidelines for human experimentation and were approved by the Queensland University of Technology Ethics Committee. Other relevant information on job descriptions provided by the company was also considered in the classification of work tasks.

Focus groups were established according to the following categories of employment: production/ longwall, maintenance, and development. To determine the important and critical issues relevant to each group it was necessary to conduct several informal interviews with workers from each category. These discussions were primarily aimed at identifying tasks perceived to be physically demanding and/or frequently performed and secondly to raise any relevant work issues of concern, with members of each group. An additional aim was to generate a representative list of key tasks to be included in a questionnaire that would be administered to a larger sample of workers at these sites and employed in these work categories. Interviews were conducted pre-shift, above ground or underground, during crib breaks at Central Queensland's Kestrel and Cook coal mines during both day and night shifts. The participating mines represented mines of differing size and mode of operation.

A total of twenty-four miners participated in the informal interviews. Their age ranged between 30 and 39 years and the average duration of employment in their current position was 8.7 years. Of the 24 miners, 23 were classified as miners within the various sub categories and one as a deputy (supervisor).

The methodology for interview followed a combination of structured and unstructured styles. Initially the interviews followed a conversational approach commonly associated with an unstructured style with no definitive questions or predetermined line of investigation. Participants were informed of the purpose of the research and the purpose of the interview prior to more detailed discussion. A questioning strategy was used to explore the work performed, with a particular focus on aspects of the work considered to be physically demanding or functionally important. The discussion took on a structure with a focus on issues associated with the nature, intensity and frequency of work tasks. The combination of unstructured and structured styles evoked useful factual, subjective opinion and objective information about various aspects of the work and the tasks involved.

Interviewing as a major method of job analysis has disadvantages. The interviews were time consuming and there is the potential for interviewer bias. Certain aspects of the work may not have been identified and problems of interpretation of some of the more subjective responses needed to be treated with caution. However this procedure provided a rich source of information which complemented other procedures used in the task analysis.

The various tasks identified by the workers in the focus group discussions and interviews were observed by the research team during 12 day and night shifts across the two mines. When safety requirements were met, some photographic records of key tasks were obtained. Qualitative information concerning the impact of the work environment and work organisation on the performance of work tasks, (eg. working hours and crew sizes) was obtained from observation and discussion. Injury data obtained from each mine site was also analysed to determine injury patterns and their potential relationship to the work tasks identified. An analysis of the equipment and consumables generally used in the performance of the various tasks was also conducted by reference to information provided by the mine site and manual inspection. Details of the size and weight of each item was used in estimating the likely load and intensity of particular tasks and in the later design of the work-related simulations to meet the criteria of safety and practicality.

1.1 Focus group and informal interview findings

Table 1.1 lists the more physically demanding daily work tasks as identified by the sample of coal miners from the focus groups and informal interviews. All tasks were descriptively listed according to frequency of response as noted in the informal interview questionnaires.

1.2 Miscellaneous feedback

During the early discussion of tasks valuable feedback occurred in relation to the additional physical demands attributed to the work environment and work organisation. Irregular surfaces, wet and muddy conditions and the difficulty of working in confined spaces were identified as issues which increased task difficulty and confirmed the significance of these conditions with respect to their potential to increase injury risk as shown in previous research (Parker et al., 2005).

The organisation of work was also identified as important in considering the impact of work tasks for example length of shifts, crew numbers and the limited opportunity to rotate tasks because of either small crew sizes and/or limited numbers qualified to operate equipment. A general consensus from the discussions was that any test of functional capacity implemented should be mining specific.

Other areas discussed which impact on the physical demands of work included:

1. The difficulty working 12 hour shifts and particularly the last two hours which were perceived as the most difficult;
2. The importance of team work in making physically demanding tasks easier;

3. The practicality of using devices in more than 50% of the lifting tasks; and
4. The fact that some physically demanding tasks cannot be avoided or re-engineered.

Table 1.1 Frequency of specific tasks in a normal work day

TASK	No. of Responses	TASK	No. of Responses
Lifting Back to Backs	9	Carrying Firebox	2
Lifting Cables	9	Driving Remote Control	2
Driving Shuttle	8	Hand Tools: Shovel	2
Lifting HT Plugs	7	Hand Tools: Sledge Hammer	2
Lifting Bolts	7	Lifting Chains	1
Mine Escape: Use Self-Rescuer	7	Lifting Cylinder	1
Lifting Tyres	6	Lifting Oil Pallets	1
Lifting & handling mesh	6	Lifting Seagulls	1
Driving Eimco	6	Lifting Hose	1
Lifting Timber	5	Lifting Gopher	1
Lifting Pumps	5	Carrying Bags	1
Pulling / Dragging Cables	5	Carrying HT Plugs	1
Walking Up Grade	5	Carrying Pumps	1
Large Machinery: Bolter	5	Carrying Tyres	1
Lifting Bags	4	Carrying Water Pipes	1
Machine Tools: Gopher	4	Carrying Borer	1
Large machinery: Continuous Miner	4	Pulling / Dragging HT Plugs	1
Mine Escape: Walking	4	Dragging Brattice	1
Machine Tools: Gopher	4	Pulling / Dragging Chains	1
Lifting Belts	3	Dragging Mesh	1
Lifting Brattice	3	Driving Mobile Bolter	1
Pulling Back to Backs	3	Walking Down Grade	1
Pulling / Dragging Hoses	3	Walking On Belt	1
Walking Uneven Ground	3	Walking After Shift	1
Lifting Rollers	2	Walking Returns	1
Lifting Water Pipes	2	Walking Drift	1
Carrying Back to Backs	2	Walking Alongside Belt	1
Carrying Belts	2	Hand Tools: Hammer	1
Carrying Bolts	2	Hand Tools: Spanner	1
Carrying Brattice	2	Hand Tools: Shifter	1
Carrying Cables	2	Hand Tools: Picks	1
Carrying Mesh	2	Carrying person / equipment	1
Carrying Timber Props	2		

An initial list of 65 tasks (Table 1.1) considered to be physically demanding was identified from these processes and these were documented for further analysis during the characterisation phase. All tasks were considered for inclusion in the questionnaire for Stage 2 of the process which involved a larger sample of miners and was used to rate the different tasks in relation to their intensity, frequency and duration. After extensive consideration between the QUT research team and consultation with the involved mining groups, the 65 tasks were categorised into a smaller generic number (16) as being representative of the major types of activities performed in an average shift (Table 1.2). These 16 generic work-related tasks were subsequently included in the questionnaire.

Table 1.2 Generic work-related tasks (in alphabetical order)

Generic work-related tasks
Bolting (using miner bolter or gopher)
Driving shuttle car / Eimco
Lifting / carrying timber
Lifting / dragging cables
Lifting / dragging monorail
Lifting & handling mesh
Lifting stone dust bags
Lifting ventilation ducts
Maintenance and repair tasks
Moving belt structure
Other demanding tasks
Repairing, extracting or extending a belt / conveyor
Shovelling (bouts)
Standing
Walking
Walking (carrying equipment)

Stage 2

Rating of work tasks by larger sample of workforce

Stage 2   Rating of work tasks by larger sample of workforce

To confirm the relative physical demands of the work tasks identified in stage one, a questionnaire was designed and administered to a larger sample of 191 mineworkers across the different work categories. The questionnaire content was restricted to basic demographic data and questions relating to the physical demands associated with the generic tasks identified earlier. Respondents were asked to indicate the intensity, frequency and duration of the tasks prioritised for inclusion in the questionnaire using a 3-point Likert scale (intensity, 1 = light; 2 = medium; 3 = hard, frequency, 1 = rarely; 2 = sometimes; 3 = frequently; and duration, 1 = short time; 2 = medium time; 3 = long time). Individual responses were aggregated and represented as a percentage of total responses, as shown in Figures 2.1, 2.2 and 2.3.

Additional questions provided demographic data and information on type of employment and mine and shift type which was valuable in the interpretation of the task related information. Refer to Appendix 1 for the complete questionnaire.

Previous studies undertaken by the research team have indicated that relying on participants to return completed questionnaires via mail is largely unsuccessful. Therefore, to maximise response rate and ensure confidentiality, questionnaires were completed under supervision at the mine site, with researchers available to answer any questions should they arise. Prior to general distribution the questionnaire was piloted with 10 miners, who provided feedback regarding the content and structure of the questionnaire. The feedback assisted in the refining of questions prior to subsequent distribution to the larger sample of miners.

2.1 Questionnaire findings

2.1.1 Demographic and work-related information

Demographic information presented in Table 2.1 shows that the majority of the 191 miners who completed the questionnaire were in the 30-39 and 40-49 year age categories which is broadly representative of the overall coal mining workforce (ABS, 2001), All tables and figures reporting on the questionnaire results show the number of responses for each question, which ranged from 120 to 190 out of 191 respondents. All statistical analyses were carried out using SPSS 13.0 for Windows and differences were considered significant at equal or below the p-value of 0.05.

Comment [QSOE1]: TONY

As shown in Table 2.2, the majority of respondents were in the operator/maintainer category (79.3%), followed by the fitters mechanics and electricians (31.5%).

Table 2.1 Demographic data for sample group of miners

Variable	% of Total
Gender (n=187)	
Male	99.5
Female	0.5
Age (n=187)	
<20 years	0.5
20 – 29 years	24.6
30 – 39 years	41.2
40 – 49 years	26.7
50 – 59 years	5.9
≥60 years	1.1

Table 2.2 Industry profile for sample group of miners

Variable	% of Total Responses	Variable	% of Total Responses
Mine Type (n=183)		**Major Duties in Occupation (n=190)**	
Longwall	73.7	Bolting	23.7
Bord & Pillar	14.7	Driving Shuttle Car	16.0
Both	3.8	Shovelling	14.1
Other	7.6	Cable Hand	12.9
Current Occupation (n=155)		Miner Operator	11.2
Deputy	10.9	Other	21.8
Supervisor	12.9	**Employment Status**	
Operator/Maintainer	79.3	Permanent	71.1
Fitter/Mechanic	18.0	Contractor	28.3
Electrician	13.5	Other	0.5
Other	10.3	**Total Years in Underground Coal Mining (n=186)**	
Years in Current Occupation (n=185)		<1 year	8.6
<1 year	20.0	1 – 4 years	28.4
1 – 4 years	45.4	5 – 9 years	29.0
5 – 9 years	17.8	10 – 19 years	20.4
10 – 19 years	10.2	20 – 29 years	10.7
20 – 29 years	3.7	≥ 30 years	2.6
≥ 30 years	2.7	**Years in Previous Employment (n=148)**	
Primary Work Focus (n=120)		<1 year	19.5
Production/Longwall	26.7	1 – 4 years	31.7
Maintenance	20.0	5 – 9 years	22.3
Development	40.0	10 – 19 years	19.3
Other	13.3	20 – 29 years	6.7
		≥ 30 years	0.6

Many miners performed more than one role at the mine, with 80% of the sampled miners acting wholly or in part as operator/maintainer. A significant number performed a higher-level position as deputy or supervisor (24%) or in a trade as a mechanic, electrician or fitter (30%). The primary workforce focus categorisation employs the term “production/longwall”. While most production miners are longwall operators, a small number of production miners from bord and pillar operations are included. Approximately 65% of the sampled miners had been working in their current occupation for less than 5 years and experience in underground mining ranged from 1 to 20 years. Normal duties varied widely with the more common tasks identified earlier featuring in the responses. Most miners were permanent staff with only 28% of the miners sampled on a contract.

Table 2.3 Shift profile for sample group of miners

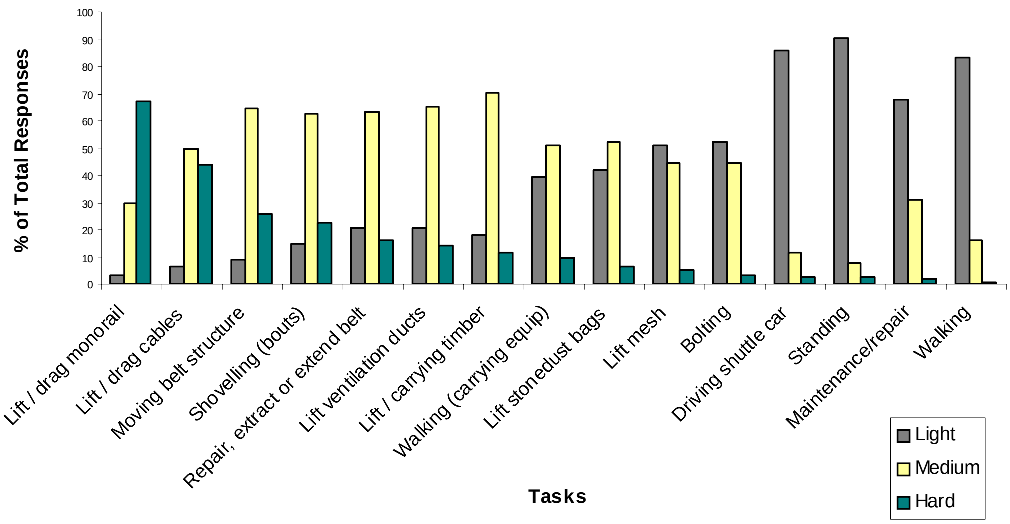
Variable	% of Responses
Roster Type (n =186)	
Fixed Shift	26.8
Rotating Shift	72.5
Usual Shift Type (n =188)	
Day Shift	21.8
Afternoon Shift	3.1
Night Shift	2.1
Combined Day & Night	65.4
Combined Afternoon and Night	7.4
Other	0.5
Usual Shift Duration (n =188)	
8 Hours	0.5
10 Hours	30.3
12 hours	69.6
Other	5.3
Max. Number of Consecutive Days Worked (n=185)	
2 days	0.0
3 days	14.0
4 days	6.4
5 days	59.4
6 days	11.3
Other	8.6
Min. Number of Consecutive Days Off Work (n=188)	
2 days	18.6
3 days	11.1
4 days	50.0
5 days	10.1
6 days	3.7
Other	6.3
Approximate Overtime Hours/ Week (n=185)	
Not applicable	55.1
1 – 4 hours	16.7
5 – 9 hours	8.1
10 – 14 hours	13.5
15 – 19 hours	2.7
≥20 hours	3.7

The majority of the miners worked forward rotating roster patterns from day to night shifts which were generally of 12 hours duration. The most common roster pattern was 5 days on and 4 off. Forty per cent of the sampled miners performed some overtime, in some cases amounting to 14 hours a week (Table 2.3).

2.1.2 Ratings of work tasks - intensity

Figure 2.1 shows that 97% of the respondents indicated that lifting/dragging monorail was the task rated as the most physically demanding. Other physically intense tasks include lifting/dragging cables (44% rated hard), moving belt structure (91% rated moderate intensity or greater) and bouts of coal shovelling (86% rated moderate intensity or greater). Most other tasks were rated as being of mainly light to moderate intensity. Lifting & handling mesh (94% rated either light or of moderate intensity), bolting, and lifting stone-dust bags were considered of lower intensity.

Figure 2.1 Perceived intensity of daily work tasks (n = 180)



Analysis of task intensity across the work categories (production, maintenance, development and longwall) showed that the intensity of effort required to complete a given task is quite uniform across sectors. All four work sectors rated lifting/dragging monorail and lifting/dragging cables as requiring the highest level of effort, while moving belt structure was also consistently rated across all sectors as being hard to perform (Table 2.4). Workers in development ranked Coal shovelling as being hard to perform (32%) and higher than workers in other job categories (average 17%).

Table 2.4 Percent response from miners in each work sector nominating the task as requiring the highest level of effort 'intensity' during the course of a normal shift.

	Highest intensity (percentage of responses)		
Task	**Production/Longwall**	**Maintenance**	**Development**
Lifting & handling mesh	12.3	9.6	4.3
Lifting Stonedust bags	7.5	6.8	5.6
Lifting ventilation ducts	18.8	20.5	13.6
Lifting/dragging cables	41.7	46.6	44.6
Lifting/dragging monorail	62.9	75.0	82.5
Lifting/carrying timber	8.6	7.3	16.2
Maintenance/repair tasks	4.3	0.0	1.1
Carrying equipment	14.0	5.4	11.5
Bolting	8.2	2.7	3.2
Driving shuttle car/EIMCO	2.2	2.7	3.4
Repair/extract belt/conveyor	19.5	9.7	24.6
Moving belt structure	24.9	14.6	38.2
Shovelling	17.7	14.5	32.2
Walking	0	0.0	1.0
Standing	1.9	0.0	3.2

2.1.3 Frequency and duration of work tasks

As shown in Figure 2.2 walking and standing were identified as the most frequently performed activities. Although not considered as specific work tasks, both activities need to be taken into account when determining the physical demands of the job particularly in relation to the long duration of these functions across the 12-hour shift as shown in Figure 2.3.

The most frequently performed tasks were carrying equipment and bolting. Tasks such as bolting were specific to development and the results expressed the repetitive nature of this task. The frequency of coal shovelling varied across work categories but was generally identified as being performed rarely or sometimes. Bolting and carrying equipment were tasks of long duration across the 12 hour shift. A majority of tasks, including those involving lifting, were rated as being of short duration.

Not surprisingly task frequency and duration differed significantly across the different work categories. Lifting & handling mesh and lifting ventilation tubes for installation, and lifting/dragging cables were more frequently performed by production and development crews, with 35% and 50% of miners from these crews respectively saying they perform each of these tasks frequently. Specific tasks performed more frequently by longwall crews included lifting/dragging monorail moving belt structure and shovelling (Table 2.5).

Figure 2.2 Perceived frequency of daily work tasks (n = 180)

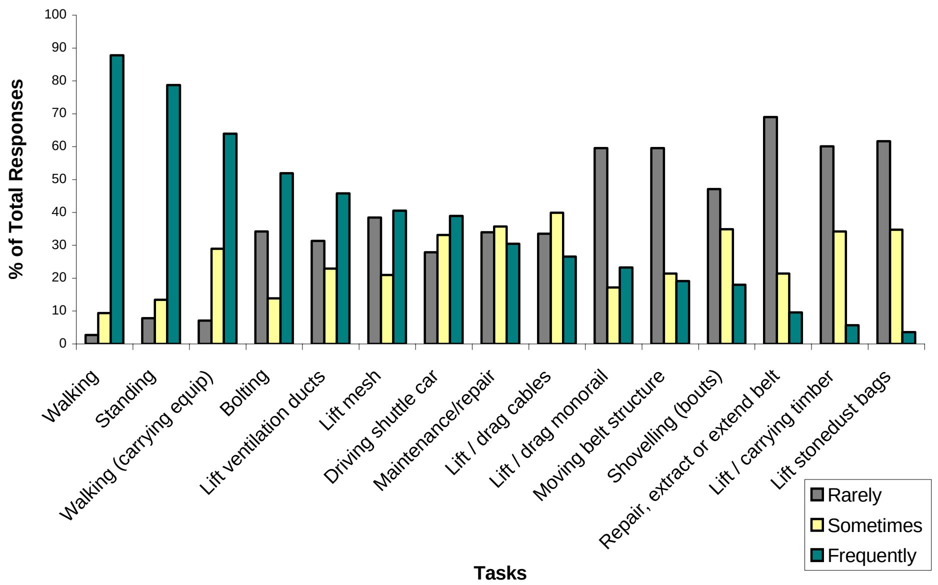


Figure 2.3 Perceived duration of daily work tasks (n = 176)

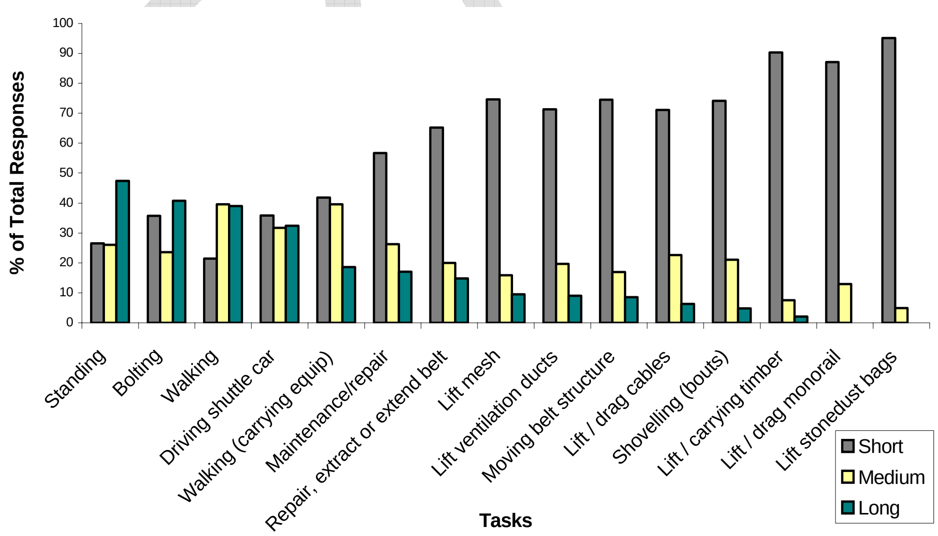


Table 2.5 Percent response from miners in each work sector nominating the task as being performed 'frequently' during the course of a normal shift.

Frequently performed tasks (percentage of responses)			
Task	Production/Longwall	Maintenance	Development
Lifting & handling mesh	23	11	53
Lifting Stonedust bags	5	0	5
Lifting ventilation ducts	20	14	56
Lifting/dragging cables	22	13	38
Lifting/dragging monorail	33	11	6
Lifting/carrying timber	6	4	5
Maintenance/repair tasks	25	49	22
Carrying equipment	61	65	61
Bolting	30	17	66
Driving shuttle car/EIMCO	26	20	47
Repair/extract belt/conveyor	6	2	4
Moving belt structure	31	9	8
Shovelling Activity	26	9	16
Walking	92	83	88
Standing	71	65	81

Table 2.6 Percent response from miners in each work sector nominating the task as being performed over either a 'medium' or 'long' time duration during the course of a normal shift.

Tasks performed for medium or long duration (percentage of responses)			
Task	Production/Longwall	Maintenance	Development
Lifting & handling mesh	8	9	29
Lifting Stonedust bags	2	5	5
Lifting ventilation ducts	9	16	34
Lifting/dragging cables	24	18	31
Lifting/dragging monorail	12	9	1
Lifting/carrying timber	6	7	6
Maintenance/repair tasks	31	74	28
Carrying equipment	49	60	57
Bolting	33	32	79
Driving shuttle car/EIMCO	39	41	65
Repair/extract belt/conveyor	19	24	18
Moving belt structure	23	14	19
Shovelling	29	15	19
Walking	82	84	75
Standing	60	60	76

Duration of the task was similar for the different job categories in the non-specific tasks such as lifting and carrying which were of relatively short duration (Table 2.6). Maintenance and development crews performed tasks over a longer period as indicated for belt change and repair (maintenance) and bolting (development). Although not requiring the same physical demands, shuttle car driving was an activity of long duration across the shift. Importantly, tasks previously noted to be of high intensity, such as those involving lifting (mesh, stonedust bags, monorail, vent ducts, timber), were generally of short duration.

The list below indicates the 10 most physically demanding tasks as identified by coal miners overall. The tasks are in numerical order related to their physical demand (1 being the most physically demanding task and 10 the least demanding).

1.	Lifting/dragging monorail
2.	Lifting/dragging cables
3.	Moving belt structure
4.	Shovelling (bouts)
5.	Repair, extract or extend conveyor
6.	Lifting ventilation ducts
7.	Lifting/carrying timber
8.	Walking (carrying equipment)
9.	Lifting stonedust bags
10.	Lifting & handling mesh

Stage 3

Task characterisation

Stage 3 Task characterisation

The aim of this stage was to use the information gained from the earlier stages of the project to identify the critical tasks which would be utilised either singularly or as combinations of multiple tasks to be included in the work-related test battery.

To determine which tasks (as rated on the questionnaires) were to progress to further analysis, an exclusion process was implemented based on the percentage of responses for each question. At each stage of the exclusion process, each task excluded was evaluated by the research team to ensure that the exclusion was appropriate and consistent with information collected during the interviews with coal miners.

For example, Figures 2.1, 2.2 and 2.3 indicate that walking, standing and shuttle car driving are the least physically demanding but most frequently performed and most time consuming activities. Walking, a frequently performed activity with aerobic demands, was excluded as a single activity but was able to be incorporated as a fundamental component of the equipment carriage task. Shuttle car driving was excluded as it was considered an activity with greater cognitive than physical demands. It is recognised however, that the task of shuttle car driving, while not presenting high physical demands, is associated with other risk factors for injury such as vibration. Similarly, tasks that cannot be re-engineered, are extremely dynamic in nature, are highly mechanised or utilise 3 to 4 people to execute, were excluded from consideration due to safety concerns with respect to developing tests.

Tasks that essentially involved the same muscle groupings, similar levels of intensity, frequency or duration were rationalised to reduce the number of potential tests and reduce the time required to conduct them. Discussions with miners on those tasks which could be redesigned were useful in eliminating tasks which were redundant in the context of the aim of the test battery and in reducing any unnecessary risk of injury. Handling monorail was one of the tasks considered to be in this category.

In addition to consideration of task intensity, frequency and duration independently for each task, some analysis was undertaken to examine their combined effects. Intensity being a primary underlying factor in task difficulty, a matrix of scores was formed from the scaled values for each response on the questionnaire. The matrix included:

- Task Intensity multiplied by frequency
- Task Intensity multiplied by duration
- Task Intensity multiplied by frequency multiplied by duration.

Although these 3 aspects of the task were not measured on a common scale and simple multiplication may not represent the combined effects of these factors in a completely valid way, it nevertheless provides some indication of the combined effects of intensity, duration and frequency. Table 3.1 summarises the intensity order generated from Figures 2.1, 2.2 and 2.3.

While the physical demands analysis in this project did not objectively quantify the frequency, intensity or duration of the commonly performed tasks involved in underground mining, the physical demands analysis does allow a subjective ranking of tasks based on their overall physical demand as well as by the effort level (intensity) and time consumed (duration and frequency). This analysis also allowed tasks to be compared across different work categories and showed that a majority of tasks in each category involved manual handling and in some cases were associated with significant physical demand. Other 'skill' tasks such as operating the shearer or continuous miner were not considered in this physical demands analysis due to the low level of physical demand required for these tasks, even though their duration may be very high for some operators.

Table 3.1 Ranking of work tasks (1 being the most intense, 15 being least intense)

	Intensity x Frequency	Intensity x Duration	Intensity x Frequency x Duration
1	Lifting / Dragging Cables	Lifting / Dragging Cables	Walking (Carrying Equipment)
2	Walking (Carrying Equipment)	Lifting / Dragging Monorail	Walking
3	Lifting Ventilation Duct	Lifting & handling mesh	Standing
4	Lifting / Dragging Monorail	Lifting Ventilation Duct	Bolting
5	Walking	Walking (Carrying Equipment)	Lifting Ventilation Duct
6	Standing	Walking	Lifting / Dragging Cables
7	Bolting	Standing	Driving Shuttle Car
8	Moving Belt Structure	Bolting	Shovelling (Bouts)
9	Shovelling (Bouts)	Driving Shuttle Car	Lifting & handling mesh
10	Lifting & handling mesh	Repair/Extract/Extend Conveyor	Moving Belt Structure
11	Lifting / Carrying Timber	Moving Belt Structure	Maintenance / Repair Tasks
12	Maintenance / Repair Tasks	Shovelling (Bouts)	Lifting / Dragging Monorail
13	Driving Shuttle Car	Maintenance / Repair Tasks	Repair/Extract/Extend Conveyor
14	Repair/Extract/Extend Conveyor	Lifting Stonedust Bags	Lifting / Carrying Timber
15	Lifting Stonedust Bags	Lifting / Carrying Timber	Lifting Stonedust Bags

Information regarding the tasks 'essential' to a job or position was considered important in the development of the functional capacity evaluation and the matching of functional capacity with work demands. Following the characterisation of the work tasks and further consultation with miners, the tasks identified below were excluded or retained for possible inclusion in the work-related component of the functional capacity evaluation.

Table 3.2 Task characterisation (excluded and included tasks)

Excluded tasks	Included tasks
• Walking	• Walking/carrying equipment
• Standing	• Lifting water pipe
• Shuttle car driving	• Lifting/dragging cables
• Bolting	• Lifting ventilation ducts
• Moving belt structure	• Shovelling bouts
• Maintenance/repair tasks	• Lifting & handling mesh
• Lifting/dragging monorail	
• Repair/extract/extend conveyor	
• Lifting/carrying timber	
• Lifting stone dust bags	

Stage 4

Development and evaluation of tests used in the functional capacity evaluation



Stage 4 Development and evaluation of tests used in the functional capacity evaluation

The results from the earlier stages of the project guided the development of the work-related tests and a more generic health-related fitness test battery to be used in the functional capacity evaluation. Information on the development and evaluation of these two test batteries is presented in the following sections.

4.1 Health-related test protocol

In addition to the work-related tests, a battery of health-related fitness tests was designed to provide a general fitness evaluation using established tests of aerobic fitness, flexibility and muscular strength and endurance consistent with the physical demands of underground coal mining. Observation of work over the 12-hour shift period and evidence from earlier studies of heart rate changes during underground mining (Abt and Tranter, 1999) suggested that the aerobic demands of the work are not generally of sufficient duration to enhance cardiovascular fitness. However, lack of fitness may place the miner at increased cardiovascular risk as a function of the high intensity physical demands associated with some less frequently performed tasks and emergency situations. Muscular strength and endurance are also essential in reducing the potential for muscular fatigue, particularly of the upper limb musculature which is commonly involved in a range of repetitive tasks with relatively high load, such as roof bolting. Similarly the performance of tasks with postures constrained by the working environment suggests the importance of flexibility in the performance of these tasks. Consequently, selection of the health-related fitness tests was based on careful consideration of the characteristics associated with the nature and demands of the tasks involved in underground coal mining.

The application of tests that focus on components of general health and fitness was also considered a necessary precursor, from a safety perspective, to the more specific work-related tests. The work-related tests are designed around tasks performed in an average shift by underground coal miners, often incorporating multiple components of general fitness into the single task. As such, an inability by the participant to demonstrate adequate performance in the health-related fitness protocol would prohibit that person from participating in the work-related tests. In addition to a medical examination the general health and fitness tests can therefore be considered a preliminary indicator of the participant's capacity to safely handle the subsequent work-related fitness tests.

The health-related fitness tests were developed by the research team who had completed the task analyses. The team included expertise in exercise physiology, functional anatomy and biomechanics and researchers who were competent in identifying existing tests which matched the physical and physiological requirements of the work. These tests were also selected on their previously reported reliability and practicality with respect to time and ease of administration at work sites. The tests were:

1. Back extensor strength	6. Abdominal endurance
2. Leg strength	7. 3-minute step test
3. Elbow flexor strength	8. Trunk rotation (L & R)
4. Shoulder flexor strength	9. Sit-and-reach
5. Abdominal strength	

4.2 Preliminary work-related test protocol

Based on the earlier task characterisation (refer to Stage 3), 6 work-related fitness tests were chosen for the preliminary FCE. They were:

1. Walking & carrying equipment	4. Vent tube hanging
2. Handling water pipe	5. Coal Shovelling
3. Lifting/dragging cable	6. Lifting & handling mesh

In addition to the representation of key work tasks, tests also incorporated the essential elements of fitness associated with the work tasks. The requirement for strength and muscular endurance was a feature in each of the tests. The structure/organisation of the tests included a progressive increase in demand on the cardiovascular system. The movement around objects, especially in the mesh handling task, contained an element of flexibility in the upper limb and trunk.

The following provides a brief description of the nature and purpose of each test:

1. Walking & carrying equipment

Task: Carry three items of differing weight (10kg, 20kg and 25kg) a total distance of 40 metres and two heavier (30kg and 35kg) items, with handles, a total distance of 10 metres.

Purpose: To test the participants' leg, back and arm muscle strength and endurance while carrying weights.

2. Handling water pipe

Task: To lift and install a commonly-used 135mm x 6.05m water pipe, with the distal end acting as a fulcrum. The pipe is passed through the overhead support structures at progressive intervals of 0.5m and hung at participant shoulder height.

Purpose: To test the participants' shoulder flexion strength and endurance when hanging water pipe.

3. Lifting/dragging cables

Task: To lift and pull as much of a standard $70mm^2$ miner cable as possible from a drum in 10m, 20m, 30m, 40m and 50 metre increments.

Purpose: To assess the participants' back, shoulder, arm and leg strength and endurance and aerobic demands required for this task.

4. Vent tube hanging

Task: Simulate the installation and removal of two commonly used vent tubes

Purpose: To assess the shoulder flexion and arm strength and endurance required for the installation and removal of vent tubes.

5. Coal shovelling

Task: Shovel as much dry coal within two minutes into a designated area as possible.

Purpose: To test a subjects' back, shoulder and arm muscle endurance and general aerobic capacity during two minutes of coal-shovelling

6. Lifting & handling mesh

Task: Simulate the carry, installation and removal of a half sheet of mesh material in a confined area.

Purpose: To assess the shoulder flexion strength, flexibility and coordination required for the installation and removal of mesh sheets, whilst also considering the safety requirements of the task.

The included work-related tasks identified were discussed with miners and were designed to simulate the more frequently performed and physically demanding tasks previously identified. These tests required access to equipment used in the key mining tasks or a simulated version of this equipment. Ideally, for maximum realism the tests would be conducted underground with environmental conditions as close to those experienced during normal work being replicated. This was not possible for safety and logistical reasons and consequently the tests were designed to be conducted above ground with conditions and equipment designed to simulate the actual conditions as closely as possible. Considerable time was expended in determining the appropriate environment and testing equipment which could be consistently applied across all underground coal mining sites.

In designing the simulated working condition, the major construction required was the design and building of a frame to simulate the task of vent tube hanging. Other details with respect to loads used and specific work controls are identified in the description of the specific tests (Appendix 4). For technical diagrams of the vent tube testing frame, refer to Appendix 8.

4.3 Evaluation of preliminary FCE

Preliminary evaluation of both the health-related and work-related test batteries was conducted at Kestrel Coal mine, located 50km north-east of Emerald, Central Queensland, Australia. Kestrel Coal mine was chosen due to the site's accessibility and onsite facilities.

Occupational Health and Safety professionals from the mine selected five volunteer miners to participate in the tests and to provide feedback on their suitability and realism in relation to their normal job demands. All participants had been free from musculoskeletal injury for the previous 18-months, had not taken time from work due to injury and had not been nominated to light duties due to injury. All subjects completed an informed consent form and a health screen questionnaire prior to participation in the study. The participants had an average age of 32 years ranging from 23-47 years. They had a mean weight and height of 87 kg (68-112kg) and 1.82 m (1.71-1.95m) respectively. With additional weights when wearing work clothes and equipment, the total average weight of the miner was 98kg (79-127kg).

Prior to the administration of the health related test protocol a health background/history questionnaire (Appendix 2) was completed by participants. The information was considered important in identifying any medical problems which may preclude the worker from further participation in the test protocol. The questionnaire covered any previous history of cardiovascular and injury problems and any current problems which may make it unsafe to participate. Other questions related to lifestyle and behavioural issues and were helpful in the interpretation of individual performances on the tests. The responses were reviewed by an exercise physiologist and any problems were clarified with the participant. If it was considered that the respondent was at risk by proceeding further, advice was given to seek medical opinion and not to participate in the test protocol.

In this preliminary trial, all pilot health-related tests were conducted on site in an air-conditioned room. Nine tests were included in the pilot test protocol, emphasising three distinct and key fitness components: strength, endurance and flexibility.

The tests were conducted in the order listed:

1. Back extensor strength	6. Abdominal endurance
2. Knee extensor strength	7. 3-minute step test
3. Elbow flexor strength	8. Trunk rotation (L & R)
4. Shoulder flexor strength	9. Sit-and-reach
5. Abdominal strength	

In the work-related testing, participants were shown the test requirements by demonstration and were given the opportunity to ask questions. They were assisted by exercise physiologists in applying heart rate monitors (Polar Electro Oy Finland) and instructed on use of the rating of perceived exertion

(RPE) as guided by the Borg scale (Borg, 1998). Heart rates, ratings of perceived exertion and split times were taken at pre-determined intervals to provide information concerning the physiological response associated with task intensity. All heart rate activity was measured continuously with the Polar S610i downloadable heart rate monitor (Polar Electro Oy Finland) and analysed with the software provided (Polar Precision Performance SW, version 4.00.022).

Comment [QSOE2]: ????

All tests were completed in a circuit fashion with the participant moving from one test to the next. Recovery time after each trial of a test and between tests was self-determined by the subject. All subjects participated in a standardised stretch session in which all major body parts were involved. For the purpose of the pilot study, subjects wore their 'usual' underground apparel for all tests to increase the realism of the test situation.

All work-related tests were performed at the training areas designated for Mines Rescue training. At one site the area consisted of a 30m x 7m steel enclosure with concrete floor replicating an underground work area, a 15m x 4m open-air concrete surface and a sanded, open-air 55m x 40m area. The 'Carriage' and 'Cable Drag' activity were both conducted on the sanded 55m x 40m area. The 'Coal Shovel' was performed on the open-air concrete area while the remaining tests were performed in the enclosed, concreted 'underground work area'. Due to the large areas required to execute the work-related tests, temperature and humidity could not be controlled.

Following the administration of the work-related tests, a feedback questionnaire was completed by each participant. This brief questionnaire asked the participant to indicate on a scale of 1 to 5 how realistic they perceived the test to be and the intensity of the physical demand when compared to performance of similar tasks underground. Additional sections were provided on the questionnaire for specific feedback regarding each test, including suggestions for improvements, and inconsistencies with normal practice of the tasks in the field. Participants were also allowed to provide more general feedback regarding the overall testing process.

4.3.1 Results of pilot testing of health-related protocol

When comparing the data in Table 4.1 with normative age matched data, 4 of the 5 participants displayed a score 'well above average' in back extensor strength, however, in knee extensor strength, no participant scored above 'poor'. Elbow flexor strength in 4 of the 5 subjects was 'above average' in contrast to shoulder flexion in which 4 subjects scored 'below average'. Three subjects tested for abdominal strength were rated as 'poor', however, no participant scored below 'average' for abdominal endurance. The cardiovascular recovery of heart rate following the 3-minute step test was classified 'below average' for all subjects. Only two of the participants obtained a score above the fiftieth percentile for the general population in the sit-and-reach test.

A review of the test results indicated low reliability in the trunk rotation test and difficulty in standardisation and accuracy of this measurement. As such the test was not retained. Also for similar reasons of reliability, the 3-minute step test was replaced by the 6-minute test. Because of the importance of back extensor function in many mining tasks, it was also considered important to incorporate a measure of muscular endurance as well as the measure of maximum isometric strength. Standardisation of the foot and body positions during the measurement of isometric strength also occurred following laboratory testing of the measurement device. Improvement of these procedures and modification of the strength testing device improved test-retest reliability across the range of isometric strength tests.

Table 4.1 Results of pilot testing of health-related protocol

	Subject					
Test	**1**	**2**	**3**	**4**	**5**	**Mean (±SD)**
Back extensor strength (kg)	98	177	225	197	216	182.6 (50.8)
Elbow flexor strength (kg)	29	46	52	46	47	44.0 (8.8)
Leg strength (kg)	148	207	218	229	220	204.4 (32.5)
Abdominal strength (level)	4	4	2	2	2	2.8 (1.1)
Abdominal endurance (# sit-ups/min)	33	27	31	39	32	32.4 (4.3)
3 minute step test (bpm)	116	130	136	128	137	129.4 (8.4)
Sit-and-reach test (cm)	-7	-8	1.5	5	8	-0.1 (7.1)
Trunk rotation (L) (cm)	-25.5	2	-19.5	-1	-15.5	-11.9 (11.9)
Trunk rotation (R) (cm)	-11	0	-27	3	-26.5	-12.3 (14.2)

Norms are based upon: Shephard (1986), Corbin et al. (2001), Durstine (1993) and Stewart et al. (2003).

4.3.2 Results of pilot testing of work-related protocol

The absence of normative data during performance of these tasks while at work underground, precluded validation of the test results against measures obtained in the real work situation. Consequently, content validation was measured using the participants' rating of intensity and realism following completion of the test protocol as described earlier.

Evaluation of the average maximum heart rate and maximum heart rate as a percentage of age-predicted maximum heart rate (APMHR) occurred in the final level of each of the work-related tasks. These values for each test (mean & ±SD) are presented in Table 4.2. Coal shovelling at 102% of APMHR incurred the highest cardiovascular demand and this was confirmed by the highest rating of perceived exertion for this activity.

Table 4.2 Pilot heart rate data for work-related fitness tests (mean ± SD)

Work-related Test	Average max. heart rate (bpm)	Average max. heart rate (% of APMHR*)	RPE
Walking & carrying equipment	150 (16.3)	81 (8.9)	12.8 (1.9)
Lifting water pipe	149 (21.7)	81 (11.1)	17.4 (1.5)
Lifting & dragging cable	182 (14.9)	98 (6.3)	17.8 (1.6)
Vent tube hanging	171 (11.9)	93 (6.5)	14.8 (2.2)
Coal shovelling	189 (6.1)	102 (5.0)	16.4 (1.1)
Lifting and handling mesh	166 (8.7)	73 (5.9)	12.6 (3.4)

* Age-predicted maximum heart rate (APMHR) = 208 - .7*Age

Table 4.3 Perceived realism and physical demand of the work-related tests (mean ± SD)

	Equipment Carriage	Water Pipe	Cable Drag	Vent tube hanging	Coal Shovelling	Mesh handling
Realism	4.4 (0.5)	3.9 (0.9)	4.2 (0.4)	4.0 (0.0)	4.2 (0.4)	4.4 (0.5)
Physical Demand	4.0 (0.0)	3.8 (1.1)	4.4 (0.5)	3.8 (0.4)	4.1 (0.5)	4.4 (0.5)

Realism: 1=unrealistic; 5=very realistic
Physical demand: 1=unrealistic; 5=very realistic

Validation results from the preliminary evaluation of the proposed work-related test protocol (Table 4.3) indicated that the perceived realism and physical demand required by each work-related task was similar to that experienced while performing underground work tasks.

Based on feedback following the preliminary trial, a number of changes were made to the work-related test equipment and procedures to enhance their efficiency, safety and potential reliability. The ‘water pipe holding’ test was discarded as it was considered to present an unnecessarily high injury risk and was a task that could be redesigned. The upper limb strength components associated with this task were also covered in two other tests. Minor adjustments were made to the other work-related tests including: modification of the vent tube frame to allow adjustment to suit participants of different height; reducing the weight of the mesh to suit handling by a single participant; and selection of a lighter cable and reel in the cable lifting and dragging test. The time of the coal shovelling activity was also extended from two to four minutes duration.

Comments related to the realism of the ground conditions and air quality above ground compared to underground were also considered, but it was felt that revision of the test protocol to address these differences could not realistically be achieved. Standardisation of test conditions above ground to improve the reliability of the tests was considered more important.

Weight limit analysis

The revised NIOSH instrument (1991) was used to ascertain the level of exposure the subjects would be experiencing while performing the various simulated work tasks. The NIOSH instrument was selected because it is universally recognised and widely used throughout the world (Russell, 2007).

The revised 1991 NIOSH instrument is a multiplicative model that uses six weighted variables: horizontal distance, vertical distance, distance travelled, and asymmetry, frequency and coupling measures. The NIOSH equation yields a recommended weight limit (RWL) and a lifting index (LI) for use in determining the relative risk of injury (Waters et al., 1993).

The RWL is thought to be the weight that all healthy workers could perform over a substantial period of time, for example up to 8 hours, without an increased risk of developing lifting-related low back pain (NIOSH, 1994). The LI is calculated by dividing the weight of the object lifted by the RWL. Because of the uncertainty of the dose-response relationship between weight lifted and risk of injury, it is not possible to quantify the precise degree of risk associated with varying increments of the LI. However, it is generally agreed that lifting tasks with an LI of greater than 1.0 pose an increased risk for low back pain for some fraction of the workforce (Waters et al., 1993).

The table listed below indicates the LI value calculated for each of the five simulated work tasks performed by the underground miners.

Table 4.4 Lifting index for five work tasks performed by underground miners.

Task	Carriage	Mesh	Shovel	Vent tubing	Cable drag
LI	1.2	0.85	0.9	0.75	1.1

For the two tasks that achieved a LI score of greater than 1.0, (the carriage and cable drag) these values represent the most arduous levels of the task. For the carriage the LI value represents levels 4 and 5, while for the cable drag the LI value represents the 40m level.

4.4 Summary

Based upon information gained from the earlier stages of the project, Stage 4 describes the development of a functional capacity evaluation for underground coal miners, consisting of health-related and work-related test batteries. The initial tests were piloted on a small sample of five incumbent workers and subsequent alterations were made to the protocols based upon test results, feedback from workers and safety considerations. The functional capacity evaluation was refined and updated to consist of 9 health-related tests and 5 work-related tests. The following stage of the project describes the evaluation and validation of the revised functional capacity evaluation on a larger sample of the workforce.

Stage 5

Evaluation and validation of revised functional capacity evaluation



Stage 5 Evaluation and validation of final FCE

It was the aim of this phase of the project to evaluate the revised health and work-related protocols using a larger sample of miners.

5.1 Health-related test protocol

Twenty-one miners working at two Central Queensland mines volunteered to participate in the test protocols. Prior to testing, subjects completed a health questionnaire and signed an informed consent form. Procedures for conduct of the tests were similar to those used during the preliminary trial (refer to Appendix 3) and testing on the health-related tests took place in an air-conditioned room. Prior to participation in the health related tests a health history questionnaire was completed and the results reviewed to identify any medical condition/s which may exclude the subject from further participation. Satisfactory completion of the health-related tests was also required before proceeding to participation in the work-related test protocol.

Results from the health-related tests were compared with results of performance on the same tests by 84 mines rescue personnel. Basic descriptive statistics (mean ± SD) were calculated for those data. The mines rescue data was collected by the same researchers during the Queensland mines rescue challenge in 2005 and 2006 and similar procedures were followed for both groups.

There were no significant differences between the underground miners and the mines rescue group in relation to age and basic anthropometric data (Table 5.1).

Table 5.1 Age and anthropometric data for underground miners and mines rescue group (mean ± SD)

Variable	Underground Mining (n=22)	Mines Rescue (n=84)
Age (yrs)	36.1 (7.3)	34.4 (8.4)
APMHR (bpm)	183 (5.1)	183 (5.8)
Height (cm)	181.6 (8.0)	178.8 (7.0)
Weight (kg)	92.2 (12.3)	90.8 (14.9)
BMI (kg/m^2)	28.0 (4.0)	28.3 (3.8)

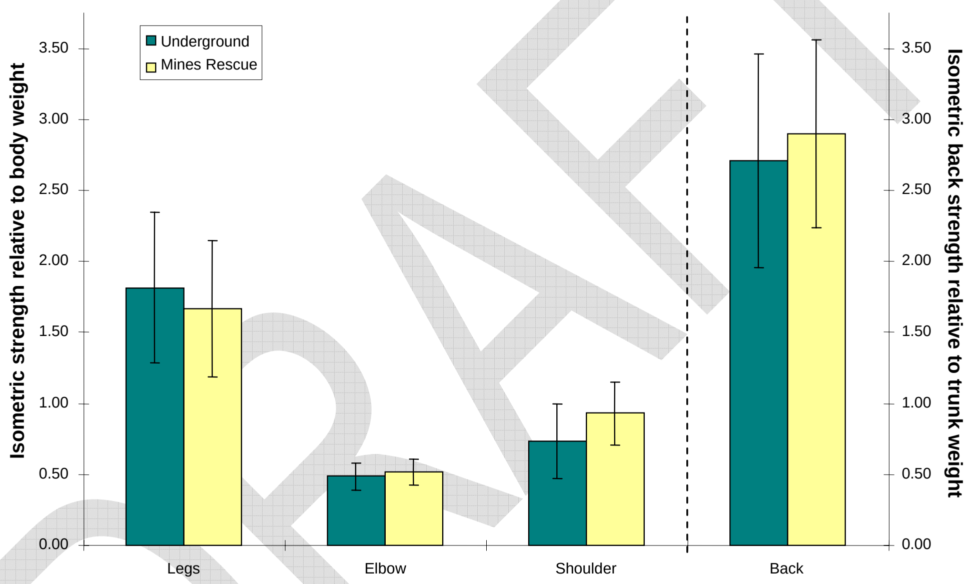
APMHR: Age-predicted maximum heart rate; BMI: Body mass index

Figure 5.1 and Table 5.2 show the results for the 9 health-related tests and comparative data for mines rescue personnel. Isometric back extensor strength, normalised for upper body mass, was the highest of the strength scores followed by knee extensor, shoulder flexor and elbow flexor strength normalised for body weight. This order of strength is consistent with normative data for these muscle groups and no significant differences were found between the two mining groups for the isometric strength scores.

Table 5.2 Measures of abdominal strength and endurance, back extensor endurance, hip and trunk flexibility and aerobic capacity (means ± SD)

Variable	Underground	Mines Rescue
Abdominal strength (level)	2.7 (1.4)	3.5 (1.7)
Abdominal endurance (#sit-ups/min)	34 (10.3)	34 (8.8)
Back endurance (seconds)	98.4 (30.0)	114 (55.5)
Sit-and-reach (cm)	4.1 (6.6)	6.4 (7.4)
Predicted V02 (6-min step test) (ml/kg/min)	38.4 (9.7)	40 (11.0)

Figure 5.1 Isometric strength of trunk, upper and lower limb muscle groups (means ± SD)



5.2 Work-related test protocol

Twenty miners proceeded to participation in the work-related test protocol. One subject was unable to continue due to personal time constraints. The average age of the participants was 36.1 years ranging from 23 to 50 years of age. Their average length of experience in underground mining was 7 years, with a range from .08 to 23 years. Procedures for conduct of the tests were similar to those used during the preliminary trial and are described in Appendix 4. The participants wore their normal work attire, including helmet and safety gear, such as gloves and eye goggles. The test environment at the 2 sites was not identical, but was similarly designed to simulate the normal work environment. The special frame constructed for the vent tube lift and drag provided identical testing conditions at both sites. For other tasks, the weight of the equipment, the height lifted and the spaces used to perform the tasks were identical. As in the preliminary trial, at the completion of the tests subjects were asked to rate the realism and physical demands of each test in relation to performance in the actual work setting (Table 5.4).

All tests were performed at normal work pace with adequate recovery periods to ensure correspondence with normal working conditions. Table 5.3 outlines the results for each level of the five work-related tests. Cardiovascular demand was determined by analysing the time taken to complete the test and the maximal heart rate attained, and which was typically reached in the final level of each test. Maximal heart rate was compared with the age-predicted maximal heart rate for the individual (calculated as 208 – (0.7 x age)) to determine relative intensity during the final and possibly most intensive section of the test. The time/duration required to complete the test (or in the case of the Coal Shovel test frequency of shovels within a set duration) was used in conjunction with the relative intensity and the participants' perceived exertion (Borg's RPE scale), to provide an estimate of the cardiovascular demand required to complete the test. It can be assumed that an inverse relationship exists between time to complete the test and the relative physical demand required. Faster performance will lead to a higher finishing heart rate and vice versa within an individual. The use of both time to complete the test, as well as relative heart rate, was incorporated to encourage participants to perform the test at a normal work pace.

Table 5.3 indicates the physical demands of the various work tasks as measured by maximum heart rate, percentage of age predicted maximum heart rates (%APMHR) and rate of perceived exertion. The final level represented the greatest physical demand with an average %APMHR ranging from 75% for the mesh handling to 99% for the shovelling task. The latter task also evoked the highest rate of perceived exertion with the task rated as hard or heavy.

The results derived from the health related tests were correlated with the work related test data to identify potential relationships between components of the two test protocols. The significant correlations are listed in Appendix 6. The purpose of examining these correlations was twofold. First, it provides a level of internal validation in cases where an underlying physical function is required for a particular work-related task. Second, it may indicate areas where, in future versions, a shorter and more efficient protocol can be developed by using only a sub-set of the tests. This would be achieved if it is confirmed in a more extensive data-set that any tests are highly correlated and information from one can be used to predict performance on the other.

For the equipment carriage work related test, the isometric knee extension strength was significantly correlated with both heart rate and %APMHR results. This finding was expected as the work related task of load carriage placed demands on the cardiovascular system of the participants and required muscular strength and endurance of the lower limbs.

Table 5.3 Work-related test results (n=22; mean ± SD)

	Walking & carrying equipment			
Level	**Time (sec)**	**Heart Rate (bpm)**	**%APMHR**	**RPE**
1	55 (17.8)	127 (18.7)	70 (10.2)	8.5 (1.7)
2	55 (15.8)	138 (17.2)	76 (9.3)	10.5 (2.2)
3	55 (18.5)	143 (17.3)	78 (9.1)	11.9 (1.9)
4	37 (19.4)	137 (17.6)	75 (9.3)	12.1 (2.0)
5	**22 (10.4)**	**137 (18.1)**	**75 (9.5)**	**12.9 (2.4)**

	Lifting and dragging cable			
Level	**Time (sec)**	**Heart Rate (bpm)**	**%APMHR**	**RPE**
1	22 (11.9)	126 (14.6)	69 (7.6)	8.3 (1.9)
2	41 (10.0)	138 (13.7)	76 (6.8)	9.8 (1.8)
3	78 (11.2)	152 (14.6)	83 (7.1)	12.2 (1.5)
4	125 (30.1)	161 (12.8)	88 (5.6)	14.5 (1.7)
5	**66 (11.7)**	**169 (12.5)**	**91 (5.1)**	**16.6 (1.8)**

	Ventilation tube hanging			
Level	**Time (sec)**	**Heart Rate (bpm)**	**%APMHR**	**RPE**
1	39 (11.9)	146 (15.4)	80 (8.4)	10.6 (2.4)
2	35 (11.7)	150 (15.5)	82 (8.1)	11.7 (2.1)
3	36 (12.8)	153 (16.5)	83 (8.5)	12.2 (2.1)
4	**35 (12.6)**	**151 (14.9)**	**83 (7.6)**	**12.5 (1.8)**

	Lifting and handling mesh			
Level	**Time (sec)**	**Heart Rate (bpm)**	**%APMHR**	**RPE**
1	23 (7.6)	129 (16.6)	70 (8.9)	8.3 (1.8)
2	21 (7.0)	136 (16.4)	75 (8.6)	9.6 (1.9)
3	25 (10.4)	139 (18.8)	76 (9.6)	10 (1.8)
4	**21 (5.7)**	**141 (20.5)**	**77 (10.6)**	**10.8 (2.1)**

	Coal shovelling			
Level	**# Shovels**	**Heart Rate (bpm)**	**%APMHR**	**RPE**
2 minute*	**59 (6.44)**	**170 (11.0)**	**93 (6.6)**	**14.9 (1.2)**
4 minute	**121 (25.9)**	**178 (14.1)**	**99 (6.7)**	**17.1 (1.5)**

*13 participants performed 2 minutes of coal shovelling and the remaining 8 participants performed 4 minutes of shovelling.

Similar results were evident for the cable drag test which showed significant relationships with heart rate and %APMHR, isometric knee extension strength and abdominal strength and endurance. This work related test is one of the more physically demanding tests in the test battery placing significant cardiovascular demands but also requiring both muscular strength and endurance of the lower limb and trunk.

No significant correlations were found between any of the isometric strength measures and the various physiological measures for both the vent tube installation and the mesh sheet installation work related protocols. However, correlations were found between the predicted maximal VO_2 and the heart rate and %APMHR obtained during the various levels of these two protocols. These results suggest that the muscular endurance demands for these two tasks are not as high as for the other three tests within the work related battery.

For the coal shovelling work related protocol, measures for both isometric back extensor and elbow flexor strength produced a strong correlation with heart rate and %APMHR during performance of the shovelling task. This was expected as the work related task of shovelling is very demanding, requiring the participants to use not only the back musculature to control forward lean in the initial part of the shovelling motion but also placing demands on the musculature of the upper limb in manipulating the shovel when the blade was loaded with coal.

As shown in Table 5.4, the average rating for all work task simulations was above 3.9 with most tasks scoring well above this figure. This indicates high content validity with respect to perception of task realism and physical demand. Note that a value of 4 corresponds to a rating of "realistic" or "similar", and 5 to a rating of "very realistic" or "very similar".

Table 5.4 Validation data for workers (n=20) who completed the validation survey

	Minimum	Maximum	Mean (±SD)
Walking & carrying equipment			
Realism	4	5	4.3 (0.4)
Physical demand similarity	3	5	4.2 (0.5)
Lifting & dragging cable			
Realism	4	5	4.7 (0.5)
Physical demand similarity	4	5	4.8 (0.4)
Vent tube hanging			
Realism	3	5	4.3 (0.6)
Physical demand similarity	2	5	4.2 (0.9)
Lifting & handling mesh			
Realism	3	5	4.1 (0.6)
Physical demand similarity	1	5	3.9 (1.0)
Coal shovelling			
Realism	4	5	4.9 (0.3)
Physical demand similarity	4	5	4.8 (0.4)

No significant differences were found between the two mine sites for the validation measure which suggests that the small differences in environmental conditions at the two sites did not have a significant bearing on these results.

SUMMARY

The project developed a series of tests designed to measure the functional capacity required to perform commonly encountered tasks in underground coal mining. The test protocol comprises two test batteries, one to evaluate generic fitness characteristics and a second battery of work-related tests. The tests were developed following analysis of the tasks involved in development, production/longwall and maintenance work categories. Focus group discussions, observation, and surveys of miners were used in the task analyses and the work-related tests were evaluated and validated on incumbent workers.

The high content validation with respect to perceived task realism and physical demand indicated that the physical demand required to perform the work-related tests was indicative of the physical demand of the corresponding task performed during an actual shift. It is recognised, however, that successful completion of a task performed only once does not indicate that the individual has the necessary fitness to perform work safely over a sustained period, such as a shift or series of shifts. Fatigue is a risk factor for injury, particularly in 24-hour industries such as mining (Dembe et al, 2005). While a miner may exhibit the necessary physical capacity to safely complete a task, the accumulated fatigue over the course of a shift, or series of shifts, may lead to reductions in their physical capacity. If fatigue results in the miner's physical capacity falling below the required level to complete the task, the associated risk of injury will exponentially increase.

Future implementation of the tests will provide a more extensive data set which may be used to develop more specific scoring systems relevant for different purposes, and more normative data for comparative purposes.

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APPENDIX 1

Questionnaire Used to Rank Order Physically Demanding Tasks

DEVELOPMENT OF FUNCTIONAL FITNESS MEASURES RELATED TO THE WORK PRACTICES OF UNDERGROUND COAL MINERS

QUESTIONNAIRE

The purpose of the questionnaire is to identify the most physically demanding tasks involved in underground coal mining.

Your answers to the questions will remain confidential, to be used solely by the independent university research group from QUT.

Complete the questionnaire individually and **DO NOT** write your name on the paper. It will take approximately 15 minutes to complete the questionnaire.

Thank you for your cooperation.

Please indicate your answer by placing a tick or cross in one box only unless directed otherwise. If any of the questions do not apply to you, tick the Not Applicable [N/A] box. The numbering on the left of the tick boxes are for coding purposes only and do not indicate ranking of answers. For all work-related questions, please refer to your current work arrangements, schedules and patterns.

1. AGE:

1 ☐ < 20 years
2 ☐ 20 - 24 years
3 ☐ 25 - 29 years
4 ☐ 30 - 34 years
5 ☐ 35 - 39 years
6 ☐ 40 - 44 years
7 ☐ 45 - 49 years
8 ☐ 50 - 54 years
9 ☐ 55 - 59 years
10 ☐ ≥ 60 years

2. GENDER:

1 ☐ Male
2 ☐ Female

3. MINE TYPE:

1 ☐ Longwall
2 ☐ Bord & Pillar
3 ☐ Both
4 ☐ Other______________________________

4. EMPLOYMENT STATUS:

1 ☐ Permanent
2 ☐ Contractor
3 ☐ Other______________________________

5. SHIFT TYPE:

1 ☐ Fixed shifts
2 ☐ Rotating shifts

6. WHAT IS THE MAXIMUM NUMBER OF CONSECUTIVE DAYS YOU WORK:

1 ☐ 2 days
2 ☐ 3 days
3 ☐ 4 days
4 ☐ 5 days
5 ☐ 6 days
6 ☐ Other______________

7. WHAT IS THE MINIMUM NUMBER OF CONSECUTIVE DAYS YOU HAVE OFF WORK:

1 ☐ 2 days
2 ☐ 3 days
3 ☐ 4 days
4 ☐ 5 days
5 ☐ 6 days
6 ☐ Other______________

8. PRIMARY WORK FOCUS (Tick more than 1 box if applicable):

1 ☐ Production
2 ☐ Maintenance
3 ☐ Development
4 ☐ Longwall
5 ☐ Other_______________

9. WHAT SHIFT DO YOU USUALLY WORK AND WHAT IS THE NORMAL SHIFT DURATION (Tick more than 1 box if applicable):

SHIFT TYPE	NORMAL SHIFT DURATION			
1 ☐ Day shift	a ☐ 8 hrs	b ☐ 10 hrs	c ☐ 12 hrs	d ☐ Other ____hrs
2 ☐ Afternoon shift	a ☐ 8 hrs	b ☐ 10 hrs	c ☐ 12 hrs	d ☐ Other ____hrs
3 ☐ Night shift	a ☐ 8 hrs	b ☐ 10 hrs	c ☐ 12 hrs	d ☐ Other ____hrs
4 ☐ Other_________	a ☐ 8 hrs	b ☐ 10 hrs	c ☐ 12 hrs	d ☐ Other ____hrs

10. WHAT IS THE NORMAL START AND FINISH TIME OF YOUR USUAL SHIFT (Indicate more than 1 time if applicable):

SHIFT TYPE	START TIME	FINISH TIME
Day shift	_____:_____	_____:_____
Afternoon shift	_____:_____	_____:_____
Night shift	_____:_____	_____:_____
Other_______________	_____:_____	_____:_____

11. APPROXIMATE OVERTIME HOURS PER WEEK:

1 ☐ N/A
2 ☐ 1 – 4 hours
3 ☐ 5 – 9 hours
4 ☐ 10 - 14 hours
5 ☐ 15 - 19 hours
6 ☐ ≥ 20 hours

12. YOUR CURRENT OCCUPATION (Tick more than 1 box if applicable):

1 ☐ Deputy
2 ☐ Supervisor
3 ☐ Operator / Maintainer
4 ☐ Fitter / Mechanic
5 ☐ Electrician
6 ☐ Other______________________

13. WHICH MAJOR DUTIES ARE INVOLVED IN YOUR OCCUPATION (Tick more than 1 box if applicable):

1 ☐ Bolting
2 ☐ Driving shuttle car
3 ☐ Shovelling
4 ☐ Cable hand
5 ☐ Miner operator
6 ☐ Other___________

14. YEARS IN YOUR CURRENT OCCUPATION:

1 ☐ < 1 years
2 ☐ 1 – 4 years
3 ☐ 5 – 9 years
4 ☐ 10 - 14 years
5 ☐ 15 - 19 years
6 ☐ 20 - 24 years
7 ☐ 25 - 29 years
8 ☐ $\geq$ 30 years

15. YOUR PREVIOUS OCCUPATION IN UNDERGROUND COAL MINING (Tick more than 1 box if applicable):

1 ☐ None (go to question 16)
2 ☐ Deputy
3 ☐ Supervisor
4 ☐ Operator Maintainer
5 ☐ Fitter / Mechanic
6 ☐ Electrician
7 ☐ Other______________________

16. YEARS IN YOUR PREVIOUS OCCUPATION IN UNDERGROUND COAL MINING:

1 ☐ < 1 years
2 ☐ 1 – 4 years
3 ☐ 5 – 9 years
4 ☐ 10 - 14 years
5 ☐ 15 - 19 years
6 ☐ 20 - 24 years
7 ☐ 25 - 29 years
8 ☐ $\geq$ 30 years

17. TOTAL YEARS IN UNDERGROUND COAL MINING:

1 ☐ < 1 years
2 ☐ 1 – 4 years
3 ☐ 5 – 9 years
4 ☐ 10 - 14 years
5 ☐ 15 - 19 years
6 ☐ 20 - 24 years
7 ☐ 25 - 29 years
8 ☐ $\geq$ 30 years

18. AFTER WORKING FOR A FULL SHIFT, WHICH BODY PARTS FEEL MOST FATIGUED AT THE END OF THE SHIFT (Tick more than 1 box if applicable):

1 ☐ Neck
2 ☐ Back
3 ☐ Shoulders
4 ☐ Arms
5 ☐ Legs
6 ☐ Hands
7 ☐ Feet
8 ☐ Other_____________________

19. WHAT IS THE **INTENSITY** OF PERFORMING EACH OF THE FOLLOWING TASKS ON A SINGLE OCCASION WHILE WORKING UNDERGROUND:

	N/A	Light (light muscle load, and / or breathing easy)	Medium (moderate muscle load, and / or slightly out of breath)	Hard (high muscle load and / or out of breath)
1. Lifting & handling mesh	1 ☐	2 ☐	3 ☐	4 ☐
2. Lifting stonedust bags	1 ☐	2 ☐	3 ☐	4 ☐
3. Lifting ventilation ducts	1 ☐	2 ☐	3 ☐	4 ☐
4. Lifting / dragging cables	1 ☐	2 ☐	3 ☐	4 ☐
5. Lifting / dragging monorail	1 ☐	2 ☐	3 ☐	4 ☐
6. Lifting / carrying timber	1 ☐	2 ☐	3 ☐	4 ☐
7. Maintenance / repair tasks	1 ☐	2 ☐	3 ☐	4 ☐
8. Walking (carrying equipment)	1 ☐	2 ☐	3 ☐	4 ☐
9. Walking	1 ☐	2 ☐	3 ☐	4 ☐
10. Standing	1 ☐	2 ☐	3 ☐	4 ☐
11. Bolting (using miner bolter or gopher)	1 ☐	2 ☐	3 ☐	4 ☐
12. Driving shuttle car / Eimco	1 ☐	2 ☐	3 ☐	4 ☐
13. Repairing, extracting or extending a belt / conveyor	1 ☐	2 ☐	3 ☐	4 ☐
14. Moving belt structure	1 ☐	2 ☐	3 ☐	4 ☐
15. Shovelling (bouts)	1 ☐	2 ☐	3 ☐	4 ☐
16. Other demanding tasks				
______________________	1 ☐	2 ☐	3 ☐	4 ☐
______________________	1 ☐	2 ☐	3 ☐	4 ☐

20. HOW **FREQUENTLY** DO YOU PERFORM EACH OF THE FOLLOWING TASKS:

	N/A	Rarely (Not every shift)	Sometimes (Few times / shift)	Frequently (Many times /shift)
1. Lifting & handling mesh	1 ☐	2 ☐	3 ☐	4 ☐
2. Lifting stonedust bags	1 ☐	2 ☐	3 ☐	4 ☐
3. Lifting ventilation ducts	1 ☐	2 ☐	3 ☐	4 ☐
4. Lifting / dragging cables	1 ☐	2 ☐	3 ☐	4 ☐
5. Lifting / dragging monorail	1 ☐	2 ☐	3 ☐	4 ☐
6. Lifting / carrying timber	1 ☐	2 ☐	3 ☐	4 ☐
7. Maintenance / repair tasks	1 ☐	2 ☐	3 ☐	4 ☐
8. Walking (carrying equipment)	1 ☐	2 ☐	3 ☐	4 ☐
9. Walking	1 ☐	2 ☐	3 ☐	4 ☐
10. Standing	1 ☐	2 ☐	3 ☐	4 ☐
11. Bolting (using miner bolter or gopher)	1 ☐	2 ☐	3 ☐	4 ☐
12. Driving shuttle car / Eimco	1 ☐	2 ☐	3 ☐	4 ☐
13. Repairing, extracting or extending a belt / conveyor	1 ☐	2 ☐	3 ☐	4 ☐
14. Moving belt structure	1 ☐	2 ☐	3 ☐	4 ☐
15. Shovelling (bouts)	1 ☐	2 ☐	3 ☐	4 ☐
16. Other demanding tasks				
____________________	1 ☐	2 ☐	3 ☐	4 ☐
____________________	1 ☐	2 ☐	3 ☐	4 ☐

21. WHEN PERFORMING THESE TASKS, HOW MUCH **TIME OF A SHIFT** DOES IT TAKE:

	N/A	Short time (< 30% of shift)	Medium time (30 - 60% of shift)	Long time (> 60% of shift)
1. Lifting & handling mesh	1 ☐	2 ☐	3 ☐	4 ☐
2. Lifting stonedust bags	1 ☐	2 ☐	3 ☐	4 ☐
3. Lifting ventilation ducts	1 ☐	2 ☐	3 ☐	4 ☐
4. Lifting / dragging cables	1 ☐	2 ☐	3 ☐	4 ☐
5. Lifting / dragging monorail	1 ☐	2 ☐	3 ☐	4 ☐
6. Lifting / carrying timber	1 ☐	2 ☐	3 ☐	4 ☐
7. Maintenance / repair tasks	1 ☐	2 ☐	3 ☐	4 ☐
8. Walking (carrying equipment)	1 ☐	2 ☐	3 ☐	4 ☐
9. Walking	1 ☐	2 ☐	3 ☐	4 ☐
10. Standing	1 ☐	2 ☐	3 ☐	4 ☐
11. Bolting (using miner bolter or gopher)	1 ☐	2 ☐	3 ☐	4 ☐
12. Driving shuttle car / Eimco	1 ☐	2 ☐	3 ☐	4 ☐
13. Repairing, extracting or extending a belt / conveyor	1 ☐	2 ☐	3 ☐	4 ☐
14. Moving belt structure	1 ☐	2 ☐	3 ☐	4 ☐
15. Shovelling (bouts)	1 ☐	2 ☐	3 ☐	4 ☐
16. Other demanding tasks				
______________________	1 ☐	2 ☐	3 ☐	4 ☐
______________________	1 ☐	2 ☐	3 ☐	4 ☐

22. Any other comments on the physical demands of your work:

____

____

____

____

____

____

Please make sure that you have answered all the questions.

Thank you for completing the questionnaire.

APPENDIX 2

Participant Health and Consent Forms



PARTICIPANT HEALTH AND CONSENT

Purpose of Questionnaire

To ensure that no person with a pre existing, or potentially existing, health condition will be exposed to physical activity that may aggravate or cause an episode.

This questionnaire will also assist in collating normative data for the development of scoring techniques for the testing protocols.

Instructions

Please complete this questionnaire before participating in the testing protocol.

Read all instructions carefully before responding to the items.

If you have any concerns or questions regarding the project, please direct all inquiries to the Project Coordinator, Andrew Keech on Ph. (07) 3864 3996; Fax (07) 3864 3996
Email: a.keech@qut.edu.au

Thank you for your time and effort in completing this questionnaire

CRICOS No. 00213J

Health Screen Questionnaire

Name________________________________Age____________Gender M F

Mine site of employment________________________Years in Service__________

Height___________Weight___________Resting Pulse________Date____/____/ 03

Stage 1: Medical Conditions

1. List any medications you take on a regular basis. Also list any dietary/energy supplements/enzymes you take:

2. Do you have diabetes? No Yes

a) If yes, please indicate if it is insulin dependent diabetes mellitus (IDDM) or non-insulin dependent diabetes mellitus (NIDDM). IDDM NIDDM

b) If IDDM, for how many years have you had IDDM? ______years

3. Have you had a stroke? No Yes

4. Has your doctor ever said you have heart trouble? No Yes

5. Do you take asthma medication? No Yes

6. Is there any other physical reason that prevents you from participating in this program (e.g., cancer, osteoporosis, severe arthritis, mental illness, thyroid, kidney, or liver disease)? No Yes

7. Do you have any of the following diseases? If so please tick those you have:

- ☐ Muscle degeneration or weakness
- ☐ Motor neuron diseases
- ☐ Mitochondrial disorders
- ☐ Liver disease
- ☐ Glycogen storage diseases- such as McArdle's disease or Pompe disease or Acid maltase deficiency
- ☐ Sickle cell disease
- ☐ Lactate Dehydrogenase Deficiency (LDHA)
- ☐ Endocrine disorder such as Addison's Disease/ Adrenal Insufficiency
- ☐ Addison's Disease: Adrenal Insufficiency
- ☐ Cushing's Syndrome
- ☐ Central serous retinopathy (CSR), also known as central serous chorioretinopathy (CSC)

Other, please specify…………………………………………………………………………..

Stage 2: Signs and Symptoms

8. Do you often have pains in your heart, chest, or surrounding areas, especially during exercise?	No	Yes
9. Do you often feel faint or have spells of severe dizziness during exercise?	No	Yes
10. Do you experience unusual fatigue or shortness of breath at rest or with mild exertion?	No	Yes
11. Have you had an attack of shortness of breath that came on after you stopped exercising?	No	Yes
12. Have you been awakened at night by an attack of shortness of breath?	No	Yes
13. Do you experience swelling or accumulation of fluid in or around your ankles?	No	Yes
14. Do you often get the feeling that your heart is beating faster, racing, or skipping beats, either at rest or during exercise?	No	Yes
15. Do you regularly get pains in your calves and lower legs during exercise that are not due to soreness or stiffness?	No	Yes
16. Has your doctor ever told you that you have a heart murmur?	No	Yes

Stage 3: Cardiac Risk Factors

17. Do you smoke cigarettes on a daily basis, or have you quit smoking within the past two years?	No	Yes
If yes, how many cigarettes per day do you smoke (or did you smoke in the past two years)?	______per day	
18. Has your doctor ever told you that you have high blood pressure?	No	Yes
19. Has your father, mother, brother, or sister had a heart attack or suffered from a cardiovascular disease before the age of 55?	No	Yes

If yes,

a) Was the relative male or female?

b) At what age did he or she suffer the stroke or heart attack?

c) Did this person die suddenly as a result of the stroke or heart attack?

Do you know your:

20. Blood pressure? ________mmHg

21. Cholesterol level? ________mmol/L or mg/dL

Stage 4: Current Exercise

22. What are your current exercise activity patterns?

   a) Frequency: ________exercise sessions per week
   b) Intensity: Sedentary Moderate Vigorous
   c) History: <3 months 3-12 months >12 months
   d) Duration: ________minutes per session

23. What types of exercises do you do?

____

____

____

24. What exercise have you done in the last 24 hours?

____

____

____

CONSENT FORM

Chief Investigator:

Tony Parker, Queensland University of Technology, School of Human Movement Studies

Project Title:

Development of functional fitness measures related to the work practices of underground miners

The investigators conducting this research project abides by the principles governing the ethical conduct of research and, at all times, avows to protect the interests, comfort and safety of all subjects.

This form and the test procedures manual have been made available to you for your own protection. They contain an outline of the experimental procedures and possible risks.

Your signature below will indicate that:

1. You have read and understood the contents of the Test Procedures manual
2. You clearly understand the procedures and the possible risks involved; and that you have been given the opportunity to discuss the contents of the Test Procedures with one of the investigators prior to the commencement of the activities
3. You understand that all the data that you have provided will only be revealed to the investigators and yourself. When the results of the study are published you will remain anonymous;
4. Your participation is voluntary and therefore may be terminated at any moment by you without comment or penalty, and without jeopardizing you involvement with the Queensland University of Technology, or you employment/relationship with the mining company.
5. You may direct any inquiries and further questions to Professor Tony Parker at the School of Human Movement Studies on 3864 3360, or email at t.parker@qut.edu.au You may also direct complaints and concerns regarding the ethical conduct of this investigation to the Secretary of the Queensland University of Technology Human Resource Ethics Committee on 3864 2902.
6. You agree to participate in the experimental procedures set out in the Test Procedures manual for the research project entitled The Development of Functional Fitness Measures Related to the Work Practices of Underground Coal Miners.

Name ………………………………………………………Signature ……………………………………….

Date …../……./03

APPENDIX 3

Health-related Tests



Guidelines

Aim	To provide a measure of the general fitness of the participant with respect to muscular strength and endurance, aerobic capacity and flexibility. The selection of the tests was based on their relationship to the underlying fitness components associated with the work of underground miners. Medical approval should be sought prior to participation in the health-related test protocol. In granting this approval the medical practitioner should be provided with a copy of the test protocols.
Pre-testing measures for all applications	Prior to the administration of the health-related test protocol a health background/history questionnaire (Appendix 2) should be completed by all participants. The information is most useful in identifying any medical problems which may preclude the worker from further participation in the test protocol. The questionnaire covers the previous history of cardiovascular and injury problems and any current problems which may make it unsafe to participate. Other questions related to lifestyle behavioural issues are helpful in the interpretation of individual performances on the tests. The responses should be reviewed by the tester, preferably a person with a medical or exercise physiology background and any problems should be clarified with the participant. If it is considered that the respondent is at risk by proceeding further, he should be advised to seek medical opinion and should not participate in the test protocol. Management or other personnel responsible for the testing should ensure that all relevant occupational health and safety procedures are implemented, following any applicable legislation and policies.
Personnel	A minimum of two people are required to administer these tests. More than two people will be needed for prolonged testing or testing more than one test-taker simultaneously. Personnel administering tests should normally be OH&S staff and trainers, trained and currently accredited for first aid and cardiopulmonary resuscitation. A first-hand knowledge of the relevant underground work tasks is essential. At least one of these personnel should be able to pass these tests and be able to provide assistance where this is required (e.g. vent-tube test), or in an emergency. The personnel should have a working knowledge of the principles of physical fitness (musculoskeletal function, aerobic and anaerobic energy systems, interpretation and use of heart rates during exercise and training), and know how to measure blood pressures, heart rates, and core temperature.
Location	Ideally all tests should be conducted at a central location, as is the case with assessments currently undertaken by Coal Services in New South Wales. A central location allows immediate access to medical and emergency services, as well as promoting more efficient and standardised testing. If it is deemed appropriate to conduct the tests at other locations, such as an individual mine-site, the testing location should be readily accessible by vehicles, including emergency services. If not adjacent to offices or other worksites where help is immediately available, secure telephone/radio communication is essential in the event of an emergency. All health-related tests should be conducted in air-conditioned room. A power supply is required for any computers used in record-keeping. The location also should have sufficient shade, seating and water, equivalent to that normally available in a crib room, as test-takers may have periods of waiting before and in between tests. Surface conditions and space requirements are specified in the individual tests.

Equipment	All testing equipment can be purchased as follows: 1. An isometric strength testing devise, including testing software can be purchased through Queensland University of Technology – Human Movement Studies or similar equipment (Sammons Preston Chatillon Muscle Strength Dynamometer) can be purchased through http://www.sammonspreston.com. 2. Mats, a stopwatch, a 2.5kg and a 5kg weight can be purchased in any sport specialised shop eg. Rebel Sport. 3. Sit-and-reach box (incorporating a sliding horizontal scale) can be purchased through www.wos.com.au.
Testing progression	Health-related tests should be administered first, and satisfactory completion of these tests should be a requirement for undertaking the work-related tests. An averaged z-score higher than -2 (minus two) may be used as a minimum score to progress to the work-related tests. This score would be achievable by approximately 97% of test-takers based on the sample of miners who completed the tests in this project. Since this standard is simply a value corresponding to the bottom end of the range of the sample, it does not indicate either levels of fitness corresponding to good health, nor does it ensure that the test-taker is at no risk of injury on the work-related tests. After completing all health-related tests, the participants should participate in a standardised stretch session in which all major body parts would be involved.
Stopping the tests	In the interests of safety testing should be stopped before completion if: a) Any test-taker states that they are experiencing pain or are feeling unwell, or b) Any test-taker is visibly injured or unwell even if they do not state that they are, or c) The basic effective temperature exceeds 29.4 degrees Celsius, as required under legislation for Queensland Coal mines, reported in the AIOH report on *"Heat Stress Standard & Documentation Developed for use in the Australian Environment"* (Di Corleto, Coles & Firth, 2003). d) After any of the work-related tests or the step test of the health-related assessments, the test-taker's recovery heart rate indicates that P1-P3 < 10 (see section on Heat, pg. 78). This criterion applies even if the basic effective temperature is < 29.4 degrees Celsius. e) Continued unsafe conduct of tasks.
Rest breaks	The health-related tests may be conducted with minimal rest between individual tests. A minimum of thirty minutes rest break should be allowed between the health-related and the work-related tests.
Test procedures	A description of each of the tests follows, including any contraindications for participation and descriptions of the test procedures. These procedures should be adhered to in order to enhance the reliability of results and comparison with normal data.

Test 1: Back extensor strength

Fitness component: Maximal isometric strength.

Basic explanation: This test measures back extensor muscle strength using an isometric strength testing device. The participant exerts a maximal static contraction for a period of 3 seconds against a resistance bar attached to a strain gauge measurement system. The force is recorded on a computer and stored for further analysis.

Contraindications: This test should not be performed by people with recent (within the last 6 months) history of:

1. Low back pain or chronic lower back pain;
2. Injury or surgery to shoulders, elbows or wrists.

Testing area: Any area with sufficient floor space may be used.

Equipment: A specialised strain gauge linked to a computer program is used for this and other strength tests included in the health related test protocol.

Test procedures:

1. The strain gauge platform is placed up against a wall. The subject sits on a mat with legs straight and feet up against the platform. The handle bar on the resistance bar is positioned at full arm's reach forward while seated with legs straight.
2. The subject bends forward at the hips until hip flexion is 90°. The back should be straight from low back to shoulder. Cue the subject using 'Chest forward, shoulders back". Adjust the resistance bar so the bar is at finger-tip level.
3. The subject should inhale and as they slowly exhale, attempt to extend the trunk at the hips by pulling backward on the bar. Arms and legs should remain straight.
4. On the command of "Ready, Go" and without arching the back, the subject then exerts a maximal force for a period of three seconds and the peak torque output (kg) is recorded.
5. A 20-second rest period is given to each subject and the test is repeated for a maximum of three trials. The highest value for the three attempts is recorded as the maximum strength.

Test 2: Knee extensor strength

Fitness component: Maximal isometric strength.

Basic explanation: This is a test of knee extensor strength in a position similar to that adopted towards the end of a lift. The subject stands on a platform in a predefined position and pulls vertically upwards on a bar attached to the platform. The amount of force is measured via a specialised strain gauge linked up to a computer program.

Contraindications: This test should not be performed by people with a recent (within the last 6 months) history of:

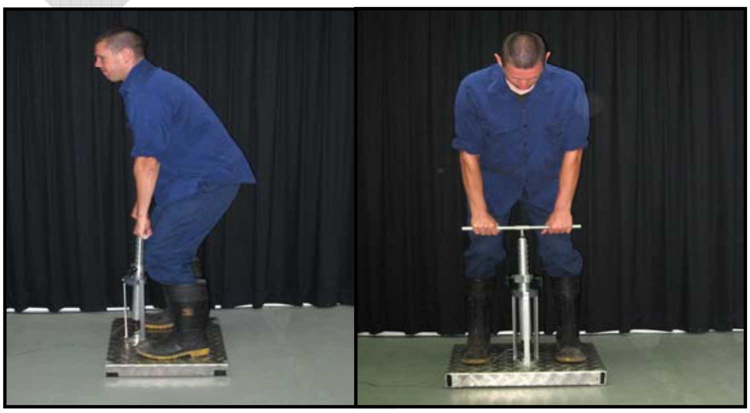
1. Low back pain or chronic lower back pain;
2. Recent abdominal surgery;
3. An existing hernia;
4. >3 months pregnant.

Testing area: Any area with sufficient floor space may be used.

Equipment: A specialised strain gauge linked to a computer program is used for this and other strength tests included in the health related test protocol.

Test procedures:

1. The subject stands on the platform with feet either side of the strain gauge attached to the platform.
2. The body weight is balanced on the feet, placed shoulder width apart. The hands should be spread the width of the shoulders and arms fully extended and hanging. The bar should be held in the centre with both palms facing downwards.
3. It is recommended that the knees be flexed to ~40^{o} with a limit of between 30^{o} to 50^{o} knee flexion. The resistance bar should be positioned slightly above the participant's kneecaps. The trunk should be flexed only slightly forward (10-15°) at the hips from vertical. Excessive forward bend results in poor leverage and could cause lower back strain.
4. On the command of "Ready, Go" and without arching the back, the subject then exerts a maximal force for a period of three seconds and the peak torque output (kg) is recorded.
5. A 20-second rest period is given to each subject and the test is repeated for a maximum of three trials. The highest value for the three attempts is recorded as the maximum strength.
6. The subject should not be allowed to lean back on the heels. The arms must not be bent during the lift. If any deviations from proper procedure are noted, the test should be repeated.



Test 3: Elbow flexor strength

Fitness component: Maximal strength isometric strength.

Basic explanation: This is a test of elbow strength. The subject stands on a platform in a predefined position and pulls vertically upwards on a bar attached to the platform. The amount of force is measured via a specialised strain gauge linked up to a computer program.

Contraindications: This test should not be performed on people with recent (within the last 6 months) history of:

1. Low back pain or chronic lower back pain;
2. Injury or surgery to shoulders, elbows or wrists.

Testing area: Any area with sufficient floor space may be used.

Equipment: A specialised strain gauge linked to a computer program is used for this and other strength tests included in the health related test protocol.

Test procedures:

1. The subject stands on the platform in the anatomical position with arms hanging by side. With hands in a supinated (palms up) position, the subject then flexes his/her elbows to 90°.
2. The resistance bar (including handgrips) is attached to the strain gauge and adjusted to the length that is appropriate for each individual based upon the above description (i.e., standing erect, arms hanging by side and elbows at 90°). Make sure the resistance bar is vertical.
3. On the command of "Ready, Go" and without arching the back, the subject then exerts a maximal force for a period of three seconds and the peak torque output (kg) is recorded.
4. A 20-second rest period is given to each subject and the test is repeated for a maximum of three trials. The highest value for the three attempts is recorded as the maximum strength.

Test 4: Shoulder flexor strength

Fitness component: Maximal isometric strength.

Basic explanation: This is a test of the strength of shoulder flexion muscles commonly used in above shoulder lifting or handling equipment. The subject stands on a platform in a predefined position and pulls vertically upwards on a bar attached to the platform. The amount of force is measured via a specialised strain gauge linked up to a computer program.

Contraindications: This test should not be performed by people with recent (within the last 6 months) history of:

1. Low back pain or chronic lower back pain;
2. Injury or surgery to shoulders, elbows or wrists.

Testing area: Any area with sufficient floor space may be used.

Equipment: A specialised strain gauge linked to a computer program is used for this and other strength tests included in the health related test protocol.

Test procedures:

1. The subject stands on the platform. Shoulders are abducted 90^{o} and elbows bent fully, such that hands are shoulder width apart and level with the chin. Wrists are pronated so that hands are facing upwards toward the ceiling. This is termed the 'rack' position as performed during power cleans.
2. The resistance bar (including handgrips) is attached to the strain gauge and adjusted to the length that is appropriate for each individual based upon the above description.
3. On the command of "Ready, Go" and without arching the back, the subject then exerts a maximal force for a period of three seconds. Peak force output is recorded.
4. A 20-second rest period is given to each subject and the test is repeated for a maximum of three trials. The highest value for the three attempts is recorded as the maximum strength.

Test 5: Abdominal strength

Fitness component: Maximal strength.

Basic explanation: This is a general test of the strength of abdominal musculature. The subject attempts to flex the trunk with the resistance of the trunk progressively increasing by changing the leverage and adding weight to the hands. Each level is performed once until no further levels can be completed. Three attempts may be allowed at any level, but the subject may not lift the feet, alter the stipulated position, or gain any advantage by rebounding off the mat. The final score will be between 0 and 7, depending on the level completed.

Contraindications: This test should not be performed by people with recent (within the last 6 months) history of:

1. Low back pain or chronic lower back pain;
2. Recent abdominal surgery;
3. An existing hernia;
4. >3 months pregnant.

Testing area: Any area with sufficient floor space may be used.

Equipment: Mats are recommended for safety and comfort, and a 90° set square.

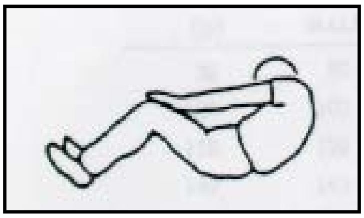
Test procedures:

1. The participant is given a demonstration of how to participate safely in the activity.
2. The subject is instructed to lie in a supine position on the floor mat:
    a. Knee angle adjusted to 90°;
    b. Both feet touching the floor.

   Feet should not be held or stabilised in any way. The test should be terminated if the subject appears to be suffering discomfort or pain. It is performed with the knees bent and feet unsecured.
3. Participant is instructed to place arms in the position for variation 1 (see Diagram).
4. Ask the subject to tilt the pelvis backwards to flatten the lower back onto the floor, then tilt the head forward and smoothly flex the trunk in a controlled manner until Variation 1 is completed. The subject returns to the starting position.
5. If the sit-up was successfully completed (as outlined above), place subject in position for next variation.
6. Repeat steps 3 and 4 until the subject is unsuccessful in 3 consecutive attempts at a variation. Record the previous sit-up as the subject's abdominal strength, i.e. the last successful sit-up is the subject's abdominal strength.
7. An attempt is unsuccessful if the subject displays poor technique during a sit-up by:
    (i) Lifting either heel off the floor;
    (ii) 'Throwing' the arms or the head forward;
    (iii) Moving the arms from the nominated position;
    (iv) Lifting the hips off the floor;
    (v) Failing to maintain the 90° knee angle;
    (vi) Being unable to complete the nominated sit-up.

Feet should not be held or stabilised in any way. The test should be terminated if the subject appears to be suffering discomfort or pain.

ABDOMINAL STRENGTH

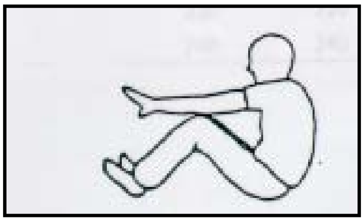


Variation 1

Start: Arms straight, hands resting on top of thighs.

Finish: Arms straight, finger tips touching patella.

VERY POOR

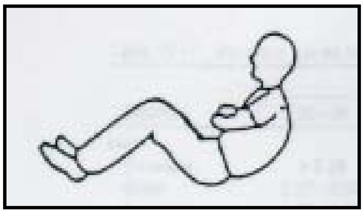


Variation 2

Start: Arms straight, hands resting on top of thighs.

Finish: Arms straight, elbows touching patella.

POOR

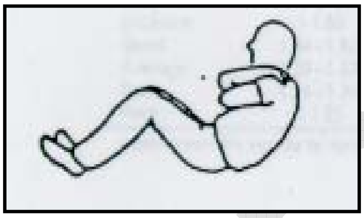


Variation 3

Start: Arms across the abdomen, hands gripping the opposite elbows.

Finish: Forearms touching the thighs.

FAIR

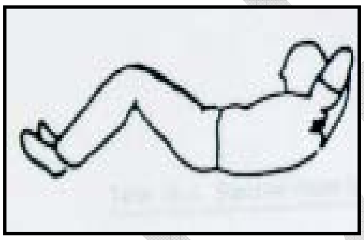


Variation 4

Start: Arms across the chest, hands gripping the opposite shoulders.

Finish: Forearms touching the thighs.

GOOD

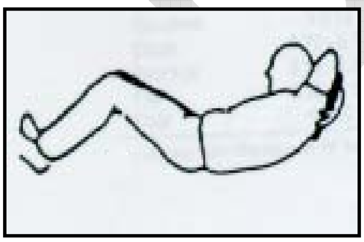


Variation 5

Start: Arms flexed behind the head, hands gripping the opposite shoulders.

Finish: Chest touching the thighs.

VERY GOOD

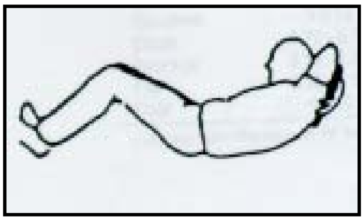


Variation 6

Start: Arms flexed behind the head, hands gripping the opposite sides of a 2.5kg weight.

Finish: Chest touching the thighs.

EXCELLENT



Variation 7

Start: Arms flexed behind the head, hands gripping the opposite sides of a 5kg weight.

Finish: Chest touching the thighs.

OUTSTANDING

Test 6: Abdominal endurance: 60 second sit-up test

Fitness component: Abdominal endurance.

Basic explanation: This is a practical test used to measure muscular endurance of the abdominal musculature. The subject lies on the back with knees bent, feet on the floor and secured by a partner or tester. The subject performs as many sit-ups as possible in 60 seconds. The number of sit-ups performed is the subject's final score.

Contraindications: This test should not be performed by people with recent (within the last 6 months) history of:

1. Low back pain or chronic lower back pain;
2. Recent abdominal surgery;
3. An existing hernia;
4. >3 months pregnant.

Testing area: Any area with sufficient floor space may be used.

Equipment: Mats are recommended for safety and comfort, a stopwatch and a 90° set square.

Test procedures:

1. The subject lays supine (face up), knees bent at 90°, and feet approximately shoulder width apart. The arms are crossed on the chest with the hands on opposite shoulders. A partner or tester holds the subject's feet to keep them in contact with the testing surface.
2. The subject curls to a sitting position, maintaining contact with the chest. The chin should be tucked on the chest and should remain in this position until the completion of the sit-up.
3. When the elbows touch the thighs, the sit-up is completed. The subject curls back down to the floor until the mid-back contacts the testing surface. Another sit-up may then be attempted.
4. The subject begins executing consecutive sit-ups on the word *"Go"*, using the signal *"Ready, Go"*. At the end of 60 seconds, the test is ended with the word *"Stop"*. The score is the number of sit-ups executed correctly during this time. Pausing between sit-ups is permissible.
5. The position assumed by the tester should be carefully checked before and during the execution of the sit-up. The test should be terminated if the subject appears to be suffering discomfort or pain.

Feet should be held or stabilised in any way. The test should be termineted if the subject appears to be suffering discomfort or pain.

Test 7: Endurance of back extensors

Fitness component: Muscular endurance.

Basic explanation: The participant lies face down on a table with only the legs and hips flat on the table. The entire upper body overhangs the edge of the table. An assistant is required to hold the participant's feet on the table.

Contraindications: This test should not be performed on people with recent (within the last 6 months) history of:

1. Low back pain or chronic lower back pain;
2. Recent abdominal surgery;
3. An existing hernia;
4. >3 months pregnant.

Testing area: Any area with sufficient floor space may be used.

Equipment: A padded table and stopwatch.

Test procedures:

1. The participant lies face down on the table with the upper body overhanging the edge. Arms are folded across the chest. An assistant holds the participant's ankles securely to the table.
2. On 'Ready, Go' the participant raises the upper body until the body is in a straight line from feet through to head.
3. Using the back extensor muscles to hold the body straight with only the legs and hips supported on the table, the participant stays as rigid as possible for as long as possible.
4. Test is ended when:
   a. Participant stops due to fatigue;
   b. The subject is unable to maintain the horizontal position.
5. The position assumed by the tester should be carefully checked before and during the execution of the test. The test should be terminated if the subject appears to be suffering discomfort or pain.

Test 8: Cardiovascular fitness: 6-minute step test

Fitness component: Muscular endurance and aerobic capacity.

Basic explanation: A test designed to measure sub-maximal aerobic capacity and estimate maximal aerobic capacity via continuous stepping up and down on a step of specific height (12"/30cm), at a specific speed (15 steps per minute for the first 3 minutes, then 27 steps/minute for a further 3 minutes). An estimation of the individual's VO_2max can be derived from a linear regression equation.

Contraindications: This test should not be performed on people with recent (within the last 6 months) history of:

1. Low back pain or chronic lower back pain;
2. Injury or surgery to hips, knees or ankles;
3. Chest pain (angina) or associated heart problems.

Testing area: Any area with sufficient floor space may be used.

Equipment: Step bench (height: 12"), 30 & 54 beats/min metronome, stopwatch.

Test procedures:

1. Demonstrate the alternating (Up 1-2 and Down 3-4) stepping cadence to the subject.
2. Allow the subject to practice stepping to the metronome cadence set at 30 bpm (2 clicks = one step cycle) for a stepping rate of 15 steps per minute.
3. The subject stands in front of the step bench. On the command *"Up"* the subject begins stepping up and down on the bench for 3 minutes at a rate of 15 steps per minute.
4. One step consists of four beats; that is, up with the left foot, up with the right foot, down with the left foot, down with the right foot.
5. At 3 minutes, heart rate and RPE are recorded. The speed is increased to 27 steps per minute for the next 3 minutes. The metronome needs to be reset at 54 bpm (2 clicks = one step cycle).
6. Heart rate and RPE are again recorded immediately upon completion of the test. The two heart rates from the two intensities are used to predict aerobic capacity.

The test should be terminated immediately if the subject feels any shortness of breath or chest pain.

Test 9: Trunk flexibility: Sit-and-reach test

Fitness component: Flexibility.

Basic explanation: This test is a measure of low back-hamstring flexibility. The subject is seated with the legs straight and feet against a flat vertical surface (sit-and-reach box). Without bending the knees, the participant reaches forward as far as possible and holds for a minimum of 2 seconds. The distance away from the vertical surface is measured via a sliding scale (a negative score is assigned if the fingertips do not pass beyond the toes).

Contraindications: This test should not be performed on people with recent (within the last 6 months) history of:

1. Low back pain or chronic lower back pain;
2. Injury or surgery to shoulders, hips, knees or ankles.

Testing area: Any area with sufficient floor space adjacent to a wall may be used.

Equipment: Sit-and –reach box (incorporating a sliding horizontal scale).

Test procedures:

1. The subject removes shoes and sits on the floor. The soles of the feet (with the legs extended) are placed flat against the sit-and-reach box. Head, back and hips are against a wall with a 90° angle at the hips.
2. Ask the subject to place one hand over the other and, whilst keeping the head and back in contact with the wall, slowly reach forward as far as possible with the arms fully extended. This is the starting position.
3. With the hands placed on top of the measuring device, the subject should reach forward as far as possible, three times, holding the position on the third reach for at least 2 seconds while the tester reads the distance on the ruler. The knees should be extended (legs straight).
4. Repeat the test and average the scores of the two trials.

If the subject reaches beyond the toes, the score is positive, otherwise the score is zero or negative.

The score, measured to the nearest centimetre, is the most distant point reached on the second trial. The fingertips of both hands should reach this point. If the reach of the two hands is uneven the test should be readministered.

Scoring of health-related tests

One purpose of the health-related protocol is to determine if an individual should progress to the subsequent work-related protocol, on the grounds that any work-related tests carry some risk of injury and should only be undertaken by those whose general physical function is adequate. It is therefore necessary to specify a performance level for the health-related tests which should be met.

The criterion score which is shown in the subsequent score sheets should be regarded as provisional, since the sample is relatively small. Data for each of the tests were assessed in relation to adequacy of normality assumption and were found to be normally distributed.

The rationale which forms the basis for the scoring system for the health related tests is as follows. All tested miners in the sample used to trial and validate the tests were uninjured, and able to carry out underground mining tasks. They also safely completed the work-related tests. These individuals are also deemed to be reasonably representative of the current coal-mining workforce. Therefore, if a person who is evaluated using the health-related tests obtains an overall score that equals or exceeds the lowest end of the distribution of scores from the test sample, that individual can be considered to have overall health-related performance within the range of the current uninjured workforce, and should be considered eligible to undertake the work-related tests. Note that this does not guarantee that this individual would be able to complete the work-related tests without injury.

The procedure by which a person's health related test scores are obtained is as follows

1. The appropriate score for each of the tests is determined and recorded.

2. The person's score for each test is converted to a z score, which enables them to be evaluated using a common set of numerical values. This calculation is shown on the test sheet. It involves subtracting from the individual's score the sample mean score minus 2 std deviations, and dividing this difference by the sample standard deviation. The relevant values are shown on the score sheet. The resulting z score will have a value of 0 if it equals the score of the approximately the 2^{nd} (2.2) percentile for the sample. It will be negative if it is below this value and positive if it is above.

3. The person's z score on each test is then evaluated. If it is greater than 0, the person should be considered to have health-related fitness at least as good as the lowest end of the distribution from the sample population, and is eligible for the work-related protocol.

Achieving this criterion score does not necessarily indicate high levels of health-related fitness. Individuals tested may be provided with information about their scores relative to the values in Figure 5.1 and Table 5.2, as well as to published norms, such as those of Edwards and Gore (1992).

The relative importance of individual health-related tests:

For reasons cited earlier, all tests are considered important in providing a measure of fitness which reflects the fitness characteristics required to perform the tasks identified in underground mining. However it is recognised that how well a specific test provides a measure of the relative risk of injury or cardiovascular stress will vary depending on the particular test. Consequently, the sit and reach test, which indicates hip and trunk flexibility, was considered a lower risk for performing the work related tasks than, for example, measures of cardiovascular function and strength. However, reduction in flexibility may increase the risk of injury if excessive force is applied. Therefore, if an individual scores below 0 on the Sit-and-Reach test, but above 0 in the remainder of the health-related tests, they should be considered eligible to undertake the work-related tests.

It is recognised that the proposed scoring system has limitations, many of which reflect the relatively small number of miners tested at this stage. Many of these limitations may be reduced when additional data has been collected on the performance results of incumbent miners.

Based on the rationale proposed for the scoring system, the threshold for satisfactory completion of the health related tests is set at 2 standard deviations below the mean of the incumbent workers tested. Using this threshold, approximately 97% of the group tested would be considered to have satisfactory performance. Although this standard may be considered to be a low one, it is consistent with the scores attained by the miners in the sample who satisfactorily completed the later work related test protocol and are currently undertaking mining work, and is consistent with the aim of the testing being to identify those who can or cannot perform the tasks satisfactorily.

Depending on the objectives of the testing program, it is possible to increase the threshold level which would effectively increase the number with unsatisfactory performance. For example, increasing the threshold level may be justified if the aim of the program is to increase the level of fitness of the workforce by establishing higher standards than would appear to exist currently. However, this would be inconsistent with the results obtained from the incumbent workers in this sample, and would require specific justification.

Name: ____________________ Weight: ________ Age: ______

Resting HR: __________ Height: ________ Resting BP: __________

Health Related Test:	Trial No. 1:	Trial No. 2:	HITS	$\frac{\text{HITS} - \text{SMS}}{\text{SSD}}$ =	z-Score
Low Back Strength Low back strength (kg)	(1) ☐	(2) ☐	Highest ☐	$\frac{\square - 75}{35}$ =	(1) ☐
Knee Extensor Strength Knee extension (kg)	(1) ☐	(2) ☐	Highest ☐	$\frac{\square - 56}{47}$ =	(2) ☐
Elbow Flexor Strength Elbow flexion (kg)	(1) ☐	(2) ☐	Highest ☐	$\frac{\square + 24}{35}$ =	(3) ☐
Shoulder Flexor Strength Isometric shoulder strength (kg)	(1) ☐	(2) ☐	Highest ☐	$\frac{\square - 36}{23}$ =	(4) ☐
Abdominal Strength Level Completed (1-7)			☐	$\frac{\square - 1}{1}$ =	(5) ☐
Lower Back Endurance Time held (sec)			☐	$\frac{\square - 37}{32}$ =	(6) ☐
Abdominal Endurance Number of sit-ups (completed)			☐	$\frac{\square - 14}{10}$ =	(7) ☐
Sit-and-Reach Reach (cm)	(1) ☐	(2) ☐	Best ☐	$\frac{\square + 8.6}{6.5}$ =	(8) ☐

Note: HITS = Highest Individual's Trial Score
SMS = Sample Mean Size
SSD = Sample Standard Deviation

TURN OVER

6-Minute Step Test

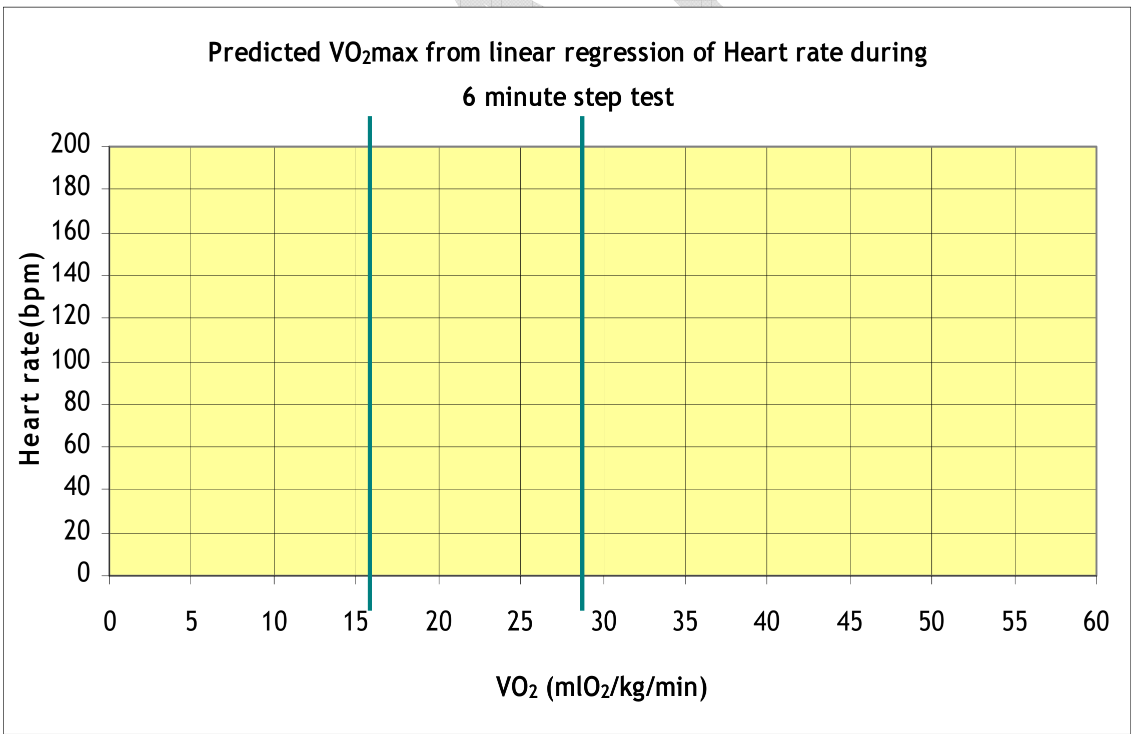
Heart rate (15 steps/min) (bpm) ☐

Heart rate (27 steps/min) (bpm) ☐

VO_2 (ml/kg/min) ☐ → $\frac{\square - 19}{11} = $ (9) ☐

To determine the score for the 6 minute step test a number of additional procedures will be taken to convert heart rate measures into measures of VO2 max. (ml/kg/min). These steps are as follows:

1. Calculate APMHR (Age Predicted Maximum Heart Rate) as follows: APMHR = 208 – (0.7 * Age)
2. Draw a line of APMHR across the graph below, which will indicate a baseline
3. Mark the Heart rate (15 steps/min) (bpm) on the graph below.
4. Mark the Heart rate (27 steps/min) (bpm) on the graph below.
5. Plot a line through both the Heart rates and extended till it reaches the baseline of APMHR.
6. Drop the line down and read the VO_2 value.



APPENDIX 4

Work-related Tests

Guidelines

	Pre-employment screening	Return to work following injury/illness	Change of job or duties	Older workers
Special pre-testing considerations	All other screening tests should be completed first, as applicants not meeting other criteria need not undertake these tasks. Applicants should be advised of the testing protocol with as much notice as possible to enable them to improve fitness as appropriate.	1. These tests should not substitute for other clinical or functional testing normally undertaken. 2. All relevant rehabilitation should be completed, and testing undertaken only when worker is otherwise judged ready to return to these duties.	If worker has previously been undertaking only sedentary or light duties, he or she should be advised of the test protocol and allowed a period to improve fitness as appropriate. A period of at least 12 weeks should be allowed for this purpose.	If a worker has medical conditions or injuries that may limit physical function, the medical clearance should take particular account of such conditions. Note that Heart rates should be age-adjusted, as outlined in the relevant instructions.
Pre-testing measures for all applications	Medical clearance should be given for testing. Clinicians providing this clearance should have available a copy of the test protocol. The work duties to be undertaken by the individual being assessed should be judged by relevant managers (e.g. OH&S manager) as essentially comparable to the test. (Some jobs may involve duties with much lower physical demands for which these assessments are not relevant). Management or other personnel responsible for the testing should ensure that all relevant occupational health and safety procedures are implemented, following any applicable legislation and policies.			
Personnel	A minimum of two people are required to administer these tests. More than two people will be needed for prolonged testing or testing more than one test-taker simultaneously. Personnel administering tests should normally be OH&S staff and trainers, trained and currently accredited for first aid and cardiopulmonary resuscitation. A first-hand knowledge of the relevant underground work tasks is essential. At least one of these personnel should be able to pass these tests and be able to provide assistance where this is required (e.g. vent-tube test), or in an emergency. The personnel should have a working knowledge of the principles of physical fitness (musculoskeletal function, aerobic and anaerobic energy systems, interpretation and use of heart rates during exercise and training), and know how to measure blood pressures, heart rates, and core temperature.			

Location	Ideally all tests should be conducted at a central location, as is the case with assessments currently undertaken by Coal Services in New South Wales. A central location allows immediate access to medical and emergency services, as well as promoting more efficient and standardised testing. If testing is conducted at other locations, such as an individual mine-site, the testing location should be readily accessible by vehicles, including emergency services. If not adjacent to offices or other worksites where help is immediately available, secure telephone/radio communication is essential in the event of an emergency. A power supply is required for any computers used in record-keeping. The location should have sufficient shade, seating and water, equivalent to that normally available in a crib room, as test-takers may have periods of waiting before and in between tests. Surface conditions and space requirements are specified in the individual tests. For example, we conducted all work-related tests at the training areas designated for Mines Rescue training. At one site the area consisted of a 30m x 7m steel enclosure with concrete floor replicating an underground work area, a 15m x 4m open-air concrete surface and a sanded, open-air 55m x 40m area. The 'Carriage' and 'Cable Drag' activity were both conducted on the sanded 55m x 40m area. The 'Coal Shovel' was performed on the open-air concrete area while the remaining tests were performed in the enclosed, concreted 'underground work area'.
Order of testing	Health-related tests should be administered first, and satisfactory completion of these tests should be a requirement for undertaking the work-related tests.
Stopping the tests	In the interests of safety testing should be stopped before completion if: a) Any test-taker states that they are experiencing pain or are feeling unwell, or b) Any test-taker is visibly injured or unwell even if they do not state that they are, or c) The basic effective temperature exceeds 29.4 degrees Celsius, as required under legislation for Queensland Coal mines, reported in the AIOH report on *"Heat Stress Standard & Documentation Developed for use in the Australian Environment"* (Di Corleto, Coles & Firth, 2003). d) After any of the work-related tests or the step test of the health-related assessments, the test-taker's recovery heart rate indicates that P1-P3 < 10 (see section on Heat, below). This criterion applies even if the basic effective temperature < 29.4 degrees Celsius. e) Continued unsafe conduct of tasks.
Safe conduct of tasks	Although the work-related tasks specify the major actions the test-taker may use, they may still be undertaken with some variance in technique. If a test-taker performs a test in a way that presents a safety risk to himself or others, the test should be stopped and feedback about the risk provided. This should include guidance about safer alternative actions or techniques. The test can be repeated after a break.
Rest breaks	A minimum of thirty minutes rest break should be allowed between the health-related and the work-related tests. A minimum rest break of 5 minutes in between the work-related tests should be allowed.
Recovery Heart rate recording	After each of the work-related tests, recovery heart rate will be measured for a period of three minutes. Rest breaks do not commence until the end of this recovery period.

Heat

As the work-related tests will most likely be conducted outdoors it is important that guidelines on performance of physical activity in hot conditions are followed. The guidelines below are based on The Australian Institute of Occupational Hygienists report *"Heat Stress Standard & Documentation Developed for use in the Australian Environment"* (Di Corleto, Coles & Firth, 2003). Extracts from the report are shown in italics below, with additional commentary specific to the current assessments added.

The overall approach recommended by the AIOH (2003) consists of three steps:

1. A basic heat stress risk assessment incorporating a simple index (eg. WBGT, BET, etc.).

2. If a potential problem is indicated from the initial step, then progress to a second level index to make a more comprehensive investigation of the situation and general environment. Ensure factors such as temperature, radiant heat load, air velocity, humidity, clothing, metabolic load, posture and acclimatisation are taken into account.

3. Where the calculated allowable exposure time is less than 30 minutes or there is an involvement of high-level personal protective equipment, then employ some form of physiological monitoring (Di Corleto et al., 1998).

For the current assessments there are particular considerations for each of these steps:

Step 1: For the calculation of WBGT, the following formula can be used:

"For a solar radiant heat load (i.e. outdoors in sunlight):

$$WBGT = 0.7NWB + 0.2GT + 0.1DB$$

Or

Without a solar radiant heat load, but taking account of all other workplace sources of radiant heat gains or losses:

$$WBGT = 0.7NWB + 0.3GT$$

Where: WBGT = Wet Bulb Globe Temperature

NWB = Natural Wet-Bulb Temperature

DB = Dry-Bulb Temperature

GT = Globe Temperature"

Steps 1 and 2: Steps 1 and 2 can be considered together if the Thermal Work Limit or Basic Effective Temperature indices are used, and if a recording device such as the Heat Stress Monitor (www.calor.com.au) is used. This measures wind speed and barometric pressure in addition to calculating WBGT, and permits other work variables to be entered. An additional feature of the use of this instrument is that it is based on research that specifically addressed underground mining:

"Brake and Bates (2002) have likewise developed their rational heat stress index, the TWL, based on underground mining conditions. TWL is defined as the limiting (or maximum) sustainable metabolic rate that hydrated, acclimatised individuals can maintain in a specific thermal environment, within a safe deep body core temperature (< 38.2°C) and sweat rate (< 1.2 kg/hr). The index has been developed using published experimental studies of human heat transfer, and established heat and moisture transfer equations through clothing. Clothing parameters can be varied and the protocol can be extended to unacclimatised workers. The index is designed specifically for self-paced workers and does not rely on estimation of actual metabolic rates. Work areas are measured and categorised based on a metabolic heat balance equation, using dry bulb, wet bulb and air movement to measure air-cooling power (W/m^2). A thermal strain meter is available for determining aspects of this index (see website at www.calor.com.au)."

This approach meets the recommendation that: *"The use solely of a heat stress index for the determination of heat stress and the resultant heat strain is not recommended. Each situation requires an assessment that will incorporate the many parameters that may impact on an individual in undertaking work in elevated thermal condition. In effect, a risk assessment must be carried out in which additional observations such as workload, worker characteristics, personal protective equipment, as well as measurement and calculation of the thermal environment, must be utilised."*

Step 3. The current assessments include heart rate monitoring. This enables Step 3 of the AIOH (2003) Report to be applied. Specifically, the heart rate recovery method (Brouha, 1967) can be used. This has the additional benefit that, while devised to detect thermal stress, this procedure may also detect individuals who should discontinue the test for other reasons (e.g. undetected cardiac problems, undetected illness, or grossly insufficient physiological capacity). Therefore it is recommended that Heart Rate recovery be measured regardless of the environmental conditions.

In implementing the following measures, each assessment can be considered a "cycle of work"

"Brouha's recovery rate method involved a specific procedure as follows:

- *At the end of a cycle of work, a worker is seated and temperature and heart rate are measured. The heart rate (beats per minute) is measured from 30 to 60 seconds (P1), 90 to 120 seconds (P2), and 150 to 180 seconds (P3). At 180 seconds, the oral temperature is recorded for later reference. This information can be compared with the accepted heart rate recovery criteria, for example:*

  P3 < 90 or

  P3 ≥ 90, P1 - P3 ≥ 10 are considered satisfactory.

  High recovery patterns indicate work at a high metabolic level with little or no accumulated body heat.

- *Individual jobs showing the following condition require further study.*

  P3 ≥ 90, P1 - P3 < 10

  Insufficient recovery patterns would indicate too much personal stress (Fuller & Smith, 1982).

	At the present time, the use of a *<u>sustained</u>* *heart rate (eg. that maintained over a 5-minute period) (Myhre, 1998) in subjects with* *<u>normal</u>* *cardiac performance, of "180-age" beats per minute (Brotherhood, 1998), is proposed as an upper boundary for heat-stress work situations where monitoring of heart rate during activities is practicable. Moreover, such monitoring, even when the screening criteria appear not to have been overstepped, may detect individuals who should be examined for their continued fitness for their task, or may show that control measures are functioning inadequately."* *"Physiological monitoring is complex and where assessment indicates the necessity of such monitoring, it must be undertaken by a competent person with proven technical skills and experience in relation to the study of heat stress and/or human physiology. This is particularly critical where there are additional medical complications arising from medical conditions or medications being administered."*
Pace	All tests should be performed at normal work pace.

Test 1: Carriage

Task: Lifting and carrying equipment.

Brief description: The following weights will be carried in the box/tray:

- o Level 1 10kg lifted from ground and carried 40metres;
- o Level 2 20kg lifted from knee height and carried 40 metres;
- o Level 3 25kg lifted from waist height and carried 40 metres;
- o Level 4 30kg lifted from waist height and carried 10 metres;
- o Level 5 35kg lifted from waist height and carried 10 metres.

A walk recovery is included after each Level completed.

Purpose: Walking and carrying equipment/timber has been nominated as one of the most intense, frequent and time-consuming activities. This test aims to measure muscular endurance capability whilst walking and carrying objects. The main muscle groups involved are elbow flexors and wrist flexors working isometrically, back extensors (isometric), and lower limb muscles (dynamic).

Equipment: Three marker cones, measuring tape, stopwatch, 35kg of various disc weights (2 x 10kg; 3 x 5kg) and a box/tray with handles.

Test set-up:

1. Equipment set-up:
   a. Cones mark out:
      1. Start;
      2. 20m marker (from the start marker);
      3. 5m marker (from the start marker) placed in opposite direction to 20m marker.
   b. All weights, the waist-high table and a knee-high surface (e.g. chair or milk crate) are place at the start marker. Weights are placed on a waist-high bench next to a box or tray. A 10kg weight is placed in the box for the first level of the test. Additional weights will be placed in the box for each level. The box needs to have handles on the sides allowing two-hand carry if desired. Lifts are performed from the ground, knee and waist height depending on the level of the test.
2. Instructions for the participant:
   a. The entire test needs to be performed at normal working pace.

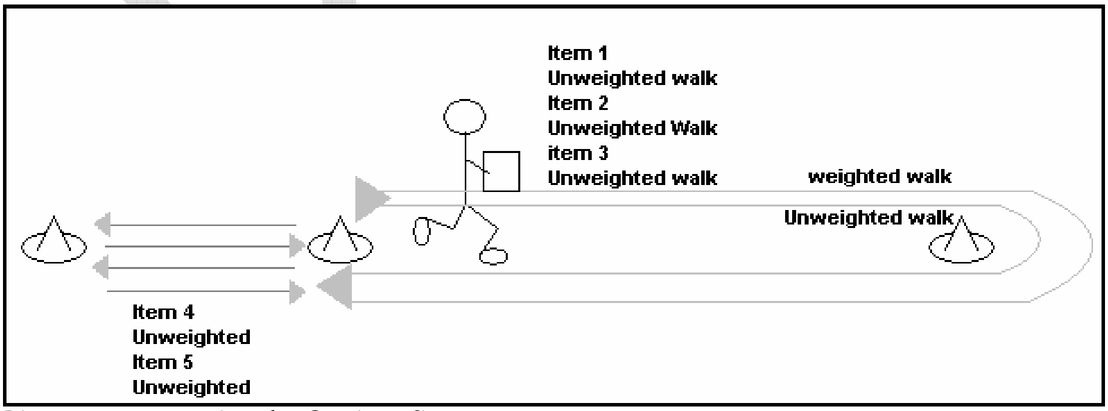


Diagram representing the Carriage fitness test

Test procedure:

1. Level 1
   The participant is instructed to lift and carry 10kg from the ground, a total of 40 metres (to the 20 metre marker and back).
   a. Upon returning to the starting marker HR, time and RPE are recorded (as the participant's foot touches/crosses the start marker);
   b. The participant must place the object on the ground and walk the 40 metre course unweighted ('recovery walk');
   c. Upon the returning from the recovery walk HR, time and RPE are recorded.
2. This process is repeated for Level 2 (20kg) and Level 3 (25kg).
   a. For Level 1, 2 and 3 weights may be lifted and carried in any way, including carrying on a shoulder or on a hip;
   b. The Level 2 weight (20kg) must be lifted from and returned to the knee-high surface;
   c. The Level 3 weight (25kg) must be lifted from and returned to the waist-high bench.
3. Level 4 (30kg) and Level 5 (35kg) must be lifted from the waist-high bench and carried to the 5m marker and back.
   a Upon returning to the starting marker HR, time and RPE are recorded;
   b Level 4 and Level 5 weights are to be carried in front of the body at waist height only.

The test is terminated (and HR, time and RPE are recorded) when:
   a. The participant completes all 5 lifts;
   b. The subject cannot lift an item in a safe and effective manner, as determined by the tester.

If the test is halted due to safety concerns, the participant is:
   1. Instructed on safe techniques;
   2. Rested for 5 minutes, and
   3. Given a second opportunity to participate from the start of the activity.

Carrying weights in front of the body at waist height.

Test 2: Cable drag

Task: Lifting and dragging cable.

Brief description: Dragging cable over set, graduating distances with a walk-back recovery.
- Level 1 Dragging cable to 10 metre marker;
- Level 2 Dragging cable to 20 metre marker;
- Level 3 Dragging cable to 30 metre marker;
- Level 4 Dragging cable to 40 metre marker;
- Level 5 Dragging cable to 50 metre marker.

Purpose: Lifting and dragging has been identified as a task that is intense, frequently undertaken and time consuming. This test aims to measure the subject's strength and muscular endurance and ability to lift, drag and pull a cable.

Equipment: 150 metres of HT cable rolled onto drum, a flat and open area (approx. 50 metres long), 75 metre measuring tape or metre wheel, stopwatch, 5 markers.

Test set-up:
1. 75 metres of HT cable is set up on cable rollers and placed at one end of a long open area.
2. The long/open area is marked on the ground at 10, 20, 30, 40, and 50 metres with markers or (preferably) spray paint.

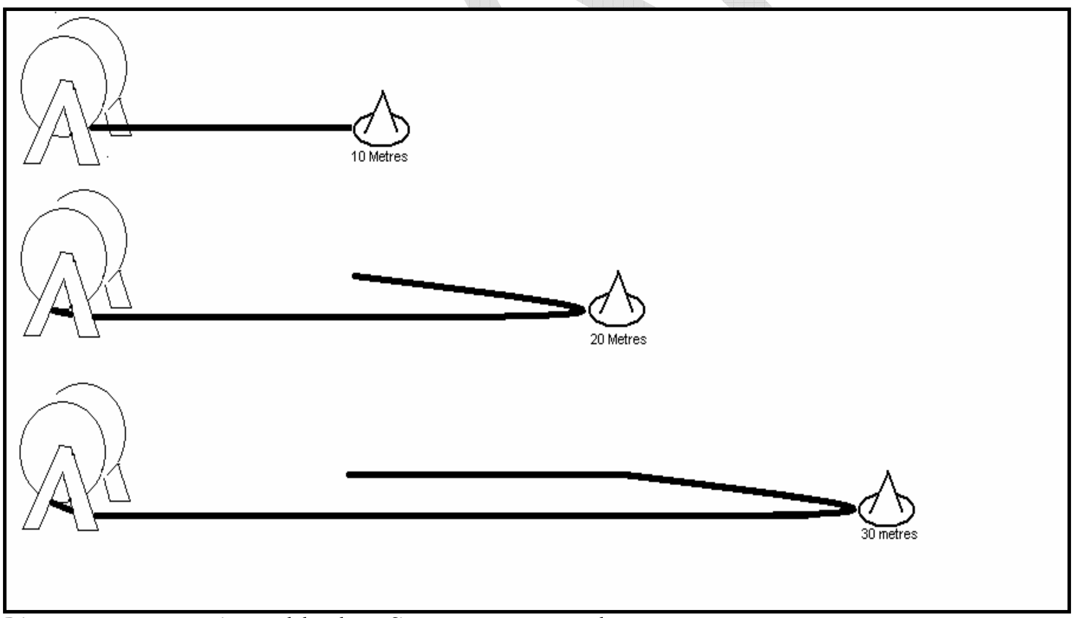


Diagram representing cable drag fitness test procedure

Test procedure:

1. Participant is instructed to grasp the cable at the starting marker. The participant may drag or pull by holding the cable in any position, for example holding the cable over a shoulder or at one hip.
2. Heart rate is recorded prior to starting.
3. On the "Ready, Go" instruction:
   a. Participant begins to drag the cable to the 10 metre mark;
   b. Timing is started.
4. The subject is instructed to pull the cable off the drum to the 10 metre mark, drop the cable and return to the drum. When the participant is ready to start the next section he must acknowledge the tester by raising his hand.
5. Upon returning to the drum, the subject grasps the cable and pulls a 'loop' to the 20 metre mark and again drops the cable and returns to the drum. This process is repeated, dragging to 30m, 40m and 50m respectively.

The test is terminated (and HR, time and RPE are recorded) when:

a. The subject completes the final Level;
b. The subject cannot pull the 'loop' in a safe manner, as determined by the tester;
c. The subject quits the test.

Dragging techniques may vary. Holding over one shoulder is a favoured method.

Cable must be dragged out to markers at a set distance from the cable roller.

Test 3: Vent tube hanging

Task: Dragging, lifting and holding above shoulder height.

Brief description: After dragging a vent tube to beneath a pre-hung vent tube, the participant must lift the butting end of the tube up into the pre-hung vent, then swap ends and lift, insert and hold the lagging end of the vent tube above the head. The vent is then lowered to the ground and dragged back to the starting position. A partner is required to help in the lifting of the vent.

- Level 1 Drag vent to under pre-hung vent;
- Level 2 Lift butting end to edge of pre-hung vent and lift lagging end to insert;
- Level 3 Hold lagging end above head for 5 seconds;
- Level 4 Lower lagging end to ground and lower butting end to ground;
- Level 5 Drag vent to start marker.

Purpose: The installation of venting ducts is a task that has been identified as intense, frequently undertaken and time consuming. This test aims to ensure the applicant has sufficient upper body strength and muscular endurance to hold one end of a standard venting tube above the head.

Equipment: 2 x Standard lengths of ventilation ducting (2900mm length x 600mm diameter) (weight: 31kg), venting/meshing rack (test frame) with chains hanging, stopwatch.

Test set-up:

1. The test frame is assembled.
2. A standard vent tube is hung from hooks on the ceiling of the test frame. The bottom of the pre-hung vent should be between 1.80-1.90 metres off the bottom of the testing frame.
3. The free vent tube should be positioned on the ground 5 metres from the pre-hung vent.

Test procedure:

1. The participant drags the vent from the starting marker to underneath the pre-hung vent.
2. The participant lifts the butting-end of the vent with an assistant pushing from the lagging end, up to the pre-hung vent. The butting end needs to be supported on the edge of the pre-hung vent.
3. The participant and assistant swap ends and the participant lifts and inserts the vent into the pre-hung vent. The assistant places support chains around the installed vent. The participant then rests for 5 seconds.
4. The assistant releases the support chains while the participant holds the vent from below. The participant lowers the vent from the pre-hung vent from the lagging end until the butting end is near the edge of the pre-hung vent.
5. The participant and assistant swap ends of the vent with the participant now lowering the vent and placing it on the ground. The participant drags the vent 5 metres back to the starting marker. Time, HR and RPE are recorded.
6. The process is repeated. Test is complete when the participant has performed the whole process five times. Time, HR and RPE are recorded upon finishing the test.

A standard length of ventilation ducting.

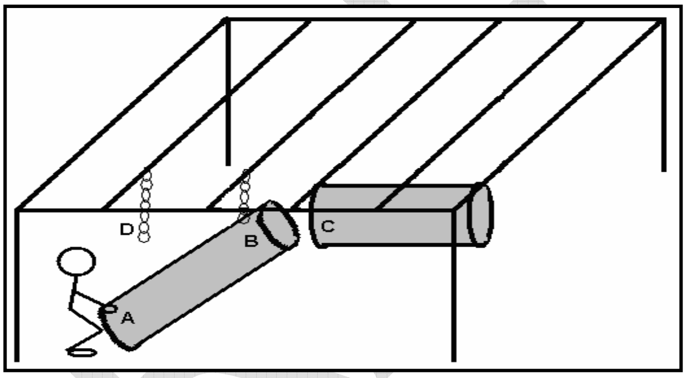


Diagram of Vent Installation Test
Note: A = Lagging end; B = Butting end; C = Pre-hung vent open end.

Lagging end of the vent needs to be lifted, inserted and held above the head.

Test 4: Lifting and handling mesh

Task: Lifting above shoulder height.

Purpose: Installing roof mesh plays an extremely important role in avoiding cave-ins and has been identified as physically intense, frequently undertaken and time consuming. This test aims to ensure the applicant has sufficient upper body strength endurance to pass a sheet of standard sized mesh at slightly above shoulder height (such as a continuous miner) in preparation for installation.

Equipment: 1 x 1/2 Standard length of mesh (1200mm x 4800mm – 22kg), venting/meshing rack, and stopwatch.

Test set-up:

1. Testing frame is adjusted according to the participant's height.
2. 1/2 sheet of standard mesh against wall 3 metres from the mesh rack.
3. Line painted/drawn between legs of testing frame (simulating unsupported roof limit).

Test procedure:

1. While standing at the mesh rack waiting for the instructions "Ready, Go", the participants heart rate is recorded.
2. On the command of "Ready, Go" the participant must walk from the mesh rack to the mesh sheets.
3. The participant must lift and carry the 1/2 sheet of mesh 3m to the side and 5m to the back and place it within the allotted area of the mesh rack:
   a. Feet must not cross painted/drawn line between rack legs (simulating unsupported roof limit);
   b. Crossings are noted on the assessment sheet;
   c. Mesh must be completely inserted with no mesh protruding from the rack;
   d. Mesh must be carried on the side of the body.
4. The participant moves to the adjacent side of the testing frame and removes the mesh sheet from the frame. The mesh is dragged or carried back to the starting marker.
5. Confines need to be restricted to simulate the cramped working environment.
6. The process is performed 5 times.
7. The test is terminated when:
   a. All 5 consecutive sheets are completed;
   b. The subject cannot manoeuvre the mesh in a safe and effective manner, as determined by the tester, or if a mesh sheet is accidentally dropped.

If the test is halted due to safety concerns, the participant is instructed on safe technique, rested for 5 minutes, and given a second opportunity to complete the test.

8. When the participant releases the mesh sheet in a final effort or the test is completed. HR, time and RPE are recorded for each of the 5 trials.

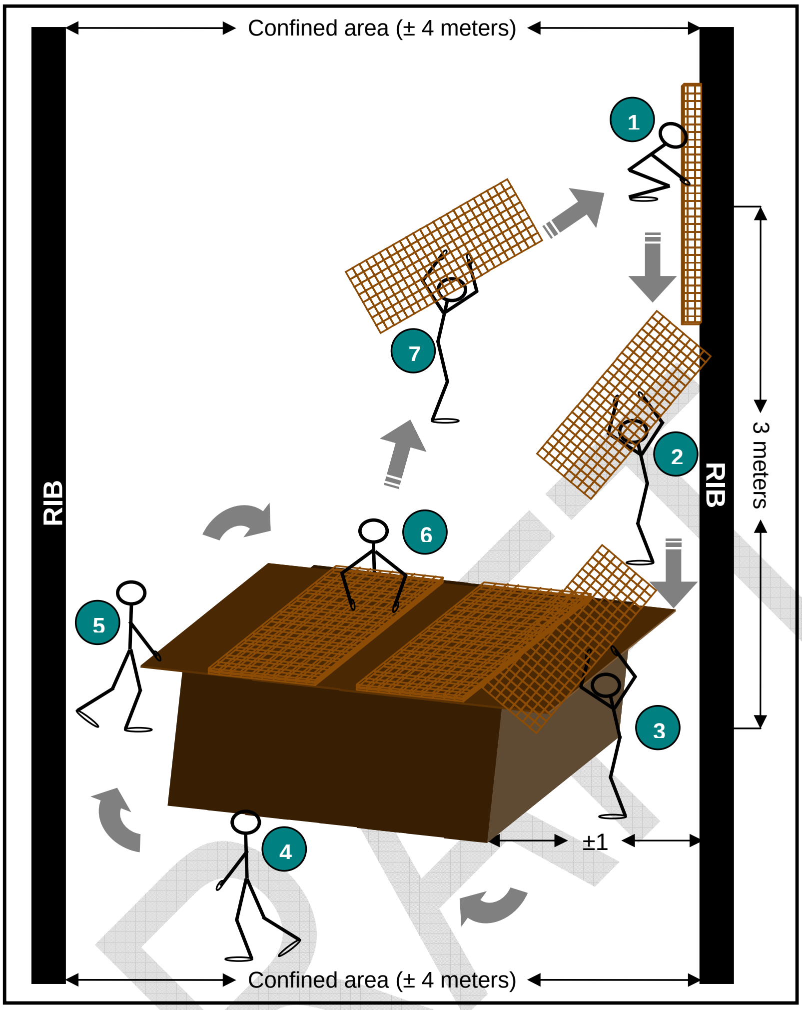


Diagram of Lifting and handling mesh

Note: That the participant must:

1 = Lift the sheet of mesh;
2 = Carry the sheet of mesh to the mesh rack;
3 = Place the sheet of mesh on the mesh rack;
4 & 5 = Move to the adjacent side of the testing frame;
6 = Remove the mesh sheet from the mesh rack;
7 = Carry the mesh sheet back to the starting marker.

Lifting and manoeuvring meshing above the head.

Test 5: Coal shovelling

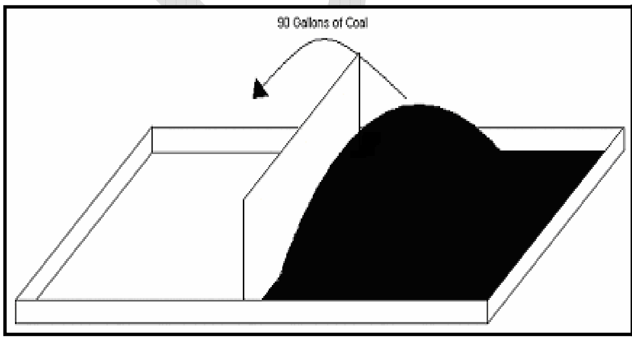
Task: Continuous shovelling for a short period at a fixed pace of 22 shovel-loads per minute.

Purpose: Shovelling requires significant amounts of energy from both anaerobic and aerobic energy systems to ensure muscle endurance. The placement or destination of the coal being shovelled can also vary in different environments. This test aims to determine if an applicant can complete a short bout of continuous shovelling at a fixed pace.

Equipment: Manufactured 'sand-pit like' container – 2 metres wide, 0.2 metre high sides and 4 metres in length divided in half by a 0.6 metre high baffle, stopwatch, metronome, standard shovel and 200kg of coal.

Test procedure:

1. The participant is instructed to:
   a. Stand in the 'sandpit' on the same side as the currently placed coal;
   b. The participant must not leave the 'sandpit' until completion of the test.
2. Prior to the "Ready, Go" command, heart rate is measured.
3. On the command of "Ready, Go", the participant commences shovelling in time with the metronome set to 22 beats per minute, and timing is begun.
4. The participant must shovel coal over the centre baffle and into the other half of the 'sandpit'. A normal "full" shovel load should be moved in each cycle.
5. Heart rate and RPE is recorded each minute.
6. The test is terminated when:
   a. On completion of two minutes, or
   b. If the subject cannot shovel the coal in a safe and effective manner- subjectively assessed by the tester.
      i. If the test is halted due to safety concerns, the participant is:
         1. Instructed on safe techniques;
         2. Rested for 5 minutes, and
         3. Given a second opportunity to participate.
7. On completion of the test HR, time (if less than two minutes), and RPE are recorded.



Scoring of work-related tests

The work-related tests (except coal shovelling) each comprise several incremental levels of performance, with perceived exertion, heart rate and duration also recorded. It is recommended that any use of these tests before a larger normative data base is available employ the following procedure:

1. The key performance measure on each test is the *level attained.* Completion of each task to the level reached by all the miners in the sample indicates that the person being tested has a capacity to complete simulated mining tasks that is equivalent to at least the lowest level of performance shown by the sample population, i.e. currently uninjured and experienced underground coal miners. This criterion of performance uses a rationale similar to that for the health-related tests.

Note that all tested miners completed all levels of every work-related test, with the exception of the cable-drag test. All tested miners, however, completed Level 4 of the cable-dragging test.

Therefore, using the same rationale as provided for the health-related tests, any person tested who finishes at least Level 4 of the cable dragging test and all levels of the other work-related tests should be considered to have a level of work-related fitness at least equivalent to the lowest level of performance of the test population.

The coal-shovelling test does not have incremental levels, but has a dichotomous outcome: completed or not completed. The rate of shovelling used in the protocol below is the lowest rate of shovelling observed in the test population (22 shovel-loads per minute for two minutes).

2. Durations, reported exertion scores, and heart rates attained during each level provide supplementary information that should be provided as feedback to the person tested. For example, a person whose heart rate reaches 90% of age-predicted maximum at Level One of the *Lifting and Handling Mesh* test, who reports a perceived exertion score of 15, and who takes 40 seconds to complete this level, could be advised that the apparent physiological cost at this level was substantially above average and the time to completion longer than average. (Note that the person's scores may be compared with those shown in Table 5.3 for each test.) This person could then be advised with respect to increasing relevant aspects of fitness.

Note that these procedures, for both health-related and work-related protocols, do not differentiate between miners in different age groups, and included no females. Future development of these tests may allow the derivation of more specific criteria and scoring methods.

Test 1 – ‘Carriage’ (Walking and Carrying Equipment)

Carry Level	HEART RATE Start	TIME min : sec	TIME Return	HR Return	RPE Return
0 No weight		00:00	:		
1 10kg		00:00	:		
2 20kg			:		
3 25kg			:		
4 30kg			:		
5 35kg			:		

(circle)
Completed: Yes No If No, last Level Completed (1-4): 1 2 3 4

Final Heart Rate: _______ Time Completed: _________

Test 2 – ‘Cable Drag’ (Lifting and Dragging Cable)

Cable Drag Level	HEART RATE Start	TIME Start	TIME End Level	HR Return	RPE Return
0 Cable Test Start		00:00	:		
1 10 metres			:		
2 20 metres			:		
3 30 metres			:		
4 40 meters			:		
5 50 meters			:		

(circle)
Completed: Yes No If No, last Level Completed (1-4): 1 2 3 4

Final Heart Rate: ________ Time Completed: ___________

Test 3 – 'Venting Tube Installation'

Vent Tube Level	HEART RATE Start	TIME Start	TIME End Level	HR Return	RPE Return
Vent Tube Start		00:00	:		
1 Installed (2)			:		
1 Returned (3)			:		
2 Installed (4)			:		
2 Returned			:		

(circle)
Completed: Yes No If No, last Level Completed (1-4): 2 3 4

Final Heart Rate: _________ Time Completed: ___________

Test 4 – 'Meshing' (Lifting and Holding Mesh)

Mesh No.	HEART RATE Start	TIME min : sec	TIME Return	HR Return	RPE Return
0 No weight		00:00	:		
1 Sheet		00:00	:		
2 Sheet			:		
3 Sheet			:		
4 Sheet			:		
5 Sheet			:		

(circle)
Completed: Yes No If No, last Level Completed (1-4): 1 2 3 4

Final Heart Rate: _________ Time Completed: ___________

Test 5 – Coal Shovel

Shovelling Bout	HR (Start)	Time (Start)	Time (Finish)	HR (Finish)	RPE
		00:00	:		

(circle)
Completed: Yes No If No, time when shovelling stopped________

Final Heart Rate: _________ Time Completed: ___________

APPENDIX 5

Participant Validation and Feedback



PARTICIPANT VALIDATION AND FEEDBACK

Purpose

To assist the researchers with the validation of the tests that will comprise the screening protocol for future coal mining applicants. We are aiming to make the tests as realistic and relevant as possible compared to the tasks normally performed during mining work. To do this we need existing miners to rate how closely the tests reflect the actual tasks, and how closely the physical demand of the tests reflects the actual tasks.

Instructions

Please complete this questionnaire as soon as you have completed the testing protocol.

Read all instructions carefully before responding to the items.

Please circle the response that most closely reflects your perception of the tests, and fill out the section below each question about how to improve the tests.

To ensure anonymity and confidentiality of the information below, please do not write your name anywhere on this form.

Although we understand that the variability of mining work makes it difficult to generalise the characteristics of certain tasks, please use your past experiences within the coal mining industry as a basis to answer the questions.

If you have any concerns or questions regarding the project, please direct all inquiries to the Project Coordinator, Andrew Keech on Ph: 3864 3996, Email: a.keech@qut.edu.au

Thank you for your time and effort in completing this questionnaire

Test 1 – Walking and Carrying Equipment

Please rate the following statements by circling the appropriate response.

On a scale of 1 to 5, rate how *realistic* the Walking and Carrying Equipment test was to your normal work duties.

Very unrealistic	Unrealistic	Uncertain	Realistic	Very realistic
1	2	3	4	5

On a scale of 1 to 5, rate how *similar* the *physical demand* of the Walk and Carrying Equipment test was to actual walking and carrying equipment during normal mining work.

Very Different	Different	Uncertain	Similar	Very Similar
1	2	3	4	5

How do you think this test can be improved to more closely reflect the actual task?

____

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____

Test 2 – Cable Drag

Please rate the following statements by circling the appropriate response.

On a scale of 1 to 5, rate how *realistic* the Cable Drag test was.

Very unrealistic	Unrealistic	Uncertain	Realistic	Very realistic
1	2	3	4	5

On a scale of 1 to 5, rate how *similar* the *physical demand* of the Cable Drag test was to the actual lifting and dragging of equipment during normal mining work.

Very Different	Different	Uncertain	Similar	Very Similar
1	2	3	4	5

How do you think this test can be improved to more closely reflect the actual task?

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CRICOS No. 00213J

Test 3 – Venting Tube Installation

Please rate the following statements by circling the appropriate response.

On a scale of 1 to 5, rate how *realistic* the Vent Tube installation test was.

Very unrealistic	Unrealistic	Uncertain	Realistic	Very realistic
1	**2**	**3**	**4**	**5**

On a scale of 1 to 5, rate how *similar* the *physical demand* of the Vent Tube installation test was to actual installation of vent tubes during normal mining work.

Very Different	Different	Uncertain	Similar	Very Similar
1	**2**	**3**	**4**	**5**

How do you think this test can be improved to more closely reflect the actual task?

____

____

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Test 4 – Manipulation of Mesh

Please rate the following statements by circling the appropriate response.

On a scale of 1 to 5, rate how *realistic* the Manipulation of Mesh test was.

Very unrealistic	Unrealistic	Uncertain	Realistic	Very realistic
1	**2**	**3**	**4**	**5**

On a scale of 1 to 5, rate how *similar* the *physical demand* of the Manipulation of Mesh test was to the actual manipulation of mesh performed during normal mining work.

Very Different	Different	Uncertain	Similar	Very Similar
1	**2**	**3**	**4**	**5**

How do you think this test can be improved to more closely reflect the actual task?

____

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____

____

Test 5 – Shovelling

Please rate the following statements by circling the appropriate response.

On a scale of 1 to 5, rate how *realistic* the Shovelling test was.

Very unrealistic	Unrealistic	Uncertain	Realistic	Very realistic
1	2	3	4	5

On a scale of 1 to 5, rate how *similar* the *physical demand* of the Shovelling test was to actual shovelling of coal that is performed during normal mining work.

Very Different	Different	Uncertain	Similar	Very Similar
1	2	3	4	5

How do you think this test can be improved to more closely reflect the actual task?

____

____

____

____

APPENDIX 6

Correlation Data Analysis



Table 1 Health-related test score vs. Carriage score

	R value	P (sig)	n
Leg Strength - Level 1 Time	-0.582	0.009	19
Leg Strength - Level 1 Heart Rate	0.469	0.037	20
Leg Strength - Level 2 Heart Rate	0.471	0.036	20
Leg Strength - Level 2 %APMHR	0.445	0.049	20
PredVO2 - Level 1 Heart Rate	-0.690	0.001	20
PredVO2 - Level 1 %APMHR	-0.727	0.000	20
PredVO2 - Level 2 Heart Rate	-0.516	0.020	20
PredVO2 - Level 2 %APMHR	-0.562	0.010	20
PredVO2 - Level 3 %APMHR	-0.461	0.041	20
PredVO2 - Level 4 HR	-0.460	0.041	20
PredVO2 - Level 4 %APMHR	-0.528	0.017	20
PredVO2 - Level 5 %APMHR	-0.519	0.019	20

Table 2 Health-related test score vs. Cable Drag score

	R value	P (sig)	n
Back Strength - Level 4 RPE	-0.649	0.003	19
Leg Strength - Level 1 Heart Rate	0.608	0.010	17
Leg Strength - Level 1 %APMHR	0.600	0.011	17
Leg Strength - Level 2 Heart Rate	0.543	0.013	20
Leg Strength - Level 2 %APMHR	0.538	0.014	20
Leg Strength - Level 3 Heart Rate	0.521	0.019	20
Leg Strength - Level 3 %APMHR	0.511	0.021	20
Shoulder Strength - Level 1 Time	-0.796	0.032	7
Abdominal Strength - Level 1 Time	-0.849	0.016	7
Abdominal Strength - Level 5 Heart Rate	0.580	0.038	13
Abdominal Strength - Level 5 RPE	0.557	0.048	13
Abdominal Endurance - Level 4 Time	-0.659	0.020	12
PredVO2 - Level 1 Heart Rate	-0.661	0.004	17
PredVO2 - Level 1 %APMHR	-0.766	0.000	17
PredVO2 - Level 2 Heart Rate	-0.562	0.010	20
PredVO2 - Level 2 %APMHR	-0.676	0.001	20
PredVO2 - Level 3 %APMHR	-0.542	0.014	20
PredVO2 - Level 4 %APMHR	-0.474	0.040	19
Sit and reach - Level 1 RPE	0.565	0.028	15

Table 3 Health-related test score vs. Meshing score

	R value	P (sig)	n
Abdominal Strength - Level 1 Time	0.511	0.025	19
PredVO2 - Level 1 Heart Rate	-0.665	0.001	20
PredVO2 - Level 1 %APMHR	-0.723	0.000	20
PredVO2 - Level 2 %APMHR	-0.529	0.016	20
PredVO2 - Level 3 Heart Rate	-0.470	0.036	20
PredVO2 - Level 3 %APMHR	-0.562	0.010	20
PredVO2 - Level 4 Heart Rate	-0.484	0.030	20
PredVO2 - Level 4 %APMHR	-0.588	0.006	20

Table 4 Health-related test score vs. Ventilation Tube Installation score

	R value	P (sig)	n
PredVO2 - Level 1 Heart Rate	-0.502	0.024	20
PredVO2 - Level 1 %APMHR	-0.557	0.011	20
PredVO2 - Level 2 Heart Rate	-0.484	0.031	20
PredVO2 - Level 2 %APMHR	-0.550	0.012	20
PredVO2 - Level 3 %APMHR	-0.476	0.034	20
PredVO2 - Level 4 %APMHR	-0.505	0.023	20
Sit and reach - Level 1 Time	-0.521	0.022	19

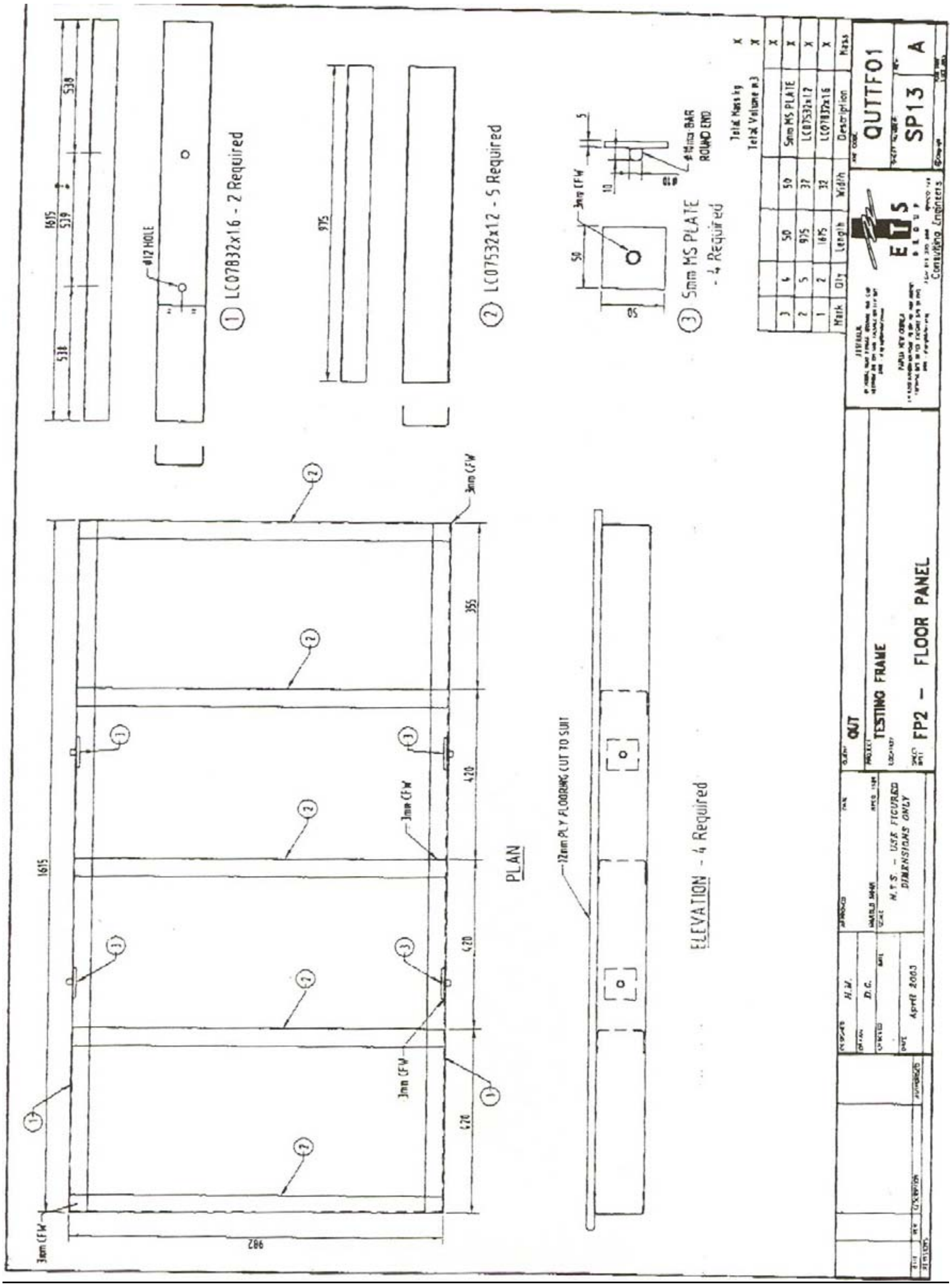
Table 5 Health-related test score vs. Coal Shovelling score

	R value	P (sig)	n
PredVO2 - All Heart Rate	-0.810	0.000	20
PredVO2 - All %APMHR	-0.844	0.000	20
PredVO2 - 2min Heart Rate	-0.810	0.006	20
PredVO2 - 2min %APMHR	-0.844	0.001	20
PredVO2 - 4min Heart Rate	-0.712	0.001	13
PredVO2 - 4min %APMHR	-0.825	0.014	13
Back Strength - All RPE	-0.538	0.017	19
Back Strength - 4min Heart Rate	0.853	0.015	7
Back Strength - 4min %APMHR	0.835	0.019	7
Elbow Strength - 4min Heart Rate	0.865	0.012	7
Elbow Strength - 4min %APMHR	0.787	0.036	7
Lower Back Endurance - 4min %APMHR	0.809	0.028	7
Sit and reach - 4min Heart Rate	-0.828	0.021	7
Sit and reach - 4min RPE	0.831	0.020	7
Sit and reach - 4min %APMHR	-0.778	0.039	7

APPENDIX 7

Technical Diagrams of Test Rig for Vent-tube Hanging




LC07B32x16 - 2 Required
LC07532x12 - 5 Required
5mm MS PLATE - 4 Required
PLAN
ELEVATION - 4 Required
12mm PLY FLOORING CUT TO SUIT
3mm CFW
Ø12 HOLE
Ø16mm BAR ROUND END
Total Mass kg
Total Volume m3
QUT
TESTING FRAME
FP2 - FLOOR PANEL
QUTTF01
SP13
A
N.T.S. - USE FIGURED DIMENSIONS ONLY
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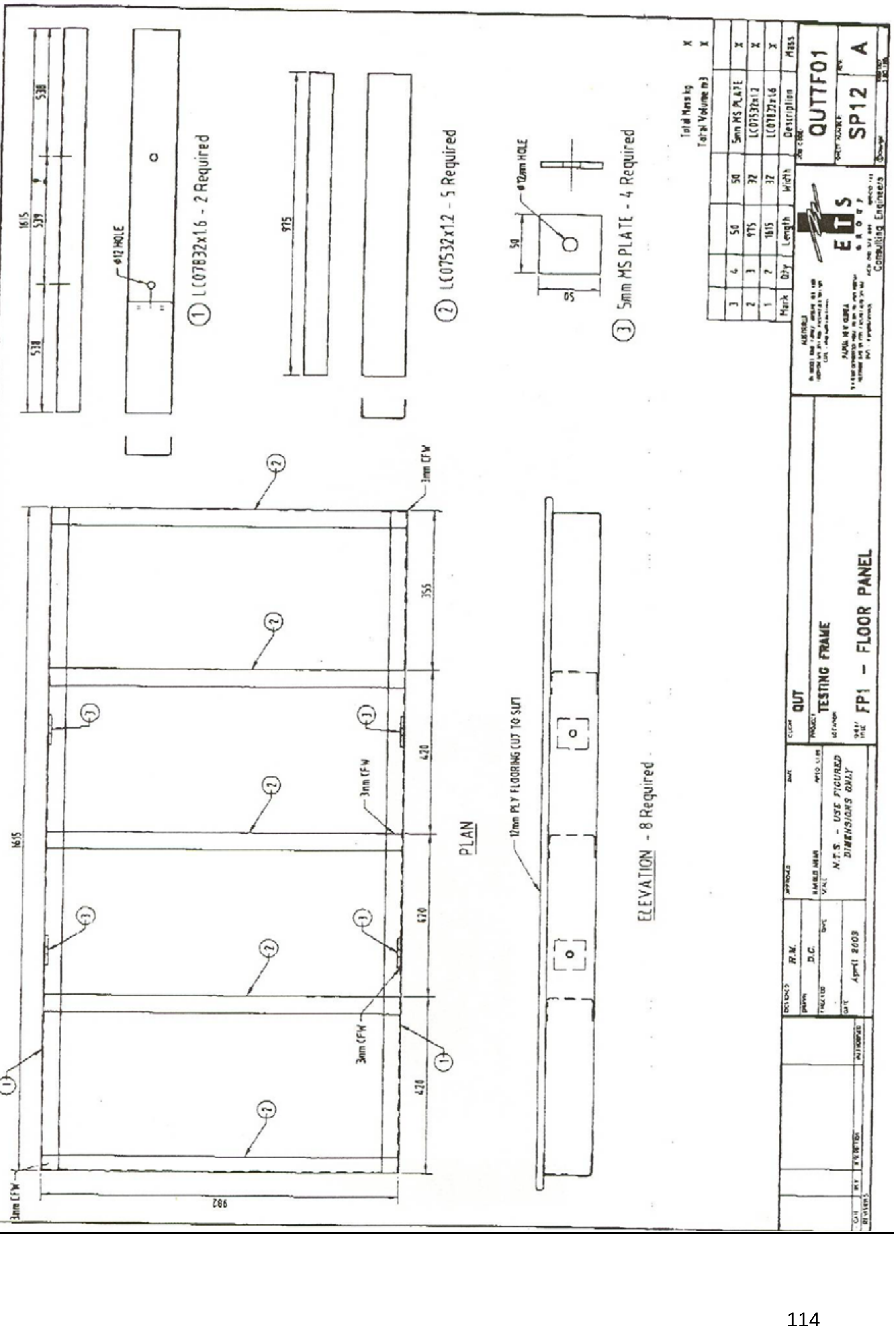
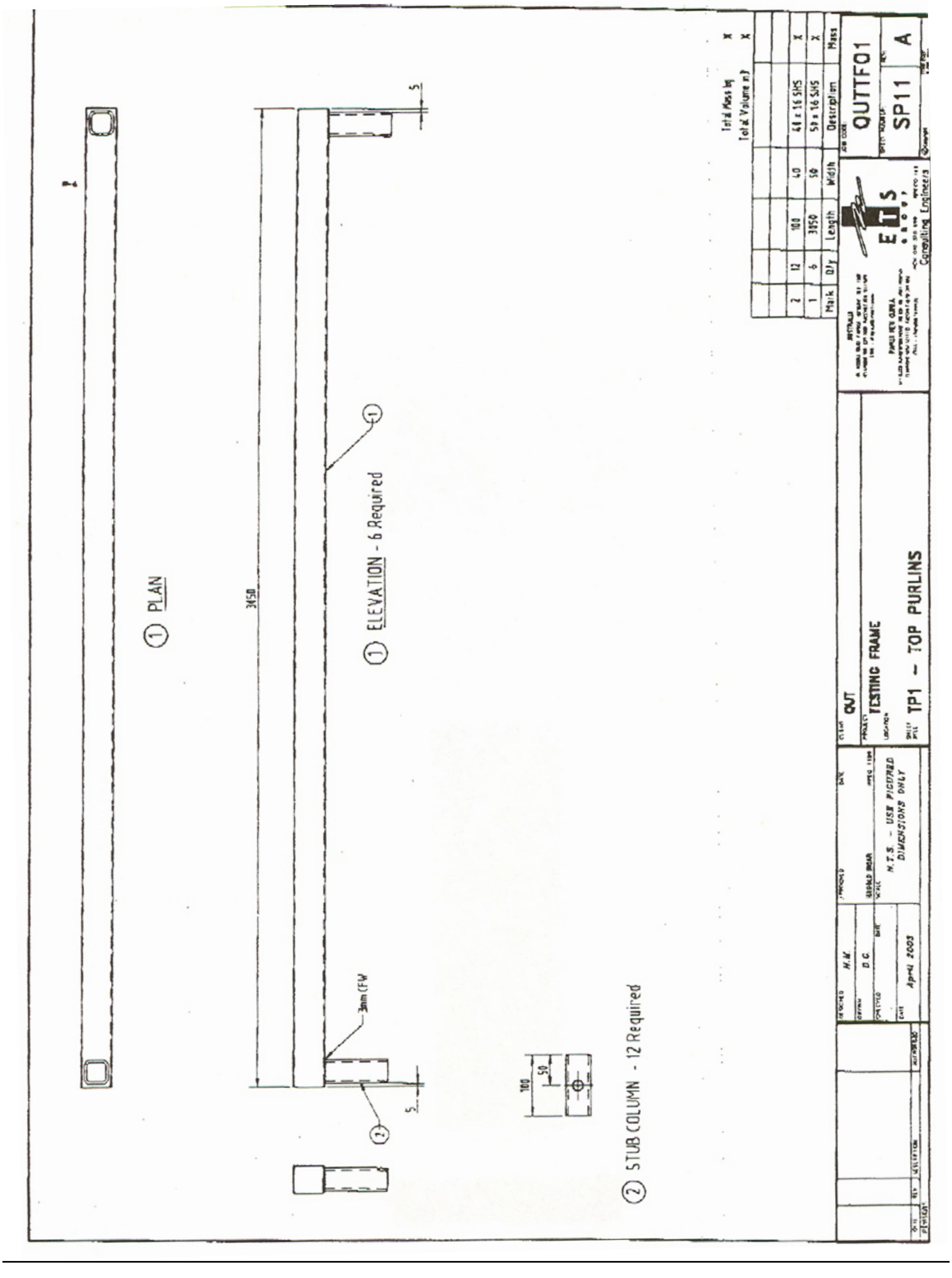

PLAN
ELEVATION - 8 Required
12mm PLY FLOORING CUT TO SUIT
3mm CFW
1615
982
538
539
355
420
Ø12 HOLE
Ø12mm HOLE
① LC07B32x1.6 - 2 Required
② LC07532x1.2 - 5 Required
③ 5mm MS PLATE - 4 Required
Total Mass kg
Total Volume m3
Mark
Qty
Length
Width
Description
Mass
5mm MS PLATE
LC07532x1.2
LC07B32x1.6
QUT
TESTING FRAME
FP1 - FLOOR PANEL
N.T.S. - USE FIGURED DIMENSIONS ONLY
April 2003
QUTTF01
SP12
A
Consulting Engineers


① PLAN
① ELEVATION - 6 Required
3450
3mm CFW
② STUB COLUMN - 12 Required
Total Mass kg
Total Volume m3
Mark
Q/y
Length
Width
Description
Mass
QUTTF01
SP11
A
Consulting Engineers
QUT
TESTING FRAME
TP1 - TOP PURLINS
N.T.S. - USE PICTURED DIMENSIONS ONLY
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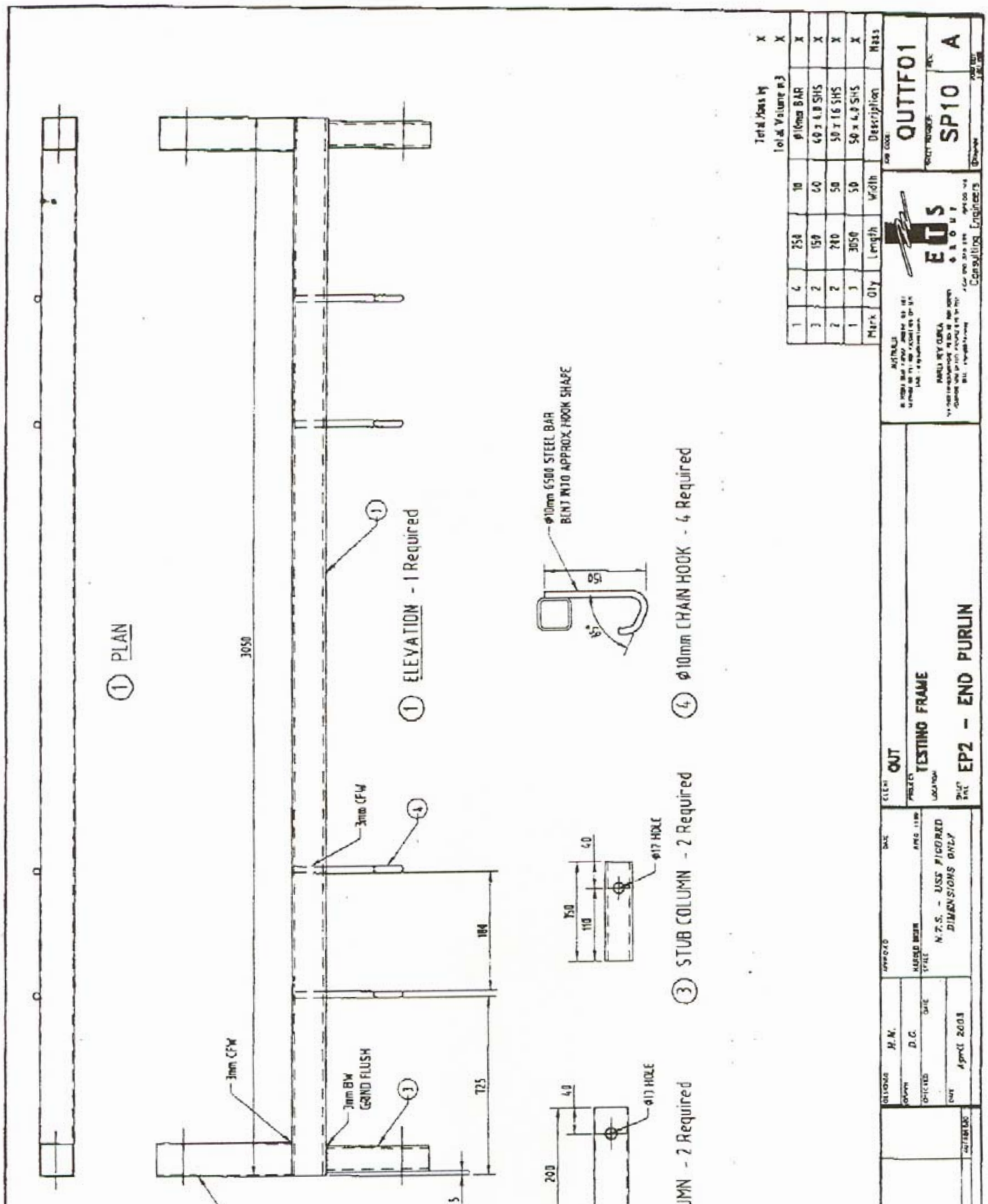
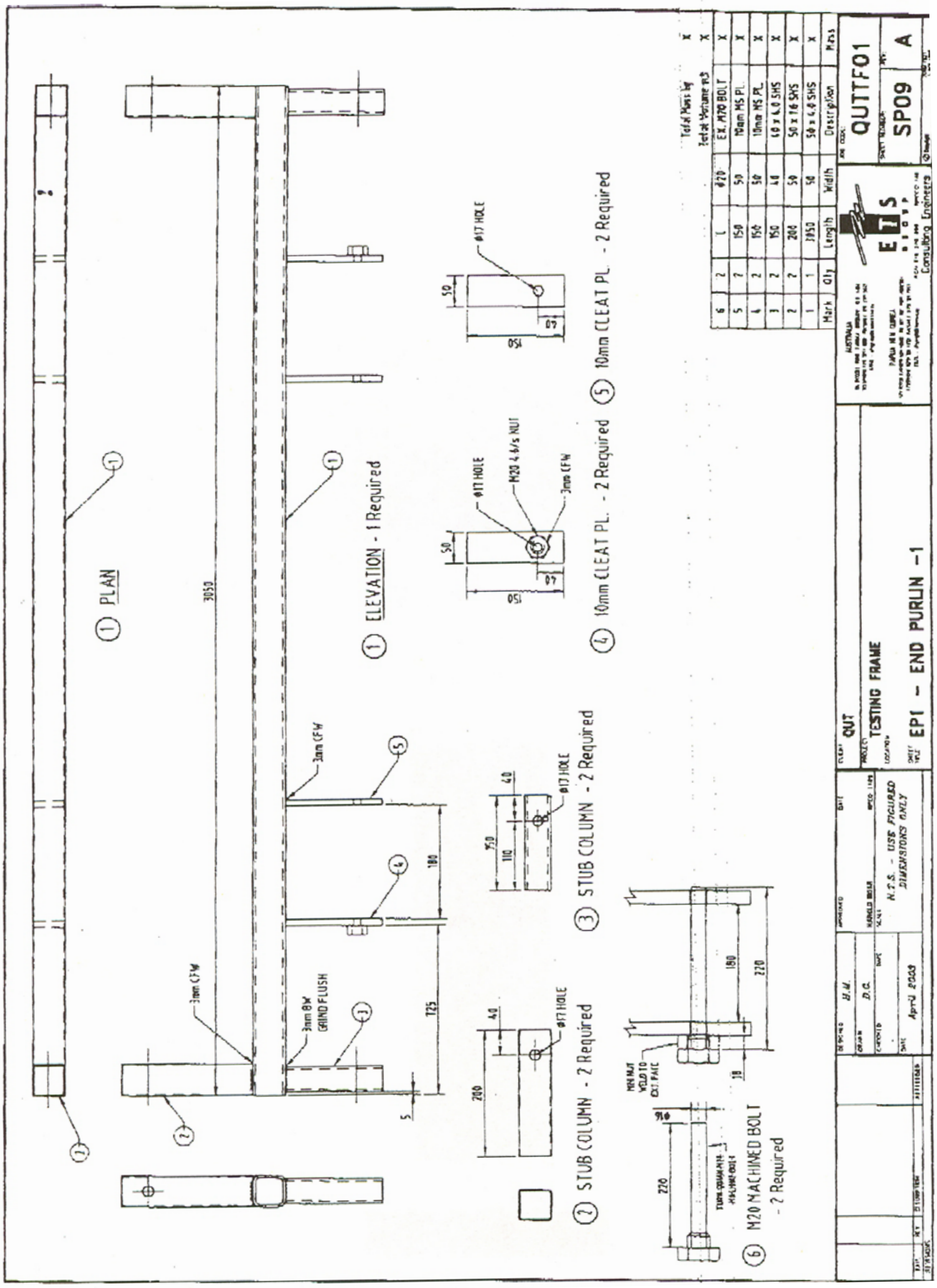
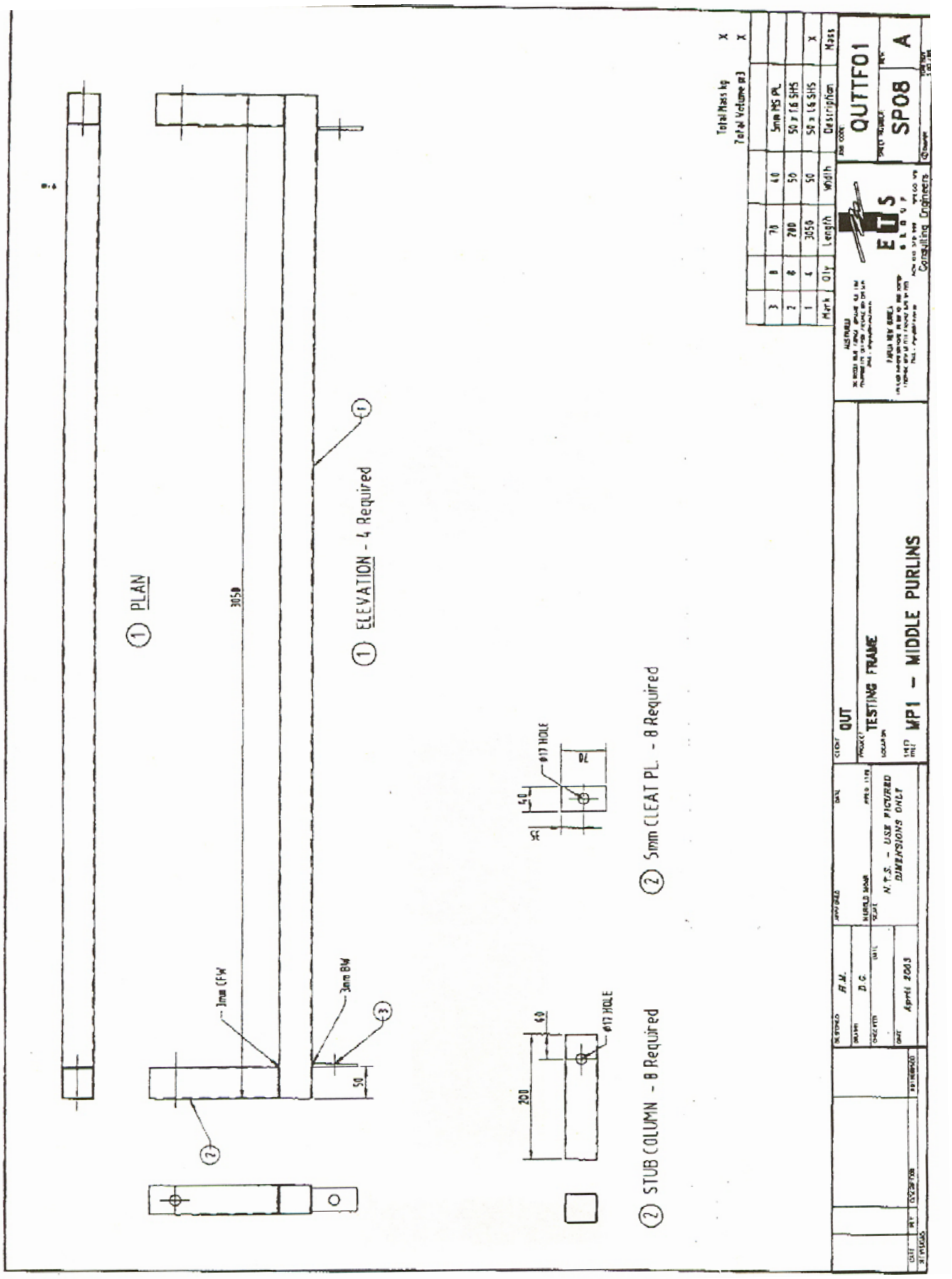
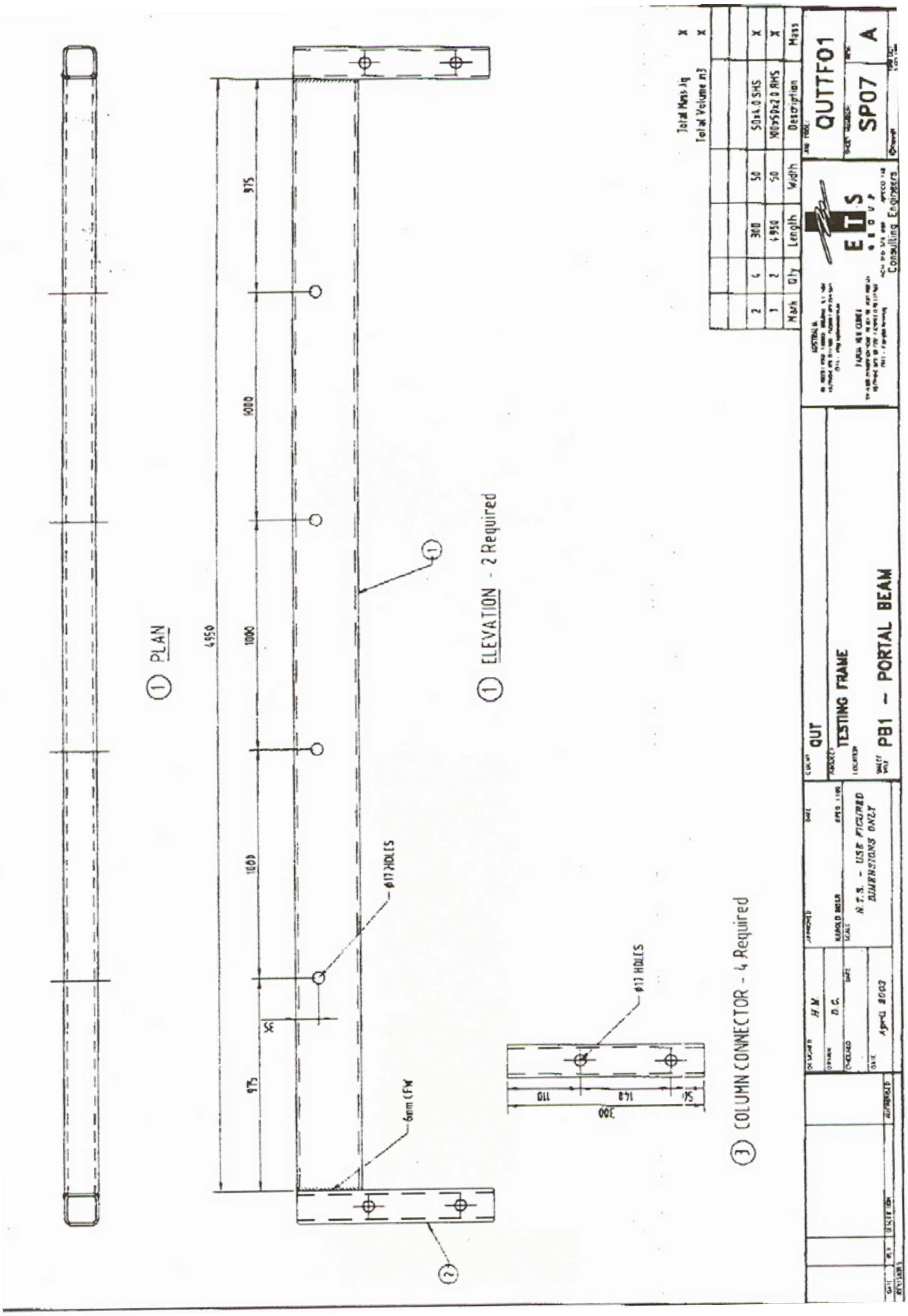


① PLAN
① ELEVATION - 1 Required
3050
3mm CFW
3mm BW GRIND FLUSH
725
184
5
② STUB COLUMN - 2 Required
200
40
ϕ17 HOLE
③ STUB COLUMN - 2 Required
150
110
④ ϕ10mm CHAIN HOOK - 4 Required
ϕ10mm G500 STEEL BAR BENT INTO APPROX. HOOK SHAPE
45°
Total Mass kg
Total Volume m3
Mark | Qty | Length | Width | Description | Mass
4 | 4 | 250 | 10 | ϕ10mm BAR | x
3 | 2 | 150 | 40 | 40 x 4.0 SHS | x
2 | 2 | 200 | 50 | 50 x 1.6 SHS | x
1 | 1 | 3050 | 50 | 50 x 4.0 SHS | x
EUS GROUP Consulting Engineers
QUTTF01
SP10
A
QUT
TESTING FRAME
EP2 - END PURLIN
N.T.S. - USE FIGURED DIMENSIONS ONLY
H.N.
D.G.
April 2003

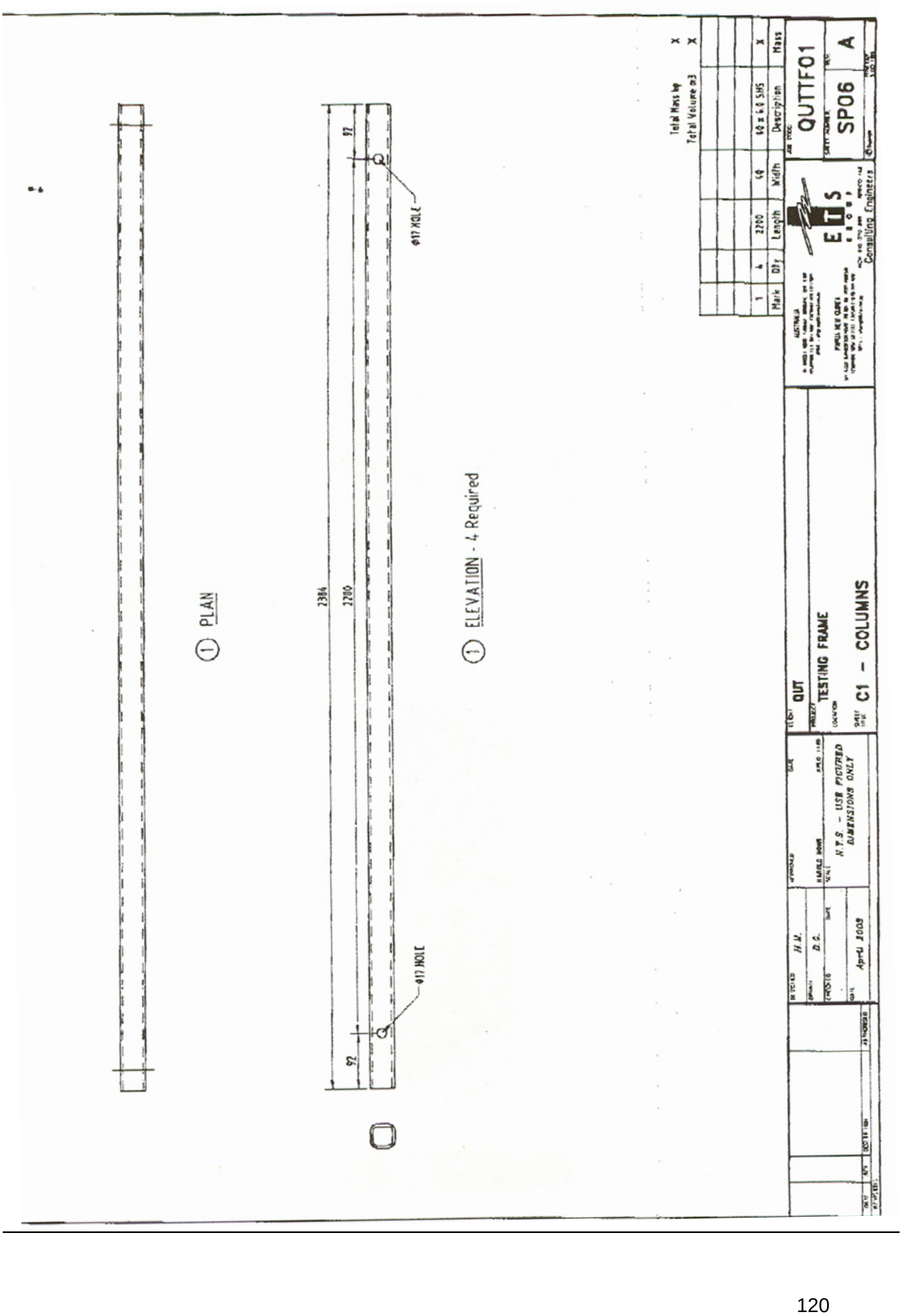

① PLAN
① ELEVATION - 1 Required
② STUB COLUMN - 2 Required
③ STUB COLUMN - 2 Required
④ 10mm CLEAT PL. - 2 Required
⑤ 10mm CLEAT PL - 2 Required
⑥ M20 MACHINED BOLT - 2 Required
3050
QUT
TESTING FRAME
EP1 - END PURLIN -1
N.T.S. - USE FIGURED DIMENSIONS ONLY
QUTTF01
SP09
A

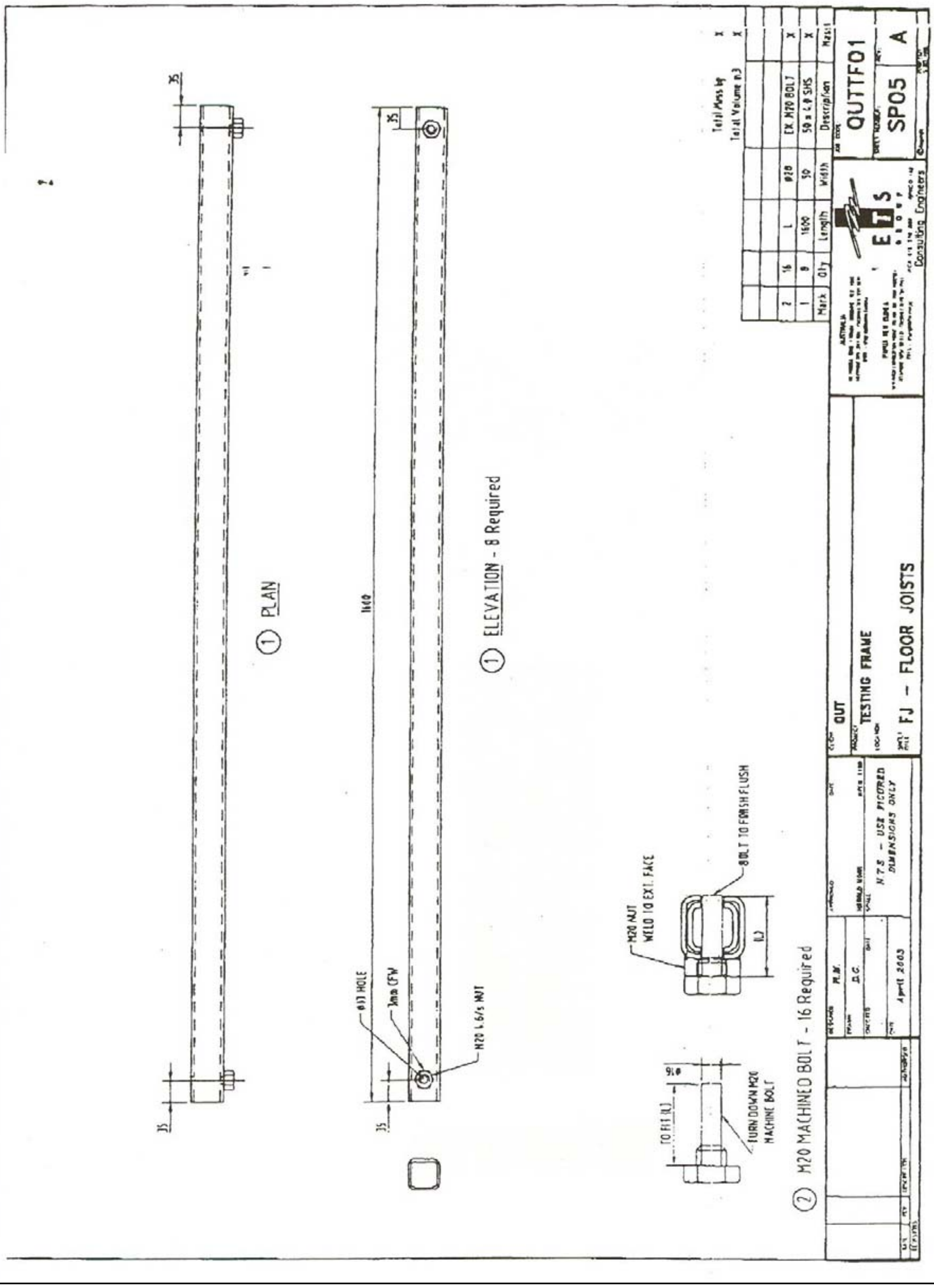


1 PLAN
1 ELEVATION - 4 Required
3050
3mm CFW
3mm BW
Ø17 HOLE
2 STUB COLUMN - 8 Required
2 5mm CLEAT PL. - 8 Required
Total Mass kg
Total Volume m3
Mark
Qty
Length
Width
Description
Mass
3 8 75 40 5mm MS PL
2 8 200 50 50 x 1.6 SHS
1 4 3050 50 50 x 1.6 SHS
Consulting Engineers
QUTTF01
SP08
A
QUT
TESTING FRAME
MP1 - MIDDLE PURLINS
N.T.S. - USE FIGURED DIMENSIONS ONLY
April 2003

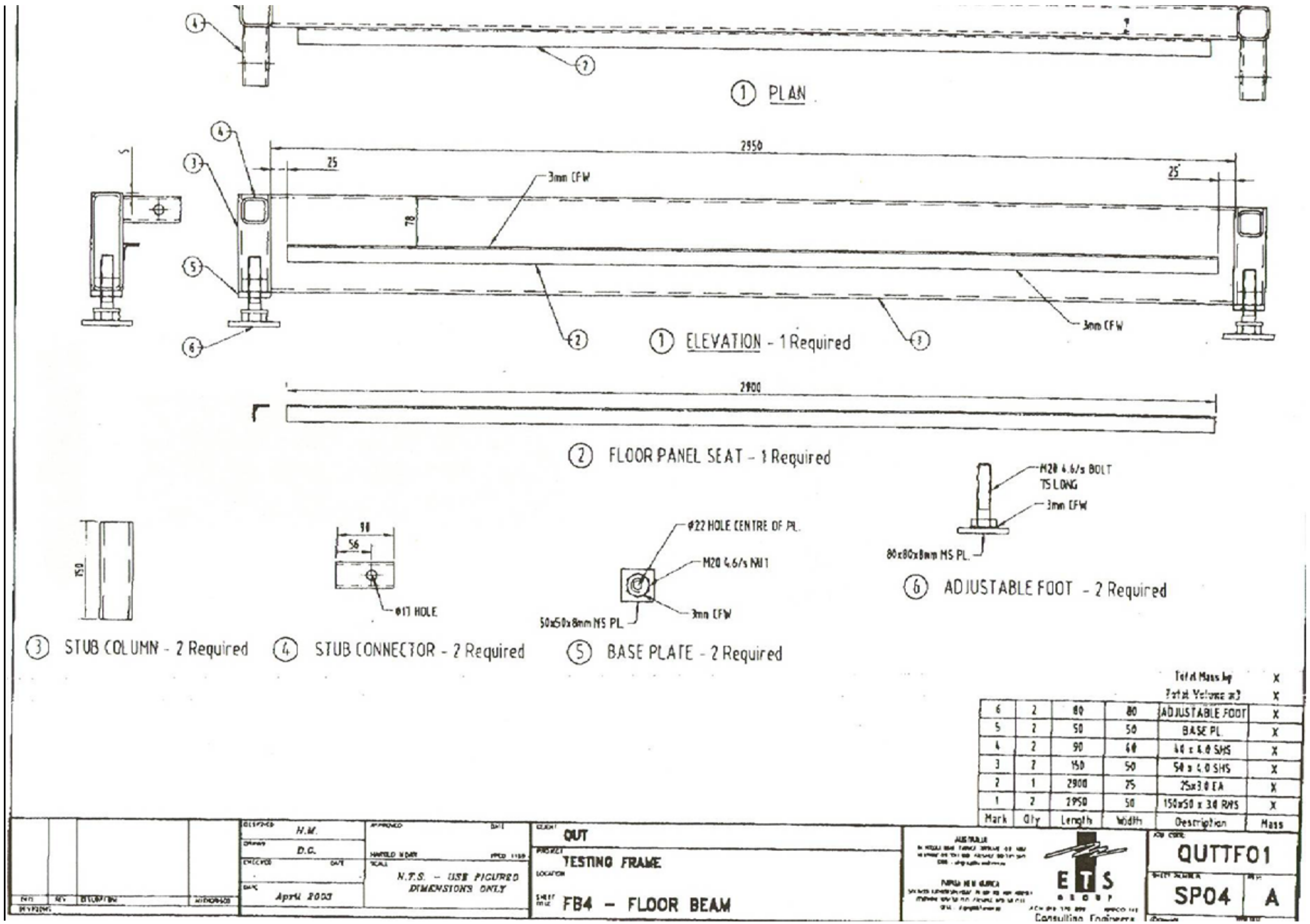


PLAN
ELEVATION - 2 Required
COLUMN CONNECTOR - 4 Required
ø17 HOLES
6mm CFW
4950
1000
975
Total Mass kg
Total Volume m3
Mark
Qty
Length
Width
Description
Mass
50x4.0 SHS
100x50x2.0 RHS
QUT
TESTING FRAME
PB1 - PORTAL BEAM
N.T.S. - USE FIGURED DIMENSIONS ONLY
QUTTF01
SP07
A
Consulting Engineers

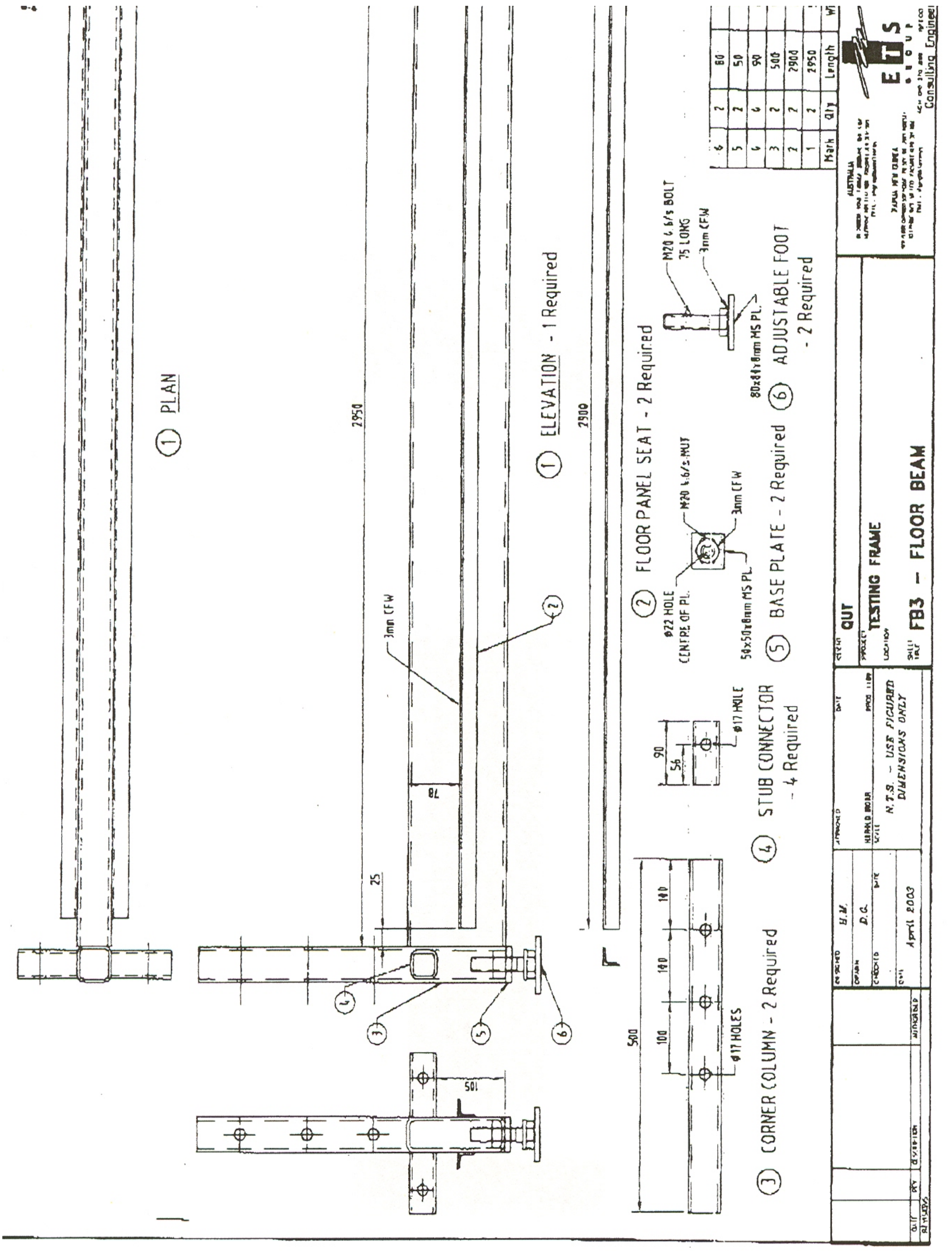

① PLAN
① ELEVATION - 4 Required
2384
2700
92
Ø17 HOLE
Total Mass kg
Total Volume m3
Mark
Qty
Length
Width
Description
Mass
QUTTF01
SP06
A
QUT
TESTING FRAME
C1 - COLUMNS
N.T.S. - USE PICTURED DIMENSIONS ONLY
April 2003
Consulting Engineers



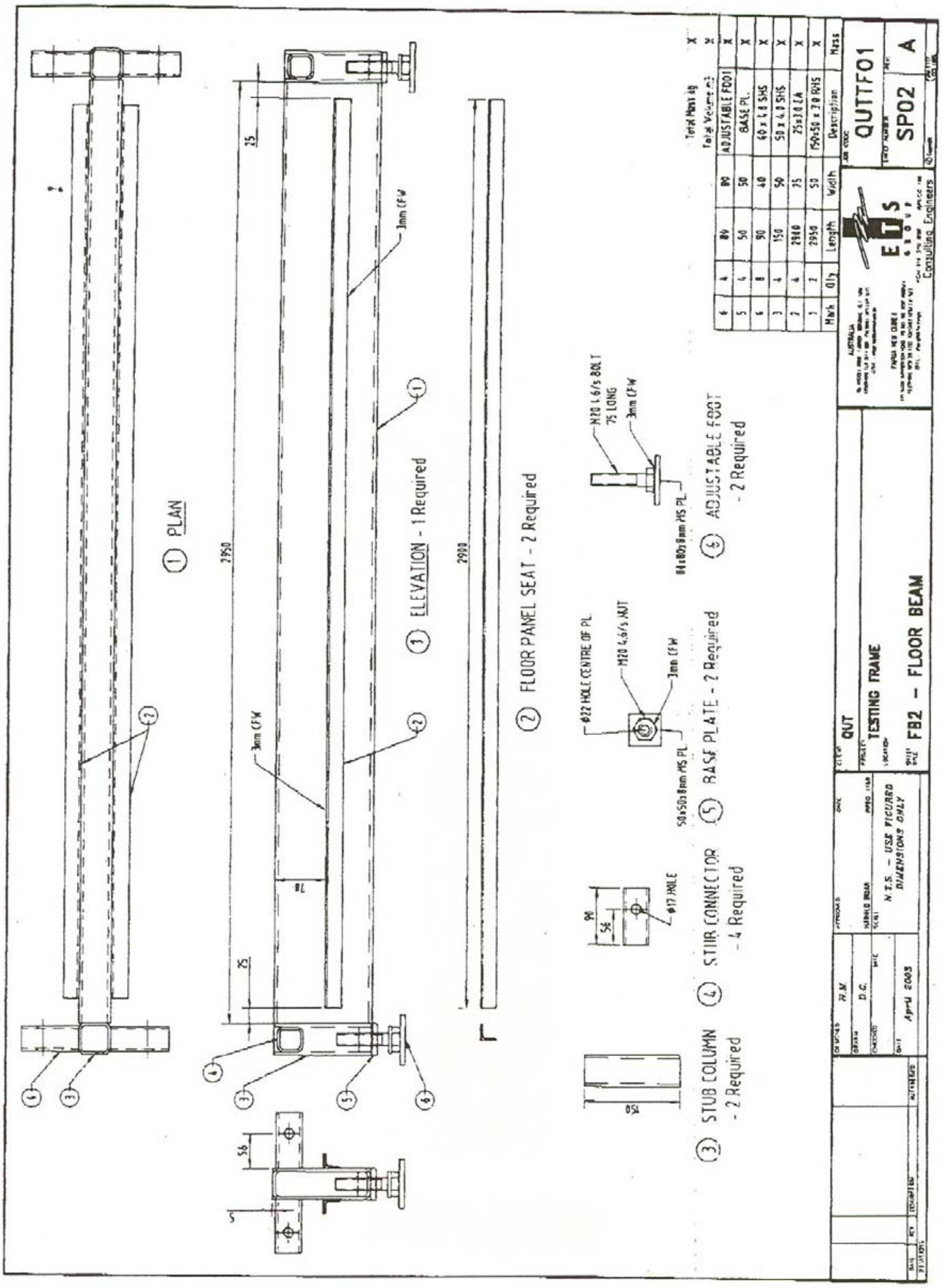
PLAN
ELEVATION - 8 Required
M20 MACHINED BOLT - 16 Required
TURN DOWN M20 MACHINE BOLT
M20 NUT WELD TO EXT. FACE
BOLT TO FINISH FLUSH
M20 L.6/s NUT
QUT
TESTING FRAME
FJ - FLOOR JOISTS
QUTTF01
SP05
A
Consulting Engineers



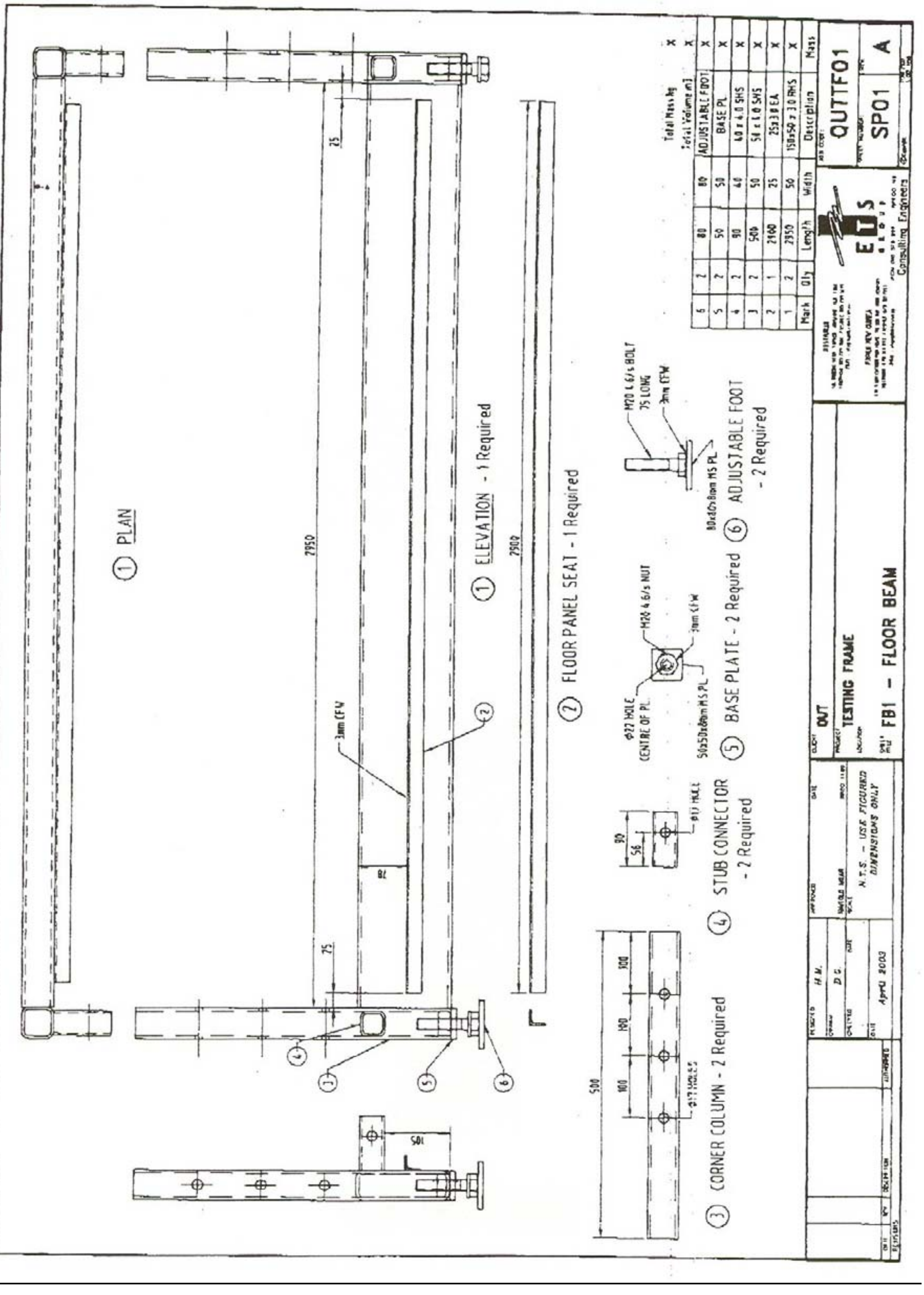
1 PLAN
1 ELEVATION - 1 Required
2950
25
25
78
3mm CFW
3mm CFW
2900
2 FLOOR PANEL SEAT - 1 Required
M20 4.6/s BOLT 75 LONG
3mm CFW
80x80x8mm MS PL.
6 ADJUSTABLE FOOT - 2 Required
Ø22 HOLE CENTRE OF PL.
M20 4.6/s NUT
3mm CFW
50x50x8mm MS PL.
5 BASE PLATE - 2 Required
90
56
Ø17 HOLE
4 STUB CONNECTOR - 2 Required
150
3 STUB COLUMN - 2 Required
Total Mass kg X
Total Volume m3 X
Mark | Qty | Length | Width | Description | Mass
6 | 2 | 80 | 80 | ADJUSTABLE FOOT | X
5 | 2 | 50 | 50 | BASE PL | X
4 | 2 | 90 | 60 | 60 x 4.0 SHS | X
3 | 2 | 150 | 50 | 50 x 4.0 SHS | X
2 | 1 | 2900 | 75 | 25x3.0 EA | X
1 | 2 | 2950 | 50 | 150x50 x 3.0 RHS | X
H.M.
D.G.
April 2003
N.T.S. - USE PICTURED DIMENSIONS ONLY
QUT
TESTING FRAME
FB4 - FLOOR BEAM
ETS
Consulting Engineers
QUTTF01
SP04
A



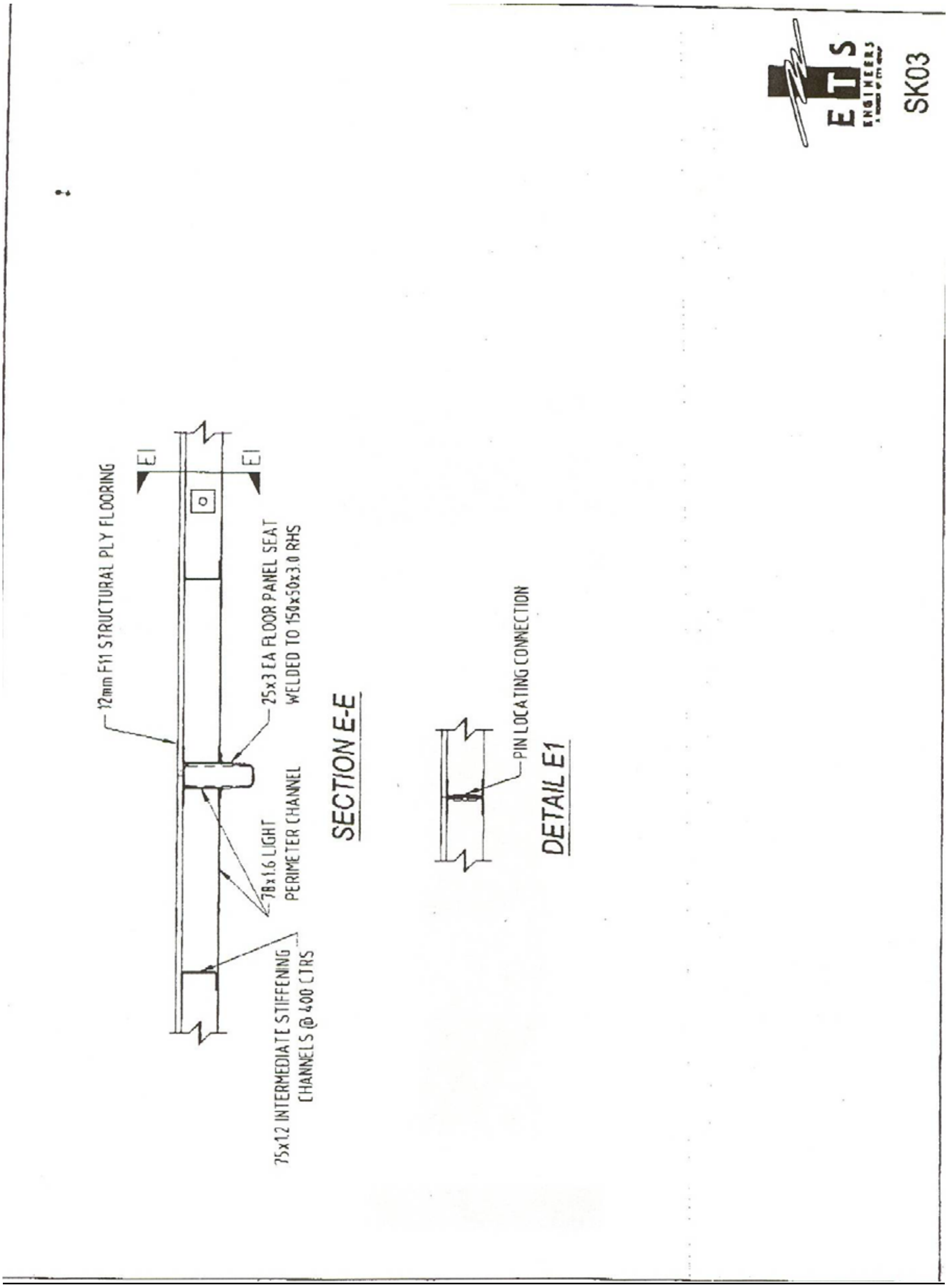
1 PLAN
1 ELEVATION - 1 Required
2950
2900
25
78
3mm CFW
2 FLOOR PANEL SEAT - 2 Required
Ø22 HOLE CENTRE OF PL.
M20 4.6/s NUT
3mm CFW
5 BASE PLATE - 2 Required
50x50x8mm MS PL.
6 ADJUSTABLE FOOT - 2 Required
M20 4.6/s BOLT 75 LONG
3mm CFW
80x80x8mm MS PL.
4 STUB CONNECTOR - 4 Required
90
56
Ø17 HOLE
3 CORNER COLUMN - 2 Required
500
100
140
140
Ø17 HOLES
105
Mark | Qty | Length
6 | 2 | 80
5 | 2 | 50
4 | 4 | 90
3 | 2 | 500
2 | 2 | 2900
1 | 2 | 2950
ETS GROUP
Consulting Engineers
N.T.S. - USE FIGURED DIMENSIONS ONLY
April 2003
QUT
TESTING FRAME
FB3 - FLOOR BEAM

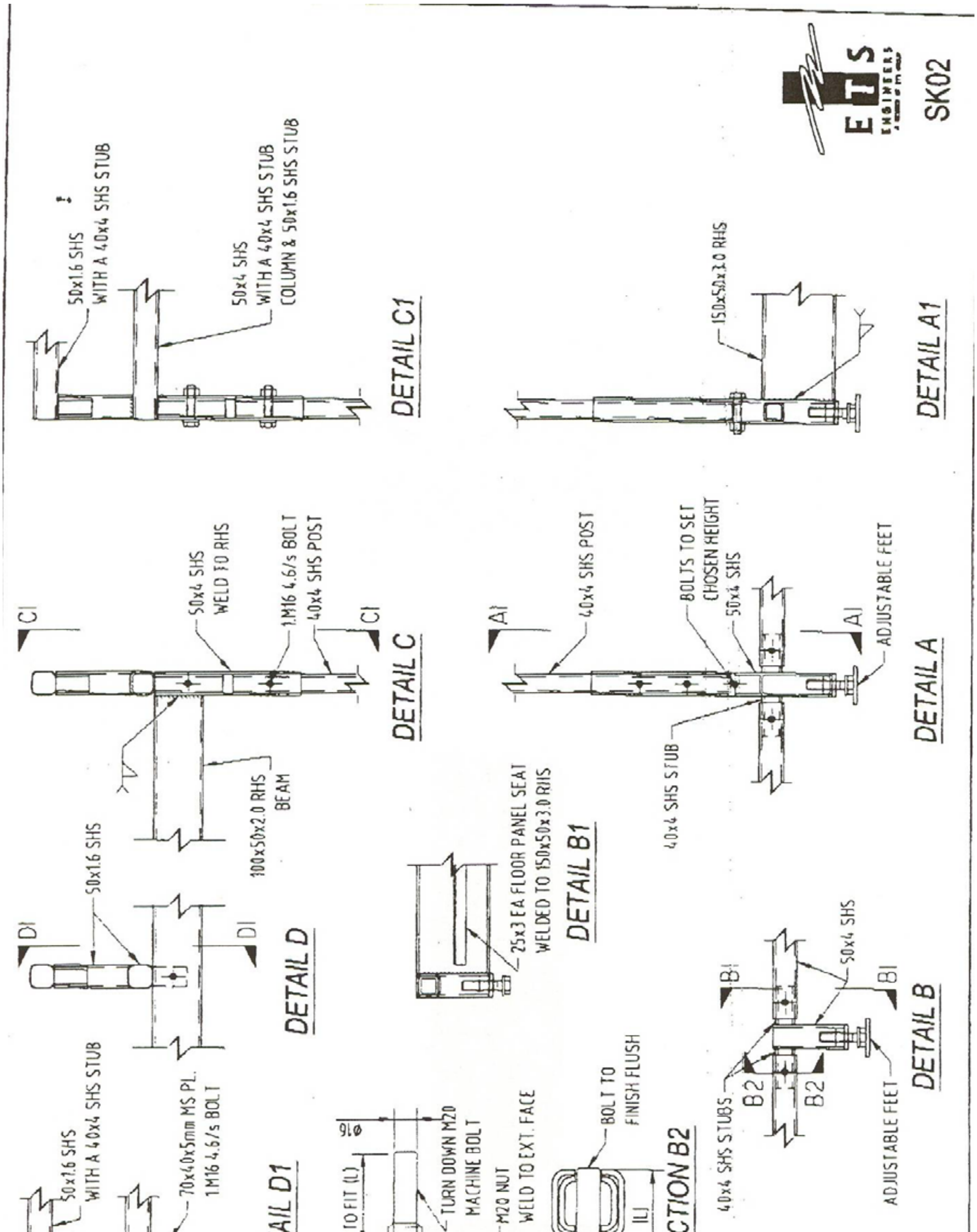


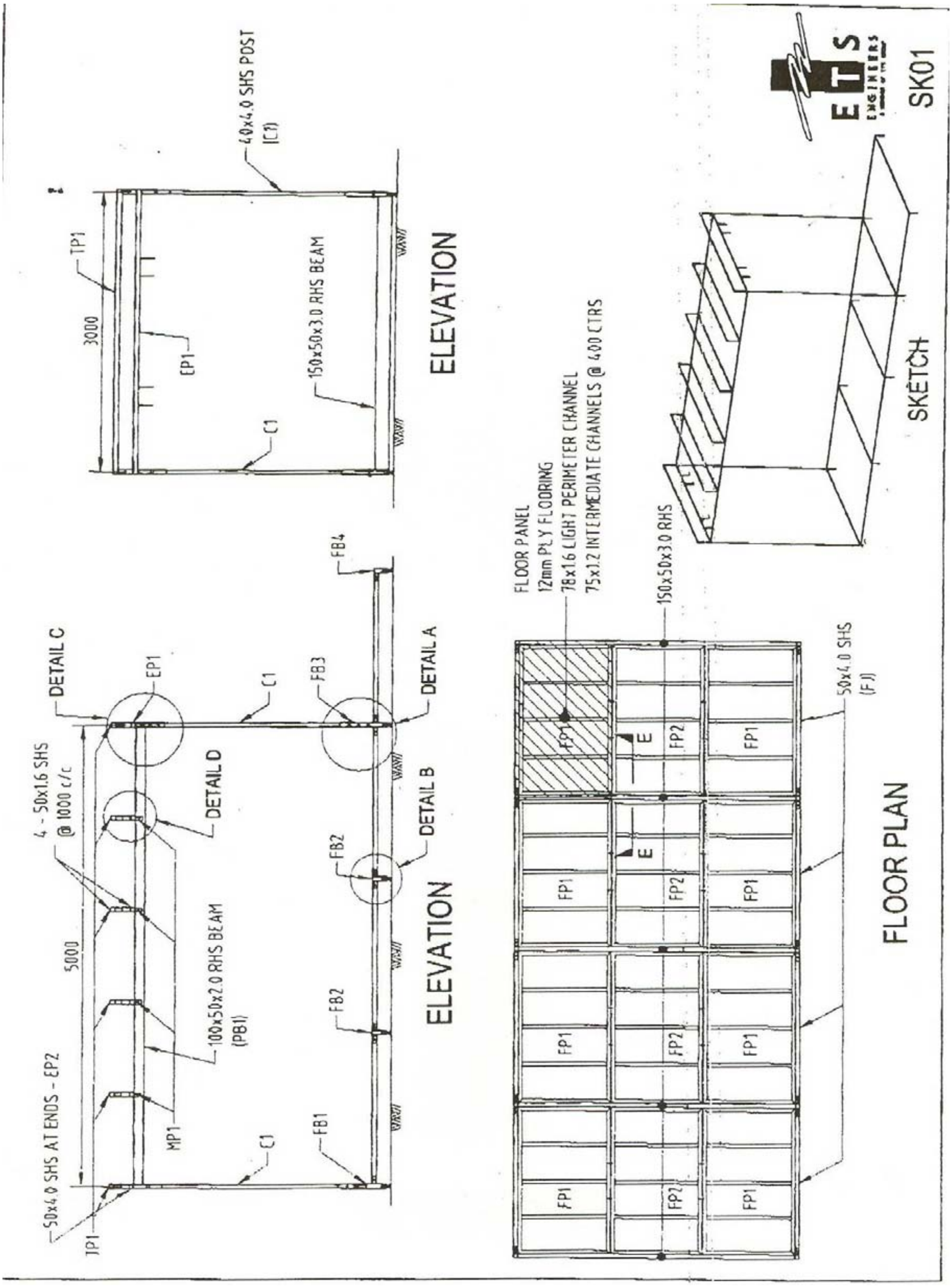
1 PLAN
1 ELEVATION - 1 Required
2 FLOOR PANEL SEAT - 2 Required
3 STUB COLUMN - 2 Required
4 STUB CONNECTOR - 4 Required
5 BASE PLATE - 2 Required
6 ADJUSTABLE FOOT - 2 Required
2950
2900
3mm CFW
M20 4.6/s BOLT
75 LONG
M20 4.6/s NUT
Ø22 HOLE CENTRE OF PL
Ø17 HOLE
ADJUSTABLE FOOT
BASE PL.
60 x 4.0 SHS
50 x 4.0 SHS
Mark
Qty
Length
Width
Description
Mass
N.T.S. - USE FIGURED DIMENSIONS ONLY
April 2005
QUT
TESTING FRAME
FB2 - FLOOR BEAM
QUTTF01
SP02
A
Consulting Engineers



1 PLAN
1 ELEVATION - 1 Required
2 FLOOR PANEL SEAT - 1 Required
3 CORNER COLUMN - 2 Required
4 STUB CONNECTOR - 2 Required
5 BASE PLATE - 2 Required
6 ADJUSTABLE FOOT - 2 Required
2950
2900
25
3mm CFW
M20 4.6/s NUT
M20 4.6/s BOLT
75 LONG
80x80x8mm MS PL
50x50x8mm MS PL
Total Mass kg
Total Volume m3
ADJUSTABLE FOOT
BASE PL
40 x 4.0 SHS
50 x 4.0 SHS
25x3 EA
150x50 x 3.0 RHS
Mark
Qty
Length
Width
Description
Mass
Consulting Engineers
QUTTF01
SP01
A
QUT
TESTING FRAME
FB1 - FLOOR BEAM
N.T.S. - USE FIGURED DIMENSIONS ONLY
April 2003


12mm F11 STRUCTURAL PLY FLOORING
25x3 EA FLOOR PANEL SEAT
WELDED TO 150x50x3.0 RHS
78x1.6 LIGHT
PERIMETER CHANNEL
75x1.2 INTERMEDIATE STIFFENING
CHANNELS @ 400 CTRS
E1
E1
SECTION E-E
PIN LOCATING CONNECTION
DETAIL E1
ENGINEERS
SK03


DETAIL D1
50x1.6 SHS WITH A 40x4 SHS STUB
70x40x5mm MS PL. 1M16 4.6/s BOLT
DETAIL D
50x1.6 SHS
D1
DETAIL C
100x50x2.0 RHS BEAM
50x4 SHS WELD TO RHS
1M16 4.6/s BOLT
40x4 SHS POST
C1
DETAIL C1
50x1.6 SHS WITH A 40x4 SHS STUB
50x4 SHS WITH A 40x4 SHS STUB COLUMN & 50x1.6 SHS STUB
TO FIT (L)
Ø16
TURN DOWN M20 MACHINE BOLT
DETAIL B1
25x3 EA FLOOR PANEL SEAT WELDED TO 150x50x3.0 RHS
M20 NUT WELD TO EXT. FACE
BOLT TO FINISH FLUSH
SECTION B2
(L)
DETAIL A
40x4 SHS POST
BOLTS TO SET CHOSEN HEIGHT
50x4 SHS
A1
40x4 SHS STUB
ADJUSTABLE FEET
DETAIL A1
150x50x3.0 RHS
DETAIL B
40x4 SHS STUBS
50x4 SHS
B1
B2
ADJUSTABLE FEET
SK02


40x4.0 SHS POST (C1)
TP1
3000
CP1
150x50x3.0 RHS BEAM
C1
ELEVATION
DETAIL C
EP1
4 - 50x1.6 SHS @ 1000 c/c
DETAIL D
C1
FB3
DETAIL A
DETAIL B
FB2
FB4
5000
100x50x2.0 RHS BEAM (PB1)
MP1
50x4.0 SHS AT ENDS - EP2
JP1
FB1
ELEVATION
FLOOR PANEL
12mm PLY FLOORING
78x16 LIGHT PERIMETER CHANNEL
75x12 INTERMEDIATE CHANNELS @ 400 CTRS
150x50x3.0 RHS
50x4.0 SHS (FJ)
FP1
FP2
E
FLOOR PLAN
SKETCH
ETS ENGINEERS
SK01