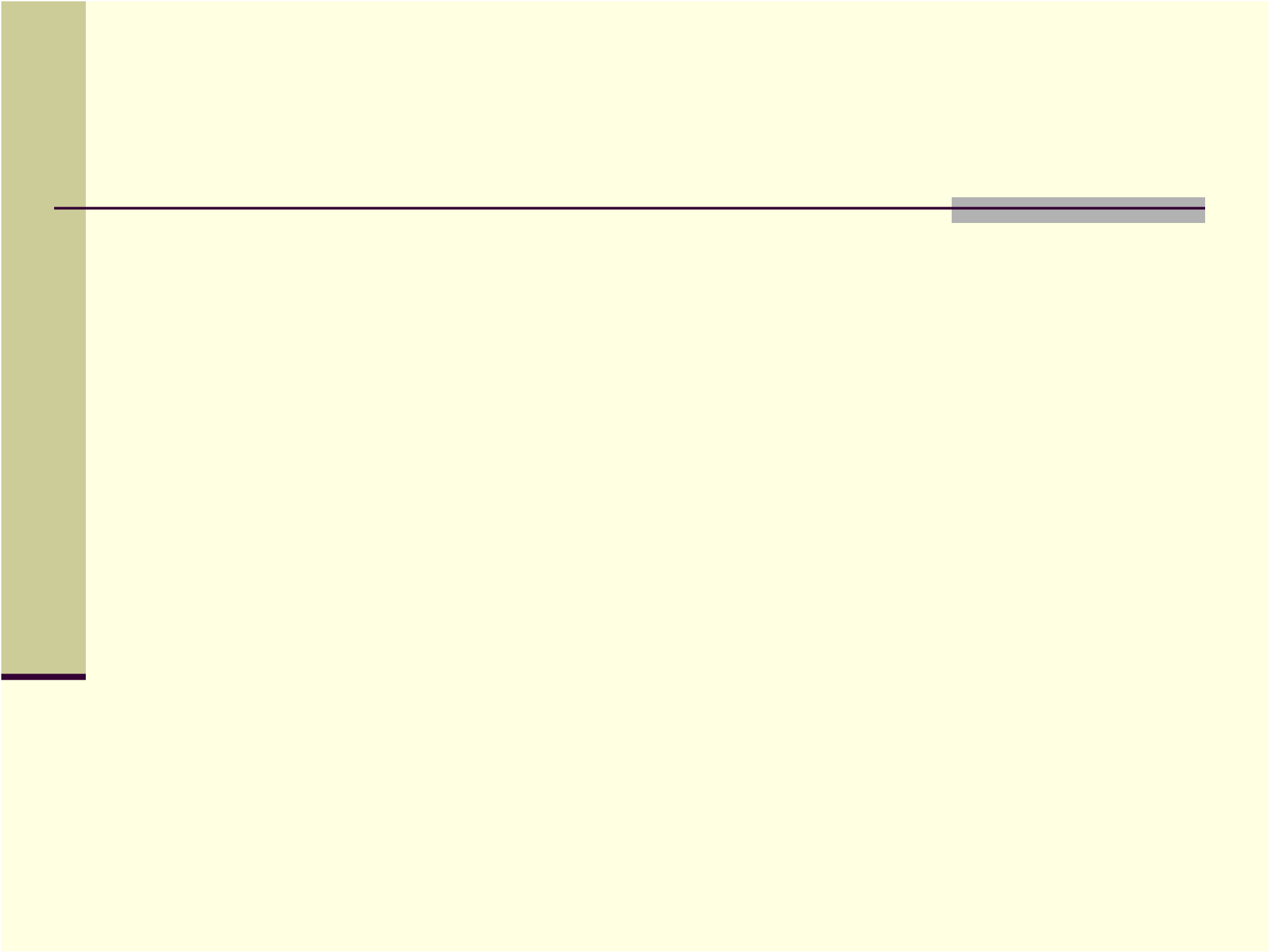


Coal Mine Refuge Chambers *Design Concept & Provisions*

Mine Escape Planning and Emergency Shelters Workshop
National Academy of Sciences
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Refuge Chamber Overview

- Critical Element of Emergency Response Plan
- Should be located within 1,500 feet of work areas in the mine or otherwise based on model studies to determine the appropriate locations.
 - Distance based on low/zero visibility, 50% supply of a 60-minute SCSR, entry height, and the respiratory rate of a miner walking under duress
 - Further reduction for entry heights less than 5 feet
- Provide a minimum of 72 hours of safe refuge to hazards caused by mine fires, inundation of water and noxious gases, and entrapment
- Types
 - Permanent
 - Temporary
 - Portable

Refuge Chamber

Travel Time and Distance Considerations

- Disorientation/indecision
- Visibility
- Miner weight & condition
- Anxiety level
- Entry height
- Debris in entries

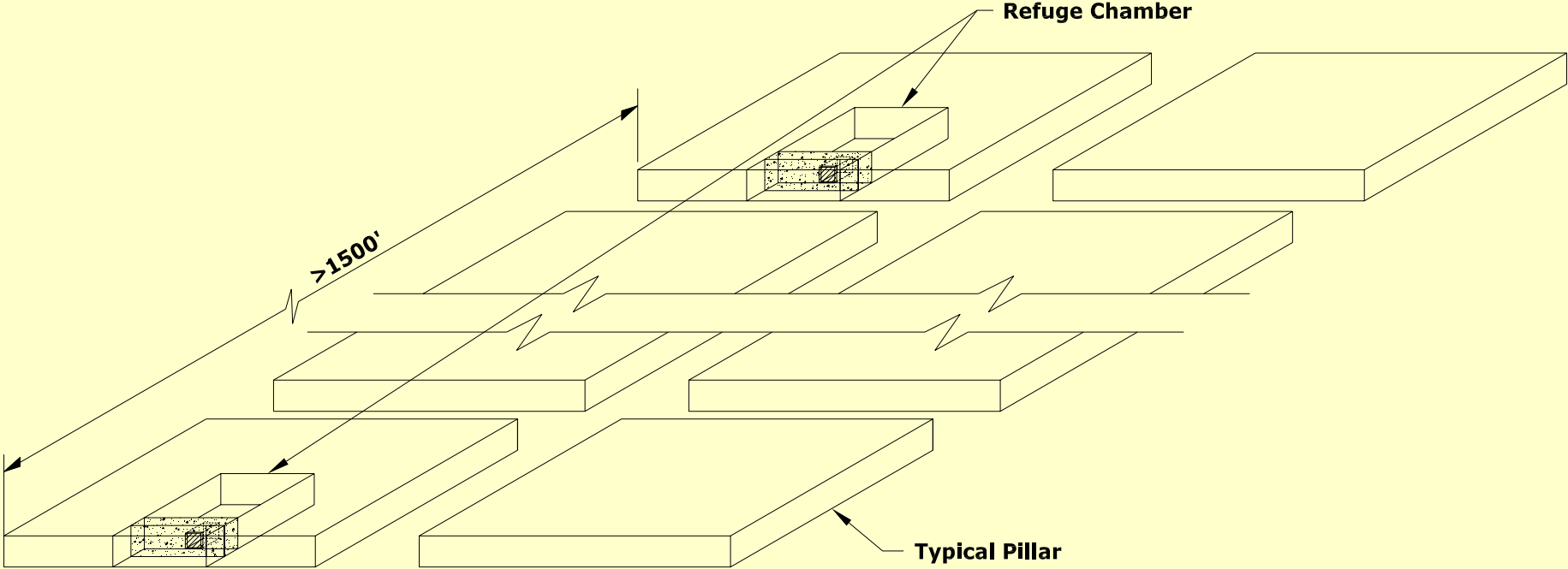
Conditions	% of Unit Rating	30-Min Unit	60-Min Unit	90-Min Unit
Normal - person under 80kg -heart rate below 120/min	100%	30 min	60 min	90 min
Normal - person over 100kg - heart rate below 120/min	80%	24 min	48 min	72 min
95% percentile - unknown weight & heart rate	60%	18 min	36 min	54 min
95% - Poor visibility - unknown weight & heart rate	36%	11 min	22 min	33 min

Actual Duration of SCSR's, 1997 ACARP Project- Number C5039

Chamber Types

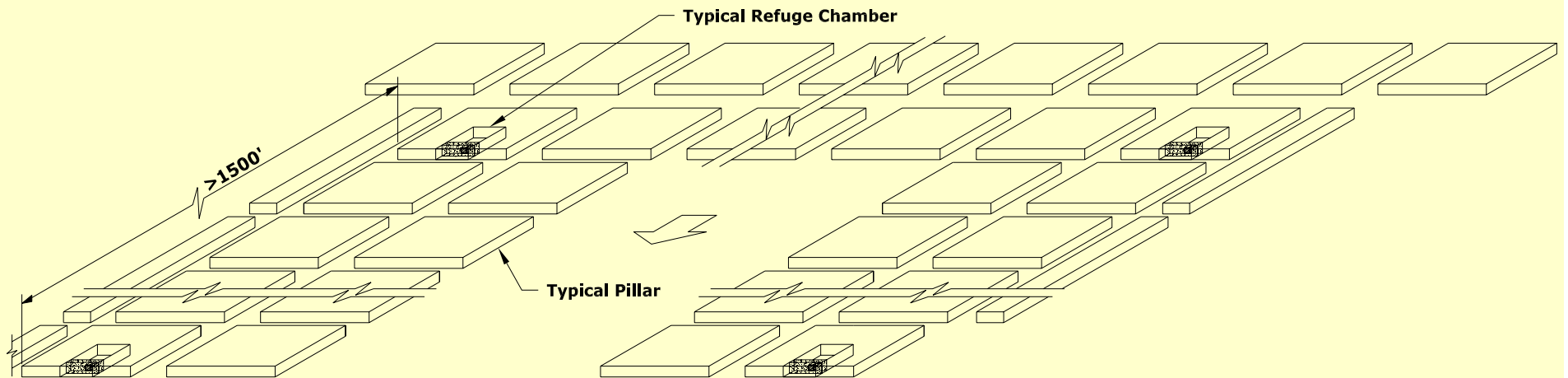
- Permanent Chambers would be installed in main travel and escapeways. Permanent borehole would be provided for continuous air supply and communications.
- Temporary Chambers would be installed in active areas. Oxygen tanks would be provided for a temporary air supply. When the areas are no longer active, the water/air-tight doors could be removed and re-used for construction of other temporary chambers.
- Portable Chambers would be located in active areas and would be moved to new areas as the mining progresses. Chambers are not considered explosion or inundation resistant and rely on oxygen tanks rather than a borehole for air supply.

Permanent Refuge Chamber for Room & Pillar Operation



**Room and Pillar Mine Refuge Chamber
General Arrangement
(Isometric View)**

Temporary Refuge Chamber for Longwall Operation



Longwall Mine Refuge Chamber
General Arrangement
(Isometric View)

Refuge Chamber Provisions

- Life Support System in the Chamber:
 - Air supply:
 - Medical-grade oxygen in bottles
 - 72-hour minimum duration for full complement of personnel
 - Consumption rate is 0.5 liters per minute per person
 - Fresh oil-free air source from surface through a cased borehole
 - Scrubbers for carbon monoxide and carbon dioxide
 - Humidity control
 - Temperature control
 - Water & Food

Refuge Chamber Provisions (continued)

- Cased borehole:
 - Surface to refuge chamber
 - Fresh air supply
 - Maintain positive pressure in refuge chamber
 - Communication/electric lines
- First aid supplies
- Lights
- Power supply
- Sanitation facility
- Seating & table
- Stretcher

Coal Refuge Chamber Requirements

30 CFR 75.1500

- Secretary may prescribe
- Properly sealed and ventilated
- Suitable locations in the mine for people to go for protection against hazards

Coal Refuge Chamber Requirements

30 CFR 75.1500 (continued)

Provisions:

- First aid materials
- Adequate supply of air and self-contained breathing equipment
- Independent communication to surface
- Proper accommodations for persons awaiting rescue
- Such other equipment Secretary may require
- Plan for erection, maintenance, and revisions to chamber
- Training of miners in their proper use

M/NM Refuge Chamber Requirements

30 CFR 57.11052

- Fire-resistant construction
- Accommodate normal number of persons in particular area of mine
- Gastight
- Provisions:
 - Compressed air line
 - Waterline
 - Suitable hand tools
 - Stopping materials

Compressed Air Line Issues

- Mine fire may vaporize rubber seals of victaulic couplings of air line
- Explosion may rupture air line
- Two incidences occurred in Ontario and Manitoba, Canada
 - Fire drew air from refuge chamber due to compromised air line seals
 - Ruptured air line transported smoke and noxious fumes into refuge chamber

Permanent Refuge Chamber

- Cut a stub entry (or dead end) into the coal and close the opening with a bulkhead, equipped with a water/air-tight door.
- Or close-off a cross-cut or entry by installing 2 bulkheads, equipped with water/air-tight doors
- This type of station should be strategically located and large enough to accommodate all miners in an area

Permanent Refuge Chamber

Design Requirements

- Resist an explosion with a minimum 80-psi overpressure and impact from projectiles such as cribs, roof fall material, etc...
- If an inundation hazard exists, the chamber should also be able to resist a minimum of 100 feet of water head
- Able to survive initial and secondary explosions
- Concrete design codes:
 - ACI 318 – for explosion
 - ACI 350 – for water inundation

Permanent Refuge Chamber

Design Requirements (continued)

- Foundation investigation
- Keyed into strata 2-feet minimum
- Anchored/dowelled into the surrounding strata
- Grout curtain around the perimeter of the bulkhead:
 - Consolidate/strengthen coal measure strata
 - Reduce permeability
- Mine roof should be extensively bolted both inby and outby the chamber

Permanent Refuge Chamber

Design Requirements (continued)

- Other supplement roof supports should be provided near the bulkhead
- Equipped with an air and watertight, fire-rated steel door – 3' diameter or 3' wide by 3' high
 - Minimum dimension for stretcher or mine rescue personnel in full apparatus
- Fire rated – (Shotcrete entrance for fire protection)
- Rock Anchors:
 - Anchor the foundation
 - Reinforce the coal measure strata

Permanent Refuge Chamber

Design Requirements (continued)

- Construction plans and specifications
- Material specifications
- The plans and specifications should be prepared and certified by a registered Professional Engineer and made available to MSHA for review and comment prior to construction
- Material tests during construction according to applicable ASTM standards
- Inspection by an independent contractor or MSHA personnel during construction for quality control

Permanent Refuge Chamber

RC Bulkhead Design

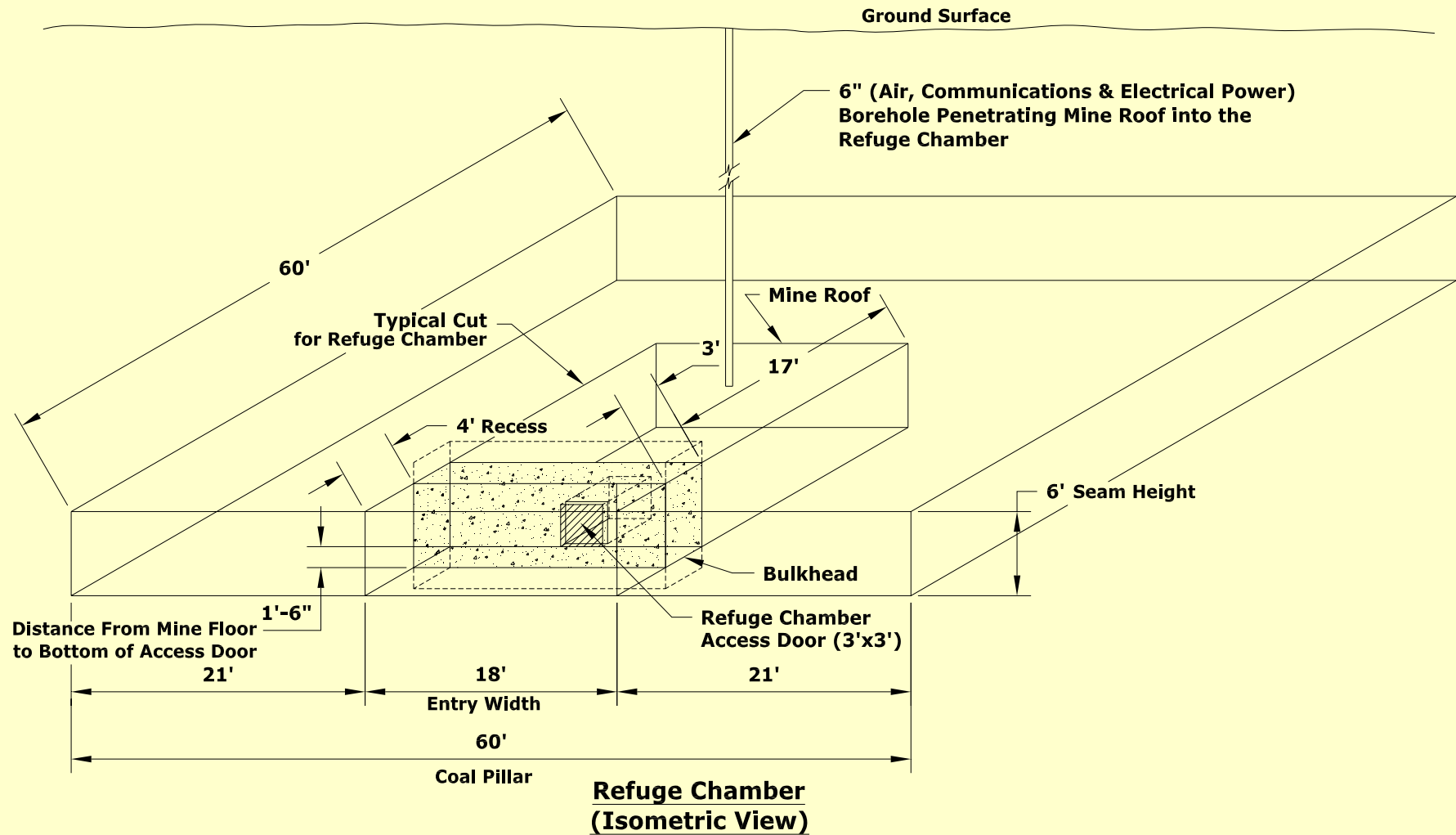
Concrete Design

- 20-ft wide x 7-ft high stub entry opening
- 3-ft thick wall for 80 psi static pressure and 100 foot hydrostatic water head

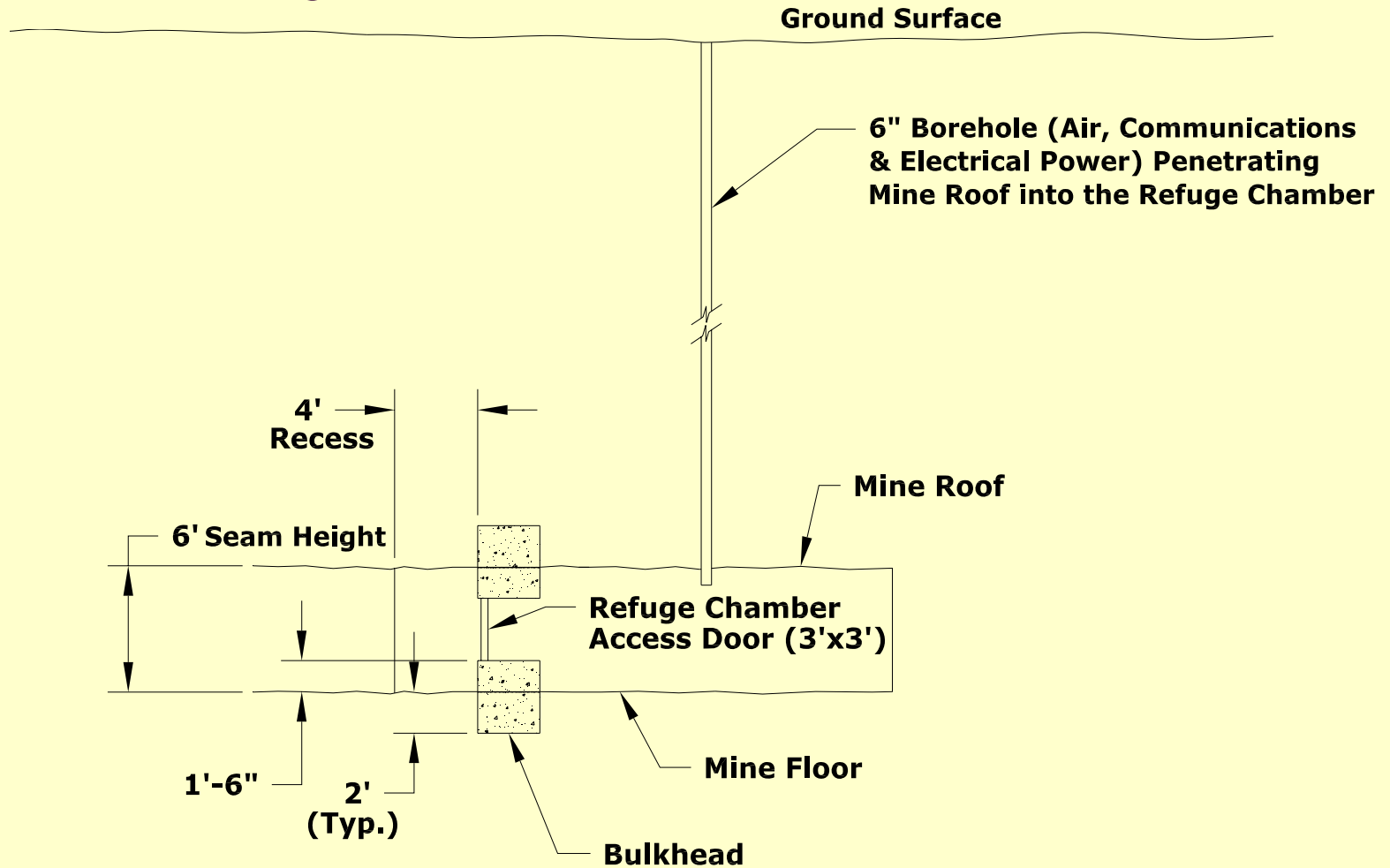
Foundation Design

- Multiple wedge failure analysis
- Seepage

Permanent Refuge Chamber



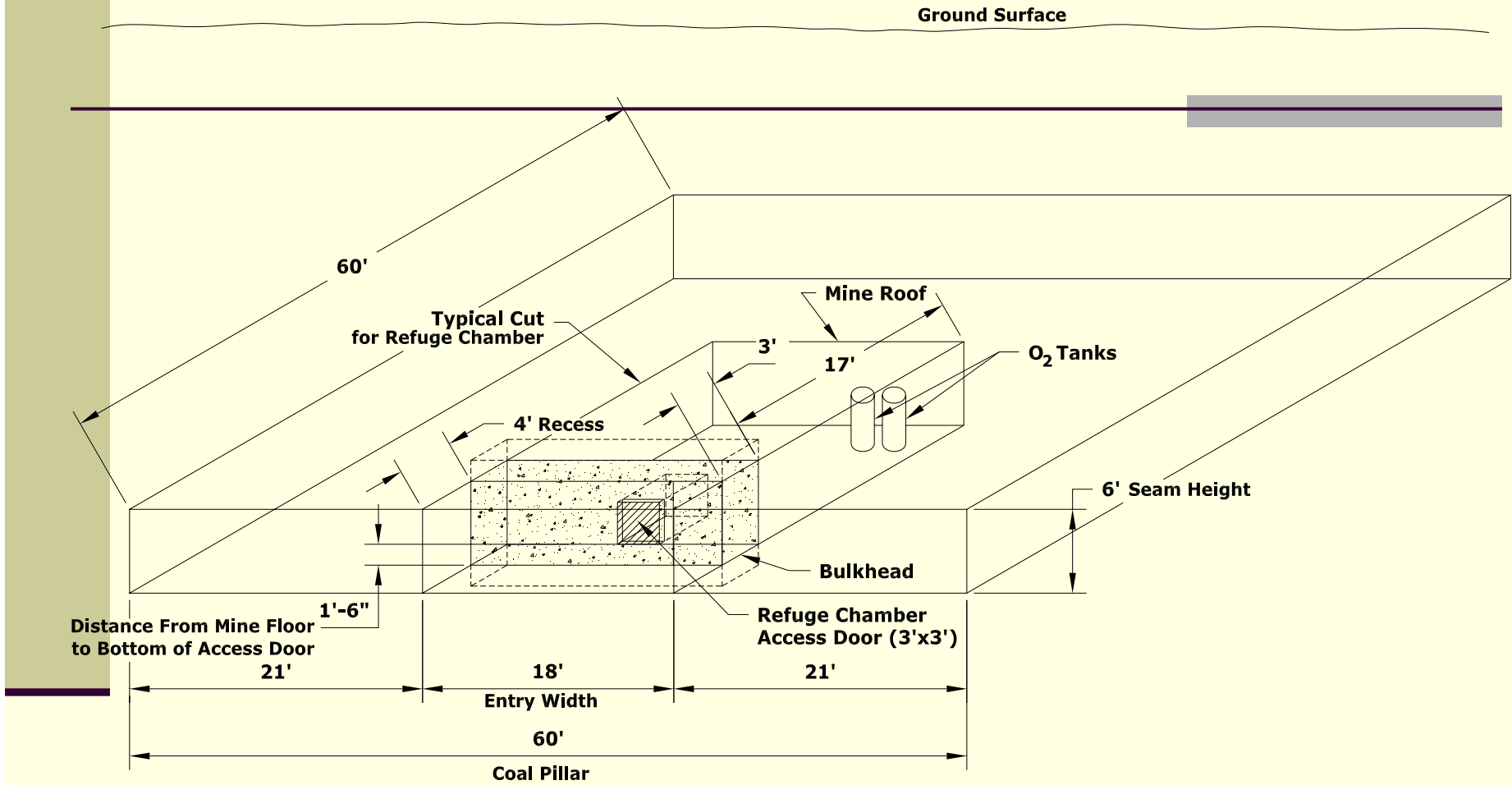
Permanent Refuge Chamber



Cross-Section through Bulkhead
(Elevation)

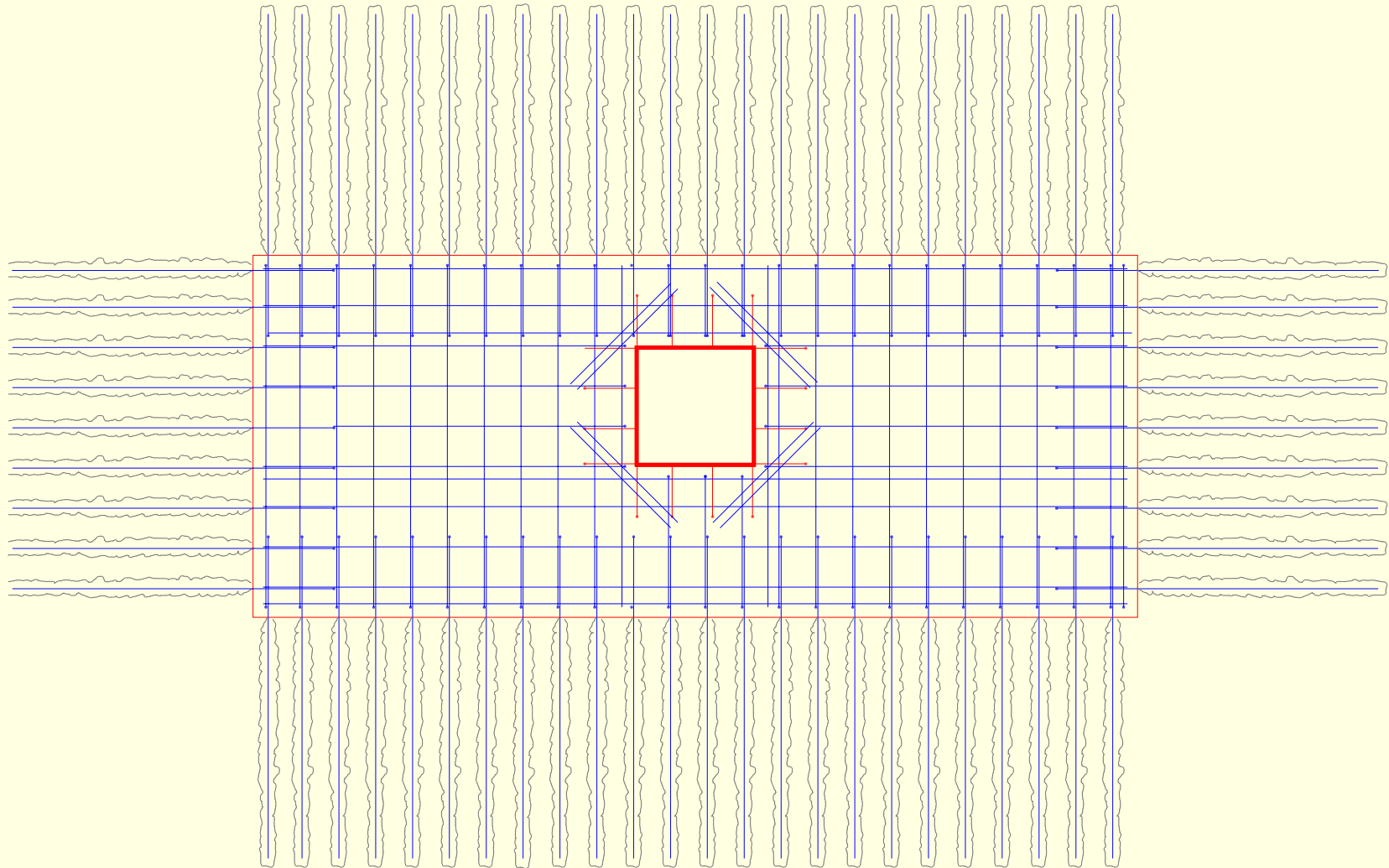
FOR REFERENCE ONLY
NOT TO SCALE

Temporary Refuge Chamber

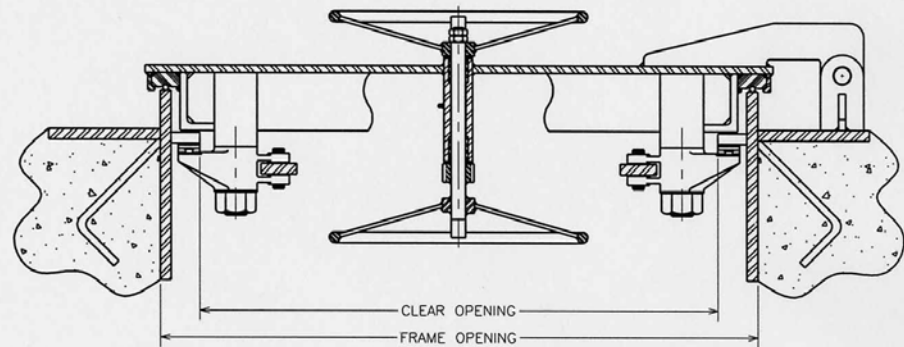
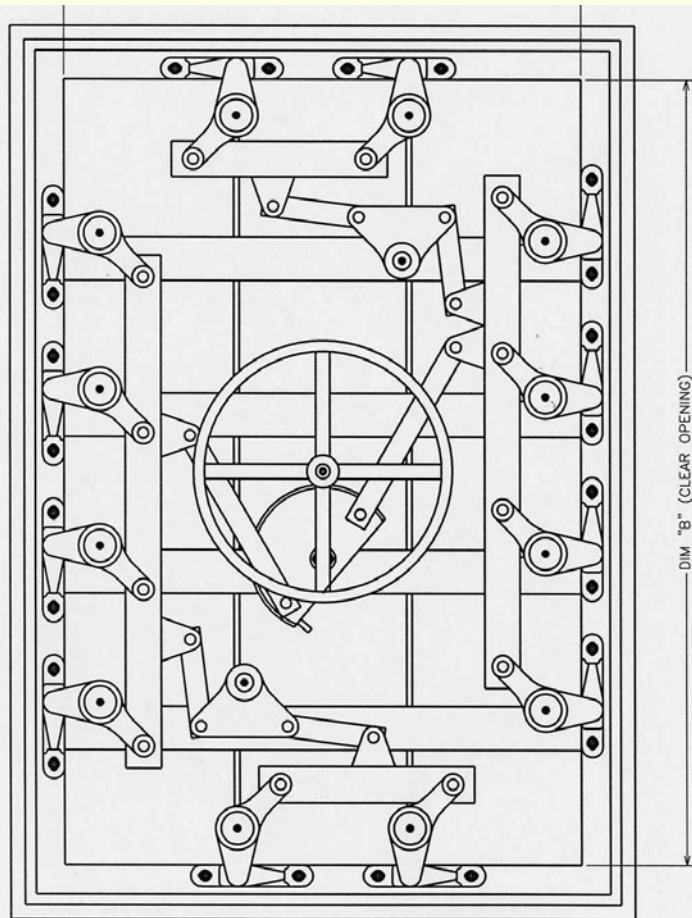


**Temporary Refuge Chamber w/O₂ Tanks
(Isometric View)**

Permanent Refuge Chamber RC Bulkhead Design (Steel Layout)



Permanent Refuge Chamber Watertight Door



TYPICAL JAMB SECTION
SHOWN EMBEDDED



Roof Dowels for Anchorage

Rib and Floor Hitching



Contact Grouting



The Mosaic Company
Potash Operations, Canada
General View of (Non-Structural) Permanent Refuge Station



The Mosaic Company
Potash Operations, Canada
View of (Non-Structural) Airlock at Entrance



Portable Refuge Chambers

- Portable steel or fiberglass enclosures are provided for remote areas in the mine near active work areas
- Capacity - up to 20 miners
- Generally equipped with compressed air or oxygen and a carbon dioxide absorbent to compensate for limited air content
- Cost ranges between \$45,000 to \$100,000 depending on the manufacturer and features
- The portable chambers are not designed to withstand explosion pressures.

Mine Arc Systems - Portable Chamber



Mine Arc Systems - Portable Chamber

- Capacity: 8 - 20 people
- Air Systems
 - Filtered and Silenced Compressed Mine Air
 - Oxygen Cylinders
 - 15 people/15 hours
 - Oxygen Candle
 - 15 people/5 hours
- Electrical System
 - Air Conditioning
 - Lighting System
 - 40-hour battery life
- Airtight Door
- Escape Hatch
- Utilities
 - Seating
 - Storage
 - Moisture Absorbent Desiccant
 - Water
 - Scrubbers for carbon monoxide & carbon dioxide
 - First Aid Kit
 - Blankets
 - Oxygen Candles
 - Tools
 - Self Contained Toilet

Shairzal Safety Engineering, Australia

Mine Refuge and Fresh Air Bases

- Capacity: 20 people
- 40+ Hours Back Up Refresh Air Scrubber, Toxic Gas Removal
- Airlock On Entry — Self Closing Door with Windows
- Internal optional equipment:
 - Lighting
 - Toilet
 - Chemical breathing apparatus
 - First aid kit
 - Phone



Portable Refuge Stations

Colonsay Potash Mine, Canada



Phone cable
plug-in

2 "H" sized
medical grade
oxygen cylinders

Drain outlet



Strata Products USA

Portable Inflatable Chamber

- Capacity: 5 – 15 miners
- Air lock entrance
- Stowed in a durable carry bag
- Single person operation
- Entire unit inflates in minutes
- May use oxygen candles and chemical carbon dioxide scrubbers



Any questions?

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