Cryogenic Air Breathing Apparatus and Liquid Air Fill Station for Outby Mine Escape

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CDC Agreement No: 12FED1213259, NASA SAA No: KCA-4357
Contents

Theory of operation

Design schematic and fabrication

Machine Tests

Human Tests

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The Cryogenic Breathing Apparatus

- Uses cryogenic (liquid air)
  - 53 lb/ft³ (1.14 gm/cm³), -318°F (77°K), store at very low pressure
  - Contains 8 liters
- Liquid air stored in 2 Dewars (metal thermos bottles)
- Liquid expands 728:1 to produce gaseous air in a heat exchanger
- Gas at 75 psi and approximately 55°F fed to mask
- Mask is conventional positive pressure, demand
How does CryoBA work?

- **2 Dewars (vacuum jacketed vessel)**
- **Heat exchanger for supply loop**
- **Pressure demand SCBA mask**
- **Buildup loop (pressurizes system)**
Two Prototypes designed
- 1 – wide spaced Dewars – minimum thickness
- 2 – close spaced Dewars – narrow pack

Add pics if CryoBA2 here
Cryogenic BA characteristics

- Operates in 90° off-vertical attitudes
- Positive pressure demand SCBA
- Provides cool source of air for 2 hours
- Carries 14 lb liquid air, total pack weight = 42 lb (19kg)
- Can meet 29 CFR part 84 requirements
- Low profile (approx 7” (17.8cm)deep)

User operated fill QD
Machine Testing

Perform machine testing on Posichek3
- Testing at NIOSH 40 l/min
- No body heat to aid heat exchanger
- No active air circulation (person moving)
- Off-vertical attitudes tested

Mask pressure waveforms
10 sec (left) - 2 hours (right)
Human Testing

- Protocols approved by NASA and NIOSH IRB’s
- Protocols per 42 CFR 84 subpart H
- Subjects instrumented for ECG
- CryoBA instrumented for O2, CO2, pressure, temp.
- Exercise per Tables 1, 3 and 4 – each for 2 hours
  - Treadmill walking, crawling
  - Wall pulley
  - Overcast carrying weight
  - Resting prone, supine, left side, right side
- Off-vertical tests – 30 minutes each
  - Full and ¼ full
  - Prone, supine, left side, right side
Human Testing in NASA Biomedical Laboratory
Human Protocols – Results

Table 3
Human Protocols - Results

Table 4

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Human Tests – Results
Protocol 3 - 4

- Additional data:
  - Mask Pressure
    - Always positive
    - Varied between +1 IWG to 3.5 IWG
  - Mask Temperature
    - Inhaled/exhaled temperature monitored
    - Ranged between 75 – 85°F
Human Testing Result

Summary

- Oxygen measure inside oral nasal mask – normal
- CO2 measured inside oral nasal mask – normal
- Mask pressure - +1 IWG to +3.5 IWG
- Mask temperatures reflect exhaled temps cooled by incoming air - 75°F to 85°F
- Duration – 2 hours
Cryogenic Air Supply and Fill Station

- Use CryoASFS to fill cryogenic breathing apparatus
- User can fill
- User can breathe on mask while filling
- Fill time – approx 4 minutes
- Prototype 1 ASFS can fill 4 units simultaneously
- ASFS has capability to perform multiple serial fills (~40)
- Locate every 1:30 in egress path

CryoBA + 3 other packs being filled
Conclusion

• This 2 hour version of the NASA Liquid Air Pack can meet 29 CFR 84 subpart H requirements
• Simple for miner to initial fill (while breathing)
• Simple for miner to refill during egress every 1:30
• This pack should meet needs of miners escaping disaster
• Could use within a Level A encapsulated suit to provide heat stress relief for hazardous material operations