ROWAN & ASSOCIATES PTY LTD

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Design Basis Report Considerations

Deployable refuge chambers for use in underground coal mines

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SCOPE OF WORK

Following initial discussions between Dr Jeffrey Kohler (CDC/NIOSH/OD) and Greg Rowan, it was agreed to compile some information briefs in relation to deployable refuge chambers. This information to consist of -

- a brief overview of issues to be considered in the development of a Design Basis Report for Deployable, Self-Contained Refuge Chambers for Use in Underground Coal Mines
- a brief overview of the current status of refuge chamber design in Australian mines
- links and references to materials that may be of value to NIOSH in their deliberations of refuge chamber design

The following DRAFT report is in recognition of these discussions.

REFUGE CHAMBERS

Integration: It is critical to the success of an *Integrated Emergency Preparedness and Response Plan* that the use and deployment of refuge chambers be considered only as an element in the overall infrastructure supporting such a plan. Over-reliance on the use of refuge chambers will surely detract from the fundamentals of a three-tiered emergency response strategy involving –

- In-seam first response
- Self-escape and
- Aided rescue

Location: The location of permanent refuge chambers, the distances between these and deployable / relocatable units together with the distances between emergency breathing apparatus (EBA) caches is vital. Brake[1] et al (1999) defined these criteria as -

> *The minimum number and placement of Emergency Refuge Stations(ERS) is based on the higher of two criteria:*
>
> - *the number to meet the requirement that no mine worker be more than 750 m from an ERS at any time, or*
> - *the numbers of mine workers that could reasonably be expected to be in an area at any time divided by the nominal capacity rating (in persons) of the ERSs*

Choice of Suitable Breathable Air Supply

The selection of an appropriate breathable air supply is paramount, however, there are a number of shortcomings in some of the more popular choices. Again Brake et al (1999) specifically recommend against the use of compressed breathing air from cylinders using individual face masks or from cachéd self contained self-rescuers for use in metalliferous mines for a number of compelling reasons, including

- *"Therapy" masks are unsuitable for refuge; proper breathable air delivery masks are required*
- *If "spare" masks or SCSRs are put in each ERS, then this negates the concept of a nominal capacity*
- *The logistics, practicality, cost and maintenance checks required to store the large number of masks/SCSRs which would be needed for the fixed ERSs*
- *The distress caused to mine workers when required to sit for many hours with a face mask/SCSR on*
- *The problems of positive pressure (supply) masks: if one of these is turned on with no one wearing it,the supply of air to the remaining masks will be rapidly expended*
- *The problems of negative pressure (demand) masks with sealing around facial hair*
- *Mask/SCSRs assume the refuge station has become or could become contaminated with fumes (i.e. is not gas tight). To be consistent, this means goggles must also be worn.*

[1] D J Brake and G P Bates.Criteria for the design of emergency refuge stations for an underground metal mine. Journal of the AusIMM, December 1999. Copyright AusIMM.

- *Masks/SCSRs make it difficult or impossible to drink water, an essential requirement for long, healthy entrapment in summer*
- *Masks/SCSRs make it difficult or impossible to communicate with other workers,*
- *Masks/SCSRs make any first aid treatment of injured workers difficult, and make administering expired air resuscitation impossible if a worker were to collapse*

This then limits the choices to -

- *Compressed mine air*
- *Compressed bottled medical air (with no masks)*
- *Oxygen supply (oxygen candles and the like) and carbon dioxide scrubbing devices*
- *Use of "dead air" space, i.e. relying on the initial uncontaminated atmosphere within the refuge station*

NB: It is unlikely that poly-pipe compressed air lines will be deemed suitable for this purpose.

Carbon Dioxide: The current refuge chambers must be fitted with some mechanism to remove CO2 from the air. Four people in a 3m x 3.5m x 2.5m refuge chamber will generate CO2 concentrations which will exceed 0.5% (the NOHSC recommended Time Weighted Average for CO2) in less than 1.5 hours.

Heat Removal: People consuming 0.5ltres of oxygen per minute generate between 150W and 200W of heat each. Eight people in a refuge chamber therefore, would generate about the same heat as a 1.4 kilowatt strip heater. This will increase the temperature in the chamber to dangerous, even fatal levels, within hours. Compounding this issue is the rapid increase in humidity within the chamber due to the moisture content of the exhaled breath and the sweating of the occupants. There are other sources of heat to be considered – emergency lighting, CO2 scrubbers, electrical devices, power inverters, communication systems etc

Options for cooling systems include –

- *Refrigeration units powered by ac inverters*
- *Votex tubes*
- *Chilled water lines*
- *Cold vests, and*
- *Stored ice*

This list is not to be considered comprehensive and each system listed has its own strengths and weaknesses

Over-pressure: If air is being introduced into a sealed chamber, provision must be made for pressure reduction devices to ensure that the persons in the chamber do not suffer from over pressure related injuries. Pressure increases as little as 0.5 bar can cause eye, ear and lung injury.

Carbon Monoxide: Research has shown that CO will build up in occupied refuge chambers. This is likely a result of the release of CO from the carboxyhemoglobin in the blood stream of persons working in the mine atmosphere (from diesel vehicles, explosives etc) and from smokers.

Hydration: In an unrefrigerated refuge chamber, people can sweat from 0.5 to 2.0 litres per hour dependant on temperature and work rates. The human metabolism however, can usually only absorb about 1.5 litres per hour through the stomach and intestinal tracts. Progressive dehydration can therefore occur even with unlimited supplies of water.

Communications: It is vital that persons trapped in a refuge chamber be provided with open and robust communication channels. All chambers should be equipped with radios and telephones with hardwired power supplies, UPS systems and back-up generators

Power and Lighting: Lighting is also critical to the sense of well-being of persons in an enclosed space. Adequate lighting with hardwired and back-up power supplies (also to run the scrubber units, communications and air-conditioning units) are critical

Odours and toxins: From painted surface, greases and oil soaked clothes, explosives use and the human body can cause severe distress to persons in a closed environment and provisions should be made for their elimination of removal

Transport: If the refuge chambers are to be relocatable, due consideration must be given to their transportability and construction - bent doors will not seal

Maintenance: The ongoing maintenance of refuge chambers is a considerable cost burden. Consideration should be given to having regular Planned Inspections &Testing and then “sealing” the chamber to prevent damage / loss. A daily inspection regime could then be introduced requiring only the examination of the seal.

Psychological Issues: Numerous articles are available on the psychological impacts of entrapment with increases in stress and anxieties and their impacts on cognitive behaviours and decision making. These factors must not be underestimated when contemplating using refuge chambers as the first, rather than the last, line of defence for an emergency response.

Any real emergency which results in “entrapment” of underground workers will create panic and high

> *levels of anxiety. For a trapped underground worker, especially if alone, there may be little difference between "entrapment" and "entombment"*[2]

The Western Australian Department of Industry and Resources has released a guideline for the Refuge Chambers in Underground Metalliferous Mines. It is attached to these brief notes as Appendix I.

[2] D J Brake and G P Bates.Criteria for the design of emergency refuge stations for an underground metal mine. Journal of the AusIMM, December 1999. Copyright AusIMM.

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APPENDIX I