NIOSH/MSHA Testing of the four Biomarine, Biopak 240S, Closed-Circuit Self-Contained Breathing Apparatus (SCBA) involved in the Storm Decline mine fatalities and rescue efforts

Prepared by
Staff
NIOSH/ National Personal Protective Technology Laboratory
MSHA/ Pittsburgh Safety and Health Technology Center

April 3, 2003

NIOSH/MSHA Testing of the four Biomarine, Biopak 240S, Closed-Circuit SCBA involved in the Storm Decline mine fatalities and rescue efforts

Purpose:

The purpose of the investigation was to determine if the Biomarine, Biopak 240S, Closed-Circuit SCBAs involved in the Storm Decline mine fatalities and rescue efforts were in conforming condition with regard to NIOSH/MSHA approval, and to run tests using a metabolic breathing simulator to make operational evaluations as compared to baseline testing of a new apparatus.

The objectives of the testing were:

1. To document the condition of the apparatus as received;
2. To determine if the four apparatus conform to NIOSH/MSHA approval requirements;
3. To assist MSHA in pursuing related laboratory inquiries.

Prior to inspection or testing, a protocol governing the investigation was developed and accepted by both Agencies. The protocol took into account the following general considerations.

General Considerations:

- MSHA maintained the chain of custody while the units were in its possession.

- Parties to the testing of the apparatus were MSHA and NIOSH. Both Agencies permitted affected parties to observe this testing. However, control of the tests and the test conditions remained in the hands of MSHA and NIOSH.

- Observers attending the testing included two representatives from Barrick Goldstrike Mining, two from Biomarine, and one consultant representing the attorney for the victims' families. The consultant was the only observer who chose to observe throughout the entire testing process.

- The role of the observers was simply to observe. They were not permitted to interfere with the testing or test procedures.

- Testing began on November 25, 2002, at NIOSH's laboratory facility (NPPTL) at Bruceton, Pennsylvania, and continued until December 16, 2002. Additional tests on Apparatus #10 were conducted at the Biomarine manufacturing facility. NIOSH and MSHA personnel, the consultant, and the Biomarine representatives were present for these tests.

- Units were opened, inspected, and tested in the presence of investigators from MSHA and NIOSH and the observers.

- No human subject tests were conducted. A Breathing and Metabolic Simulator (BMS) was used to make functional assessments of the devices' performance. (This testing was not regarded as a direct substitute for human subject testing specified at Title 42, Code of Federal Regulations, Part 84.)

- The time frame for testing was governed by findings and the availability of supplies and consumables. It should be noted that both Agencies were in agreement on the acceptability of any components or supplies needed for nominal refurbishment when testing. The Agencies used oxygen provided by MSHA's mine rescue team and other material as obtained from the Barrick Goldstrike mine rescue station.

Test Protocol and Results:

- Step 1: Perform received-hardware inspection.
  - All package-opening actions were videotaped.
  - With minimal disturbance to the units, the physical condition of each unit with respect to approved condition was evaluated**.** Each apparatus was named according to the number on its outer housing, and each number was unique. (Apparatus names were: #1, #7, #10, and #15.)
  - All observations were recorded**.** Units and original packaging were retained as evidence and remained in MSHA's custody throughout.
  - Figure 1a, Appendix III, is a photograph of the units after unpacking.
  - Figure 1b, Appendix III, is an engineering drawing of a Biopack 240S, which is included for the sake of reference.
  - Spreadsheet 1, Appendix III, is a summary of the initial visual inspection findings.

- Step 2: Oxygen Cylinder Gas Analysis
  - The purpose of this test was to sample and analyze the chemical composition of the gases remaining in each oxygen cylinder.

- Figure 2, Appendix III, shows cylinder BA253, which has a nonstandard gauge, next to cylinder WJ173, which has a standard gauge.
- Spreadsheet 2, Appendix III, is a summary of oxygen cylinder gas analysis results.
- A copy of the MSHA gas analysis report is attached as Appendix I.
- It should be noted that all of the cylinders were nearly empty. Also, there was a spare cylinder, WJ188, which was packed in the box that contained Apparatus #7.

❖ Step 3: Run 30-minute BMS test on units in as-received condition.
- The purpose of this test was to determine life support performance, running the units in an as-received condition. Because the oxygen cylinders on all four apparatus were nearly empty, they were replaced with fully charged cylinders and each unit was tested on the BMS for 30 minutes.
- The BMS tests performed on the recovered Biopak 240S's were conducted according to the experimental procedure documented in NIOSH RI 9650, "Performance Comparison of Rescue Breathing Apparatus" (ISSN 1066-5552).
- During the tests, life support variables such as breathing gas concentrations, pressure drops, and gas temperature were monitored and recorded on a continuous basis.
- The units were used, left in the mine, and later recovered. Therefore, the test results were not expected to be indicative of a brand new unit. Furthermore, the results may not be indicative of how the units performed at the time of the accident.
- Figure 3, Appendix III, is a photograph of a 30-minute BMS test on Apparatus #7.
- Spreadsheet 3, Appendix III, contains a summary of the test results.
- Charts 3a through 3d, Appendix III, are graphs showing how each apparatus performed compared to a new apparatus.
- Each chart displays the average value over the test duration for the named variable.
- All performance criteria compared well with the baseline test.

❖ Step 4: Restoration of Oxygen and Scrubber
- Restoration meant refilling oxygen and scrubber, as well as freezing the Gel Tube freeze form.
- Figure 4a, Appendix III, is a photograph of the restoration process.

- Spreadsheet 4a, Appendix III, summarizes the findings of the visual inspection that took place during the restoration.
- Figure 4b, Appendix III, is a photograph of Apparatus #10, showing a Gel Tube installed in the coolant canister.
- Figure 4c, Appendix III, is a photograph of Apparatus #1, showing that the coolant canister is empty and no Gel Tube is installed.
- In addition, samples of the scrubber material were collected and analyzed.
- Spreadsheet 4b, Appendix III, reports the results of the scrubber material analysis.
- The MSHA scrubber material analysis report is attached as Appendix II.

❖ Step 5: Run 2-hour BMS test on units with consumable supplies restored.
- The purpose of this test was to determine if life support performance conformed to BMS baseline tests when the units were nominally refurbished.
- Baseline testing was conducted with a new Biopak 240S.
- Each unit, after it was refurbished, was run for 2 hours on the BMS.
- Spreadsheet 5, Appendix III, contains a summary of the test results.
- Charts 5a through 5d, Appendix III, are graphs showing how each apparatus performed compared to a new apparatus.
- Each chart displays the average value over the test duration for the named variable.
- With the exception of the higher inhalation and exhalation pressures noted on Apparatus #10, all performance criteria compared well with the baseline test.

❖ Step 6: Bench Testing
- The purpose of this step was to run the required bench tests, as specified in Biomarine Biopak 240S Bench Manual, which must be performed prior to normal use. These tests included: High-pressure leak test, Low-pressure leak test, Flow test, and Face piece leak test.
- Since the chest gauge on Apparatus #15 was found to be leaking, it was replaced with a new one. Figure 6a, Appendix III, is a photograph showing the leak at the chest gauge. The leak rate for chest gauge was quantified at about 243 ml/minute.
- In addition to the leaky gauge, another leak was discovered in Apparatus #15 at a T-connection during the high-pressure leak test. Figure 6b, Appendix III, is an engineering drawing identifying the

location of the leak at the T-connection. Figure 6c, Appendix III, is a photograph of the T-connection leak.
- Spreadsheet 6, Appendix III, summarizes the bench test findings.

❖ Step 7: Run certification bench tests which are required for approval of SCBAs under 42 CFR Part 84.
- Spreadsheet 7a, Appendix III, contains the applicable certification bench tests.
- Although the certification bench tests required that an apparatus be partially disassembled, the tests were nondestructive.
- Figure 7, Appendix III, is a photograph of NIOSH 136, Demand Flow Test. It is included as an example.
- Spreadsheet 7b, Appendix III, summarizes the findings of the tests.
- It should be noted that, on Apparatus #15, the leak previously identified as being associated with the chest gauge was, in fact, located at the point where the gauge was connected to the flexible hose.
- Evidence pointing to the gauge connection was the presence of water deposits on the chest gauge O-ring seal, as well as direct confirmation that the gauge worked properly.

❖ Step 8: Special BMS Tests
- Because Apparatus #10 and #15 did not have Gel Tubes, 2-hour BMS tests were conducted to evaluate how well all four apparatus performed without coolant.
- Apparatus #10 and #15, the two that arrived without Gel Tubes, were run in that condition, while the other two, Apparatus #1 and #7, were run with Gel Tubes, which were not frozen.
- Spreadsheet 8, Appendix III, contains a summary of the test results.
- Charts 8a through 8d, Appendix III, are graphs showing how each apparatus performed compared to a new apparatus with a frozen Gel Tube.
- Each chart displays the average value over the test duration for the named variable.
- With the exception of the higher inhalation and exhalation pressures noted on Apparatus #10, all performance criteria compared well with the baseline test.

<u>Discussion</u>:

❖ Testing began on November 25, 2002, at NIOSH's NPPTL at Bruceton, Pennsylvania, and continued until December 16, 2002.

- ❖ The objectives of the testing were accomplished.

    - The condition of the four Biopak 240S SCBAs, as received, was documented.
    - The life-support performance of each unit was evaluated according to a BMS test protocol and compared to benchmark test results for a new apparatus. All four apparatus were subjected to a battery of NIOSH/MSHA approval tests.
    - To assist MSHA in pursuing related laboratory inquiries, special 2-hour BMS tests were conducted to evaluate how well the apparatus performed without coolant compared to a new apparatus with coolant.

- ❖ Spreadsheets 9a and 9b, Appendix III, are executive summaries of the test results, listing all of the differences or exceptions discovered during the course of testing.

- ❖ The findings of nonconformance are listed below:

    - o As received from the mine, Units #10 and #15 did not have Gel Tubes installed. Use without a Gel Tube does not conform to conditions of approval.

    - o One of the oxygen cylinders shipped with the apparatus had a nonconforming gauge.

    - o As received, Unit #15 had two high-pressure leaks. The leak at the chest gauge was detected during BMS testing, the other was discovered while oxygen and scrubber were being restored. The chest gauge leak was later measured at 243 ml/minute. The second leak was detected by following the approved bench procedure for preparing the apparatus. The second leak was located at the "T" connector, making it impractical to measure. Either leak would cause the apparatus not to conform to conditions of approval.

    - o During NIOSH certification tests, a number of failures were observed. Failure during any of the tests indicates that the apparatus is nonconforming.

- All four apparatus failed the relief valve pressure test.
- All four apparatus failed the exhalation resistance test
- Units #1, #7, and #10 failed the inhalation resistance test.
- Unit #15 failed the alarm pressure activation test.
- Unit #1 failed the alarm sound level test.

❖ These findings of nonconformance need to be viewed along with the results of BMS testing. The results compare the overall life support performance of Units #1, #7, #10, and #15 against a baseline of a new apparatus in the same configuration. All the apparatus, with the exception of Unit #10, had comparable performance to the baseline. Unit #10 exhibited higher exhalation breathing resistance, as well as higher average and minimum inhaled CO_2 concentrations.

❖ Because unit #10 exhibited higher exhalation breathing resistance values than the other units tested, NIOSH and MSHA took the unit to Biomarine's facility in Exton, Pennsylvania, on January 30, 2003, for the purpose of subjecting the unit to Biomarine's examination. It was found that the exhalation breathing resistance values were reduced to within Biomarine's specifications through the application of routine maintenance procedures.

Biomarine makes use of a PosiCheck breathing machine to measure breathing resistance. Performing maintenance in a step-by-step fashion, the breathing resistance was measured after each maintenance procedure was completed. The procedure that had the largest effect was the relubrication of the relief valve.

When the unit was returned to Pittsburgh, exhalation breathing resistance was measured again to confirm that the procedures had indeed lowered the breathing resistance. Testing was performed on February 12, 2003. Exhalation resistance values were reduced and were found to be in the approximate range of the values measured on units #1, #7, and #15. These results underscore the significance of strictly following all field maintenance procedures according to the methods the manufacturer stipulates.

Appendix I

MSHA Gas Analysis Report

Request for Laboratory Analysis

U.S. Department of Labor
Mine Safety and Health Administration

1. Event Number	2. Mine ID Number 26-02300
3. Mine/Mill Name STORM EXPLORATION DECINE	4. Company BARRICK GOLD STRIKE
5. Contractor Name/Number	6. Commodity
7. Collector WALOSKI/ROBINSON	8. AR Number
9. Field Office	

Sampling Data 2002087397 2002087398 2002087399 2002087400 2002087401

	Control/Blank					
10. Area/Personal (A/P)		AIR CYL UNDER →				
11. Date Collected		11/25/02	11/25/02	11/25/02	11/25/02	11/25/02
12. Time Collected						
13. Pre-seal Intact (Y/N)						
14. Field Sample No.		WJ 188	WJ 173	BA 253	WJ 112	WJ 135
15. Sample Type*	CB	#15	#11	#5	#3	#1
16. Analysis Requested Note: Must match with 15.		G	G	G	G	G
17. Flow Rate (LPM)						
18. Material Listed (Y/N)						
19. Job Code						
20. Job Description						
21. Last Name						
22. First Name						
23. Location Code						
24. Location/Site Description						
25. Miners Exposed (Y/N)						
26. Personal Protection (Y/N)						
27. Volume of Air (cfm) †						

*SAMPLE TYPE List (common examples)	
B - Bulk (silica, asbestos)	OV - Organic Vapor (badge)
CB - Control/Blank	R - Respirable Dust (quartz)
F - Fiber (asbestos)	T - Total Dust (listed nuisance)
Hg - Mercury Vapor	W - Welding Fume (16 element)
M - Mist (acid, caustic, oil)	WS - Wipe (Pb, Hg, Ag)
MD - Metal Dust (single, or 16)	ST - Silica Gel Tube (methanol)
MF - Metal Fume (single, or 16)	CT - Charcoal Tube (solvents)
G - Gas (vacuum samplers)	MISC - Other (specify)

† Required for Methane Liberated in 24 hrs

Special Instructions-
Comments (optional)

Interim MSHA Form 4000-29, Jun 00 (Revised)

MSHA Mine Safety and Health Administration Department of Labor

Pittsburgh Safety and Health Technology Center Laboratory
Cochrans Mill Road, Building 38, Pittsburgh, PA 15236
Phone: 412-386-6979 Fax: 412-386-6154

ANALYTICAL REPORT

Report ID: AR0012060754
Page 1 of 4
Date Printed: **Friday, December 6, 2002**

COLLECTOR: MIKE VALOSKI
AR#:
FIELD OFFICE NAME: Pittsburgh Tech Support
ADDRESS: Toxic Agents Division, Bld 38
P.O. Box 18233
Brucetion PA, 15236

MINE ID: 2602300
CONTRACTOR:
MINE NAME: Barrick Gold Strike
COMPANY:
COMMODITY: GOLD ORE MINING, N.E.C.
DATE SAMPLED: 11/25/2002
DATE RECEIVED:
DATE REPORTED: 11/25/02

REMARKS:

LAB ID #	FIELD Sample No	Type of Sample	INSTR \ METHOD	ANALYTE	RESULT
2002087397	WJ188 #15	G-	GC-GAS~GC	ACETYLENE	nd ppm
2002087397	WJ188 #15	G-	GC-GAS~GC	ARGON	nd %
2002087397	WJ188 #15	G-	GC-GAS~GC	CARBON DIOXIDE	0.01 %
2002087397	WJ188 #15	G-	GC-GAS~GC	CARBON MONOXIDE	nd ppm
2002087397	WJ188 #15	G-	GC-GAS~GC	ETHANE	nd ppm
2002087397	WJ188 #15	G-	GC-GAS~GC	ETHYLENE	nd ppm
2002087397	WJ188 #15	G-	GC-GAS~GC	HYDROGEN	nd ppm
2002087397	WJ188 #15	G-	GC-GAS~GC	METHANE	nd %

RESULT COMMENT
Data apply only to the listed analyte for the specified sample. This report is intended only for the entity to which it is addressed. Calculations based on parameters received.

MDL Method Detection Limit
LOQ Limit of Quantitation
TLV Threshold Limit
STEL Short Term Exposure Limit
ND Not detected above MDL

ANALYZED BY: ROBINSON-JOSEPH
APPROVED BY: VALOSKI-MICHAEL

SUPERVISOR NAME: Michael Valoski
SUPERVISOR TITLE: Laboratory Supervisor
SIGNATURE:

LAB ID #	FIELD Sample No	Type of Sample	INSTR \ METHOD	ANALYTE	RESULT
2002087397	WJ188 #15	G-	GC-GAS~GC	NITROGEN	2.00 %
2002087397	WJ188 #15	G-	GC-GAS~GC	OXYGEN	95.97 %
2002087398	WJ173 #11	G-	GC-GAS~GC	ACETYLENE	nd ppm
2002087398	WJ173 #11	G-	GC-GAS~GC	ARGON	nd %
2002087398	WJ173 #11	G-	GC-GAS~GC	CARBON DIOXIDE	0.02 %
2002087398	WJ173 #11	G-	GC-GAS~GC	CARBON MONOXIDE	nd ppm
2002087398	WJ173 #11	G-	GC-GAS~GC	ETHANE	nd ppm
2002087398	WJ173 #11	G-	GC-GAS~GC	ETHYLENE	nd ppm
2002087398	WJ173 #11	G-	GC-GAS~GC	HYDROGEN	1 ppm
2002087398	WJ173 #11	G-	GC-GAS~GC	METHANE	nd %
2002087398	WJ173 #11	G-	GC-GAS~GC	NITROGEN	12.74 %
2002087398	WJ173 #11	G-	GC-GAS~GC	OXYGEN	85.98 %
2002087399	BA253 #5	G-	GC-GAS~GC	ACETYLENE	nd ppm
2002087399	BA253 #5	G-	GC-GAS~GC	ARGON	nd %
2002087399	BA253 #5	G-	GC-GAS~GC	CARBON DIOXIDE	0.01 %
2002087399	BA253 #5	G-	GC-GAS~GC	CARBON MONOXIDE	nd ppm
2002087399	BA253 #5	G-	GC-GAS~GC	ETHANE	nd ppm
2002087399	BA253 #5	G-	GC-GAS~GC	ETHYLENE	nd ppm

RESULT COMMENT

Data apply only to the listed analyte for the specified sample. This report is intended only for the entity to which it is addressed. Calculations based on parameters received.

MDL Method Detection Limit
LOQ Limit of Quantitation
TLV Threshold Limit
STEL Short Term Exposure Limit
ND Not detected above MDL

ANALYZED BY: ROBINSON-JOSEPH
APPROVED BY: GERO-ANDREW

SUPERVISOR NAME: Michael Valoski
SUPERVISOR TITLE: Laboratory Supervisor
SIGNATURE:

LAB ID #	FIELD Sample No	Type of Sample	INSTR \ METHOD	ANALYTE	RESULT
2002087399	BA253 #5	G-	GC-GAS~GC	HYDROGEN	nd ppm
2002087399	BA253 #5	G-	GC-GAS~GC	METHANE	nd %
2002087399	BA253 #5	G-	GC-GAS~GC	NITROGEN	5.54 %
2002087399	BA253 #5	G-	GC-GAS~GC	OXYGEN	92.58 %
2002087400	WJ112 #3	G-	GC-GAS~GC	ACETYLENE	nd ppm
2002087400	WJ112 #3	G-	GC-GAS~GC	ARGON	nd %
2002087400	WJ112 #3	G-	GC-GAS~GC	CARBON DIOXIDE	0.03 %
2002087400	WJ112 #3	G-	GC-GAS~GC	CARBON MONOXIDE	nd ppm
2002087400	WJ112 #3	G-	GC-GAS~GC	ETHANE	nd ppm
2002087400	WJ112 #3	G-	GC-GAS~GC	ETHYLENE	nd ppm
2002087400	WJ112 #3	G-	GC-GAS~GC	HYDROGEN	nd ppm
2002087400	WJ112 #3	G-	GC-GAS~GC	METHANE	nd %
2002087400	WJ112 #3	G-	GC-GAS~GC	NITROGEN	22.76 %
2002087400	WJ112 #3	G-	GC-GAS~GC	OXYGEN	76.40 %
2002087401	WJ135 #1	G-	GC-GAS~GC	ACETYLENE	nd ppm
2002087401	WJ135 #1	G-	GC-GAS~GC	ARGON	nd %
2002087401	WJ135 #1	G-	GC-GAS~GC	CARBON DIOXIDE	0.04 %
2002087401	WJ135 #1	G-	GC-GAS~GC	CARBON MONOXIDE	nd ppm

RESULT COMMENT

Data apply only to the listed analyte for the specified sample. This report is intended only for the entity to which it is addressed. Calculations based on parameters received.

MDL Method Detection Limit
LOQ Limit of Quantitation
TLV Threshold Limit
STEL Short Term Exposure Limit
ND Not detected above MDL

ANALYZED BY: ROBINSON-JOSEPH
APPROVED BY: VALOSKI-MICHAEL

SUPERVISOR NAME: Michael Valoski
SUPERVISOR TITLE: Laboratory Supervisor
SIGNATURE:

LAB ID #	FIELD Sample No	Type of Sample	INSTR \ METHOD	ANALYTE	RESULT
2002087401	WJ135 #1	G-	GC-GAS~GC	ETHANE	nd ppm
2002087401	WJ135 #1	G-	GC-GAS~GC	ETHYLENE	nd ppm
2002087401	WJ135 #1	G-	GC-GAS~GC	HYDROGEN	nd ppm
2002087401	WJ135 #1	G-	GC-GAS~GC	METHANE	nd %
2002087401	WJ135 #1	G-	GC-GAS~GC	NITROGEN	26.29 %
2002087401	WJ135 #1	G-	GC-GAS~GC	OXYGEN	73.03 %

RESULT COMMENT

Data apply only to the listed analyte for the specified sample. This report is intended only for the entity to which it is addressed. Calculations based on parameters received.

MDL Method Detection Limit
LOQ Limit of Quantitation
TLV Threshold Limit
STEL Short Term Exposure Limit
ND Not detected above MDL

ANALYZED BY: ROBINSON-JOSEPH
APPROVED BY: VALOSKI-MICHAEL

SUPERVISOR NAME: Michael Valoski
SUPERVISOR TITLE: Laboratory Supervisor
SIGNATURE:

Appendix II

MSHA Scrubber Material Analysis Report

MSHA Technical Support
Dust Division

January 9, 2003

MEMORADNUM FOR JEFFEREY H. KRAVITZ
Chief, Mine Emergency Operations

THROUGH: EDWARD J. MILLER,
Chief, Pittsburgh Safety and Health Technology Center

ROBERT A. HANEY
Chief, Dust Division

FROM: MARK H. WESOLOWKI
Lab Director

SUBJECT: Analysis of Bulk Samples of CO_2 Absorbent taken on November 26, 2002 at the Storm Decline Mine, Mine ID No. 26 02300

Six bulk samples were taken on November 26, 2002, as part of the Storm Decline Mine fatality investigation. Four of the six samples, were taken from self-contained breathing apparatus used during the incident; two samples were unused material from the operator's stock room. Six 4 oz. precleaned borosilicate glass VOC vials, with Teflon lined caps, were filled with each bulk. A portion of each sample was analyzed at the Pittsburgh Safety and Health Technology Center lab for moisture and a suite of 19 elements; other increments of each bulk were submitted to Data Chem Laboratories Salt Lake City, Utah facility, for the analysis of sulfides, cyanides, antimony, selenium, and mercury. The Dust Division has retained three vials of each sample.

A summary of the findings is presented below. All analyses were reported on an "as received" basis; the samples were not dried prior to analysis.

1. The antimony content of each sample was below the Method Detection Limit (MDL) of 3 ug/g (3 parts per million on a weight/weight basis). The analytical method employed for this analysis was NIOSH Method 7300.

2. Mercury was analyzed by EPA Method 7471; all results were below the MDL of .02 ug/g.

3. Cyanide was determined by EPA Method 9012; all results were below the MDL of .5 ug/g.

4. Data Chem employed NIOSH Method 7903 for the determination of sulfides. This method measures sulfide indirectly, after oxidation to sulfate, which is analyzed via ion chromatography. Any sulfate present in a form that was soluble in the dilute sodium carbonate/bicarbonate solution used to extract the sample, would be a positive interference to the sulfide determination. The reported sulfide values ranged from 41 to 55 ug/g; the results for the unused Limepak samples were 47 and 53 ug/g respectively.

5. Selenium was analyzed by NIOSH Method 7300. The result for the Device 10 sample was 40 ug/g, which was above the MDL of 30 ug/g but below the Level of Quantification of 90 ug/g. All other selenium results were below the MDL.

6. The results of the PSHTC Laboratory analyses are given in tabular form below. Moisture was determined by drying the samples at 105 C^{o} for 2 hours, while the elemental analysis was performed by MSHA Method P-3, where 1.0 gram of bulk material was digested with nitric and hydrochloric acids and analyzed by ICP spectroscopy.

Sample	Unused Limepak	Device 1	RWMSHA 10640	Device 7	Device 10	Device 15
H_2O %	15.1	18.9	15.4	16.4	17.5	17.3
Aluminum ug/g	*470*	*450*	*450*	*410*	*480*	*460*
Arsenic ug/g	ND	ND	ND	ND	ND	ND
Beryllium ug/g	ND	ND	ND	ND	ND	ND
Cadmium ug/g	ND	ND	ND	ND	ND	ND
Calcium ug/g	400,000	380000	400,000	360,000	380,000	390,000
Chromium ug/g	(6)	(5)	(5)	(5)	(6)	(6)
Cobalt ug/g	ND	ND	ND	ND	ND	ND
Copper ug/g	ND	ND	ND	ND	ND	ND
Iron ug/g	380	350	350	330	380	360
Lead ug/g	ND	ND	ND	ND	ND	ND
Magnesium ug/g	1600	1500	1400	1400	1500	1500
Manganese ug/g	98	98	97	90	100	100
Molybdenum ug/g	ND	ND	ND	ND	ND	ND
Nickel ug/g	(2)	(2)	(2)	(1)	(2)	(2)
Potassium ug/g	110	100	110	90	120	110
Sodium ug/g	1300	1200	1100	1200	1300	1200
Titanium ug/g	(7)	(5)	(6)	(6)	(6)	(6)
Vanadium ug/g	(8)	(7)	(7)	(7)	(8)	(8)
Zinc ug/g	17	17	17	14	17	18

Data Chem also determined many of the same elements as part of their antimony and selenium protocol. Their results for calcium averaged approximately 10% higher; their magnesium results were 15% higher. The numbers in parentheses correspond to analyze masses that are above the method reporting limits for welding fumes; for bulk samples these values should be considered semi-quantitative.

Appendix III,

Figures, Spreadsheets, Charts

Spreadsheet 1: Visual Inspection	#1	#7	#10	#15
1) Record readings on chest gauge.	0 psi	0 psi	0 psi	0 psi
2) Record type of face piece.	Scott	Scott	Scott	Scott
3) Record condition of face piece:				
a) lens	OK	OK	OK	1 scratch
b) hoses and connections (for tightness)	Green connector not tightened, retightened with 1/8th turn	OK	Face piece was not connected to breathing hoses.	OK
c) parts missing or damaged	Anti-fog lens missing	OK	Anti-fog lens missing	OK
d) inner cup in place	OK	OK	OK	OK
e) inhalation and exhalation valves	OK	OK	OK	OK
f) Face piece part number	D46A011	D46A011	D46A011	D46A011
4) Check approval label	TC-13F-466	TC-13F-466	TC-13F-466	TC-13F-466
5) Check serial number	00001	00007	00010	00022
6) Check if there are any worn, missing or loose parts/damage.	a) Small dent in scrubber canister, b) Bottom clip on scrubber housing not engaged	2 large dents in scrubber canister	a) Small dent on scrubber canister, b) Cylinder strap reversed	Oxygen cylinder not secured
7) Check and record cylinder pressure gauge.	0 psi	0 psi	0 psi	0 psi
8) Record position of cylinder valve and the number of turns it is opened.	Closed	Closed	Closed	Closed
9) Check cycle and handle for oxygen cylinder.	OK	OK	OK	OK
10) Check hydrostatic date	Mar-99	Mar-00	Mar-99	Mar-99
11) Check pressure rating on cylinder	#N/A	#N/A	#N/A	#N/A
12) Check serial number	BA253 (See Note)	WJ173	WJ135	WJ112
13) Manufacturing date cylinder	Aug-94	Sep-88	Sep-88	Sep-88
14) Check cylinder, valves and gauge for damage.	OK	OK	OK	OK
15) Check oxygen cylinder sealing washer for damage.	OK	OK	OK	OK

Note: Columns highlighted in blue refer to units taken into the mine by the mine rescue team, while the yellow highlighted columns refer to units worn by the victims.

Note: Apparatus #1, Item 15: Cylinder guage is different from the other 3. Manufactured by ERIE.

Note: An extra oxygen cylinder was packed in the box which contained Apparatus # 7. Its condition as received was: 0 psi on cylinder guage and valve closed. Hydrostatic test date was Mar-99, Manufactured date Sep-88, and serial number WJ188.

Figure 1a: (From left-to-right.) Apparatus #10, #15, #1 and #7.

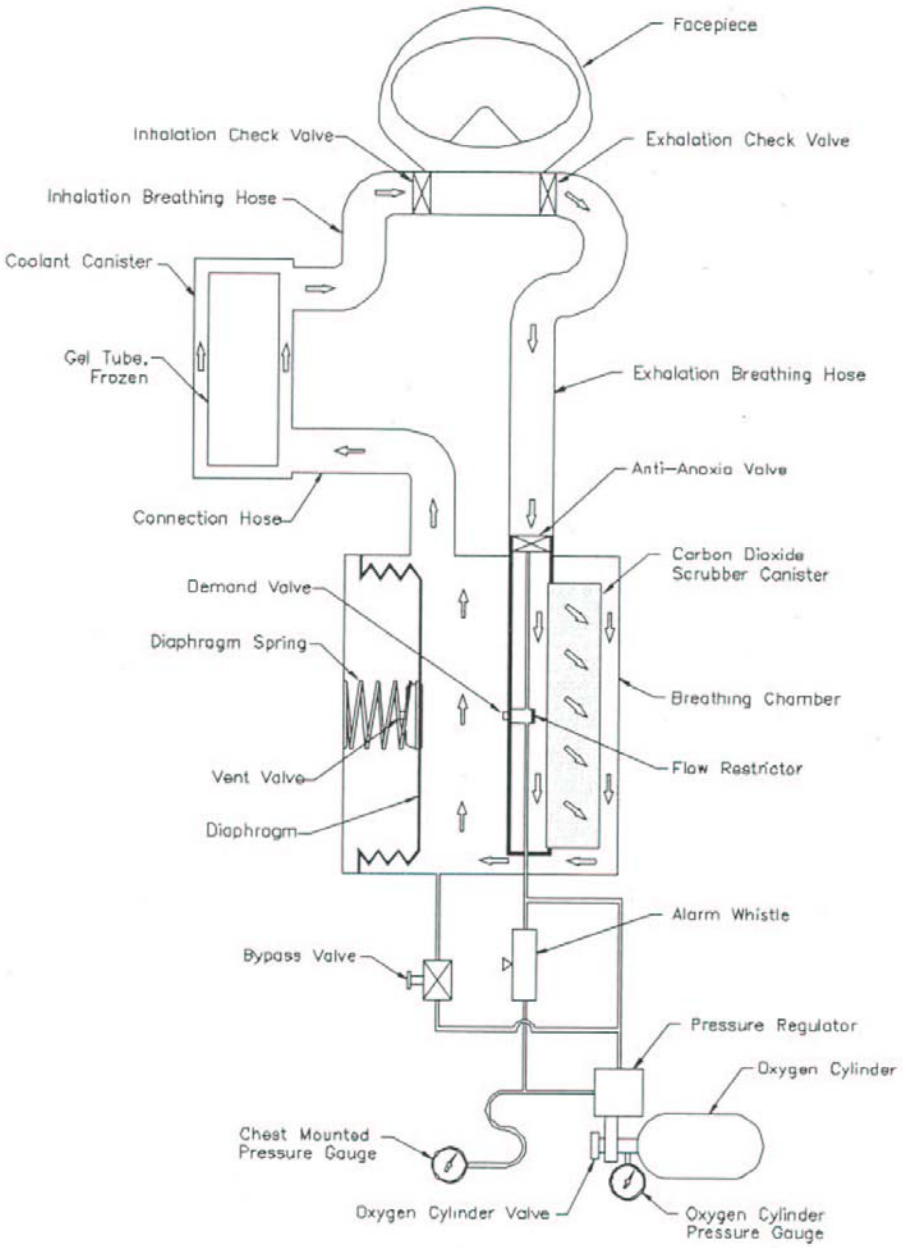


Figure 1: Biopak 240S Flow Diagram

Figure 1b: Engineering Drawing of Biopak 240S from Biomarine Benchman Manual

Specialty Gas Analysis	Sample	#1	#7	#10	#5
Cylinder Number	V18	B53	V23	V15	J12
Cylinder Pressure	0psi	0psi	0psi	0psi	0psi
Oxygen	97%	98%	8%	73%	0%
Nitrogen	20%	54%	4%	29%	6%
Carbon Dioxide	01%	01%	2%	04%	03%
Carbon Monoxide	00%	00%	0%	00%	00%

Note: Cylinder V18 was labeled as
low oxygen and Apparatus #7

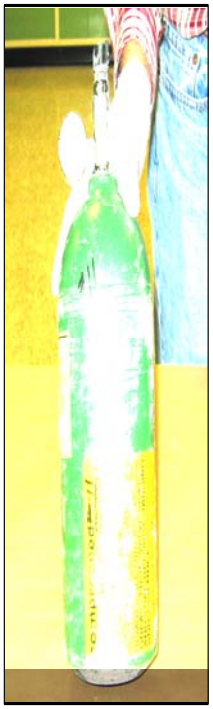


Figure 2: Cylinder B53 with standard gas and cylinder V23 with standard gas

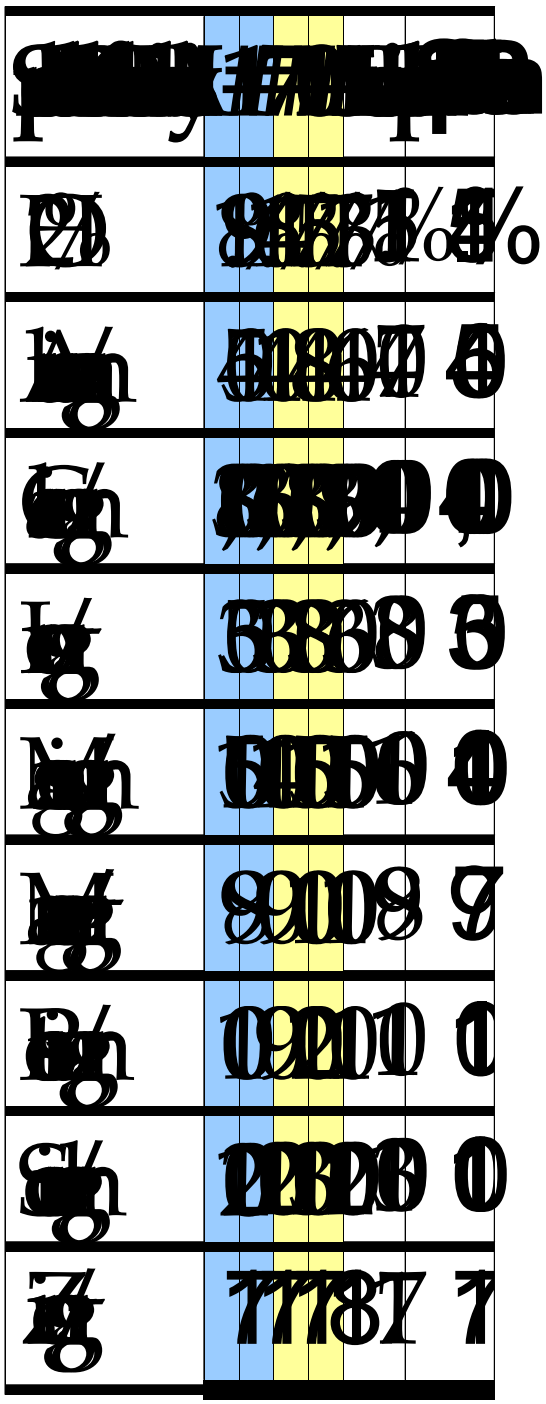
1	0	8	6	5	4	2	7	N
7	2	3	1	4	3	2	7	N
0	3	1	6	4	3	2	7	N
5	2	9	6	4	3	2	7	N
1	1	8	8	2	2	2	7	N

Specific Restoration Procedure	#1	#7	#10	#5
1) Visual inspection of components and housings for damage, corrosion, and proper installation of the GelPak cushion	a) Submerge in solvent, b) Brush cushion using solvent	a) Submerge in solvent, b) Brush cushion using solvent	a) Submerge in solvent, b) Brush cushion using solvent	Oxygen cylinder and second stage regulator exhibit corrosion damage
2) Inspect housing and cushion assembly for damaged O-rings	OK	OK	OK	OK
3) Check cushion pad	OK	OK	OK	OK
4) Verify that cushion pad contains 18 thin wafers and covers at least 1/2 of the cushion area. Wafers should be evenly distributed over the cushion area.	OK	OK	OK	OK
5) Verify that cushion pad is attached to shell with proper fit	OK	OK	OK	OK
6) Obtain analyze samples	#N/A	#N/A	#N/A	#N/A
7) Check for damage	None	None	None	None
8) Check internal parts for damage	OK	OK	OK	OK
9) Check for leaks	OK	OK	Missing	Missing
10) Check for moisture in cushion pad	Replace to remove water	OK	OK	OK

Figure 4b: Apparatus #10 with GelPak missing

Figure 4c: Apparatus #1 with GelPak installed

Figure 4a: Restoration process



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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Spreadsheet 6: Bench Testing Summary	#1	#7	#10	#15
High pressure leak test	OK	OK	OK	Failed. Leak at T-connection and chest guage. (See engineering drawing)
Low pressure leak test	OK	OK	OK	OK
Flow test	OK	OK	OK	OK
Face piece leak test	OK	OK	OK	OK

Note: "T" connection tightened with a 1/2 turn. Chest guage replace with a new one.

Figure 6a: Leak at chest gauge on Apparatus #15

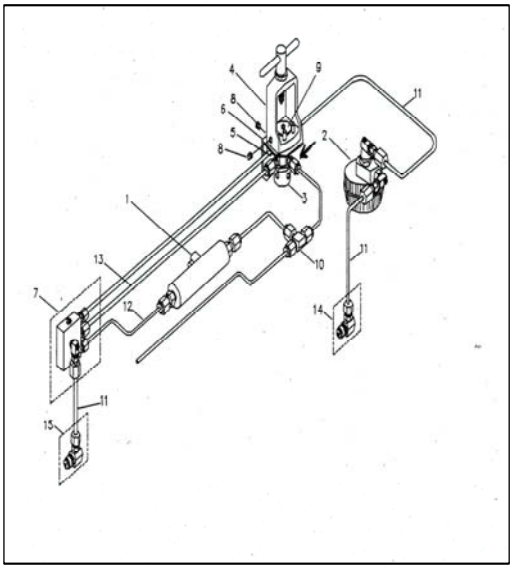

Figure 6b: Engineering drawing showing the location (at arrow) of the leak at the T-connection on Apparatus #15

Figure 6c: Leak at T-connection on Apparatus #15

Spreadsheet 7b: NIOSH Bench Tests Summary	Requirement	#1	#7	#10	#15
137 Constant Flow (CF)	=1.5 L/min	1.640 L/min	1.510 L/min	1.500 L/min	1.735 L/min
138 Relief Valve Pressure	0.28-0.75 in H_2O	0.24 in H_2O	0.20 in H_2O	0.25 in H_2O	0.25 in H_2O
135 Exhalation Resistance (ER)	=2.0 in H_2O	2.6 in H_2O	2.2 in H_2O	3.2 in H_2O	2.6 in H_2O
135 Exhalation Resistance (ER) [Recheck after maintenance]	=2.0 in H_2O			2.45 in H_2O	
127 By-Pass Flow (BPF)	=30 L/min	220 L/min	227 L/min	210 L/min	230 L/min
117 Inhalation Resistance (IR)	=0 in H_2O	-1.5 in H_2O	-0.5 in H_2O	-0.2 in H_2O	0 in H_2O
124 Alarm Pressure	6.0-7.5 psi	6.83 psi	6.92 psi	6.75 psi	7.05 psi†
145 Alarm Sound Level	=80 dBA	79.4 dBA	81.6 dBA	84.1 dBA	80.8 dBA
136 Demand Gas Flow (DGF)	=30 L/min	223 L/min	175 L/min	170 L/min	229 L/min
148 Remote Gauge Leak	=3.67 L/min	0.09 L/min	0.05 L/min	0.07 L/min	0.10 L/min
128 Accuracy Gauge	Difference				
@ 50 psi	±1.5 psi	0 psi	-5 psi	-3 psi	+5 psi
@ 100 psi	±1.5 psi	-1 psi	-4 psi	-2 psi	-1 psi
@ 150 psi	±1.5 psi	-1 psi	-2 psi	-5 psi	-1 psi
@ 200 psi	±1.5 psi	-4 psi	+1 psi	+1 psi	+1 psi
@ 250 psi	±1.5 psi	-3 psi	+2 psi	+2 psi	+5 psi
@ 300 psi	±1.5 psi	-4 psi	+2 psi	+4 psi	-3 psi

Figure 7: Photograph of NIOSH Test 136 - Demand Gas Flow on Apparatus #10

Note: Failing results are indicated in red text.

†Figure shown is the average of five runs - alarm failed to activate during first run performed

Chart 3a: Breathing Resistance

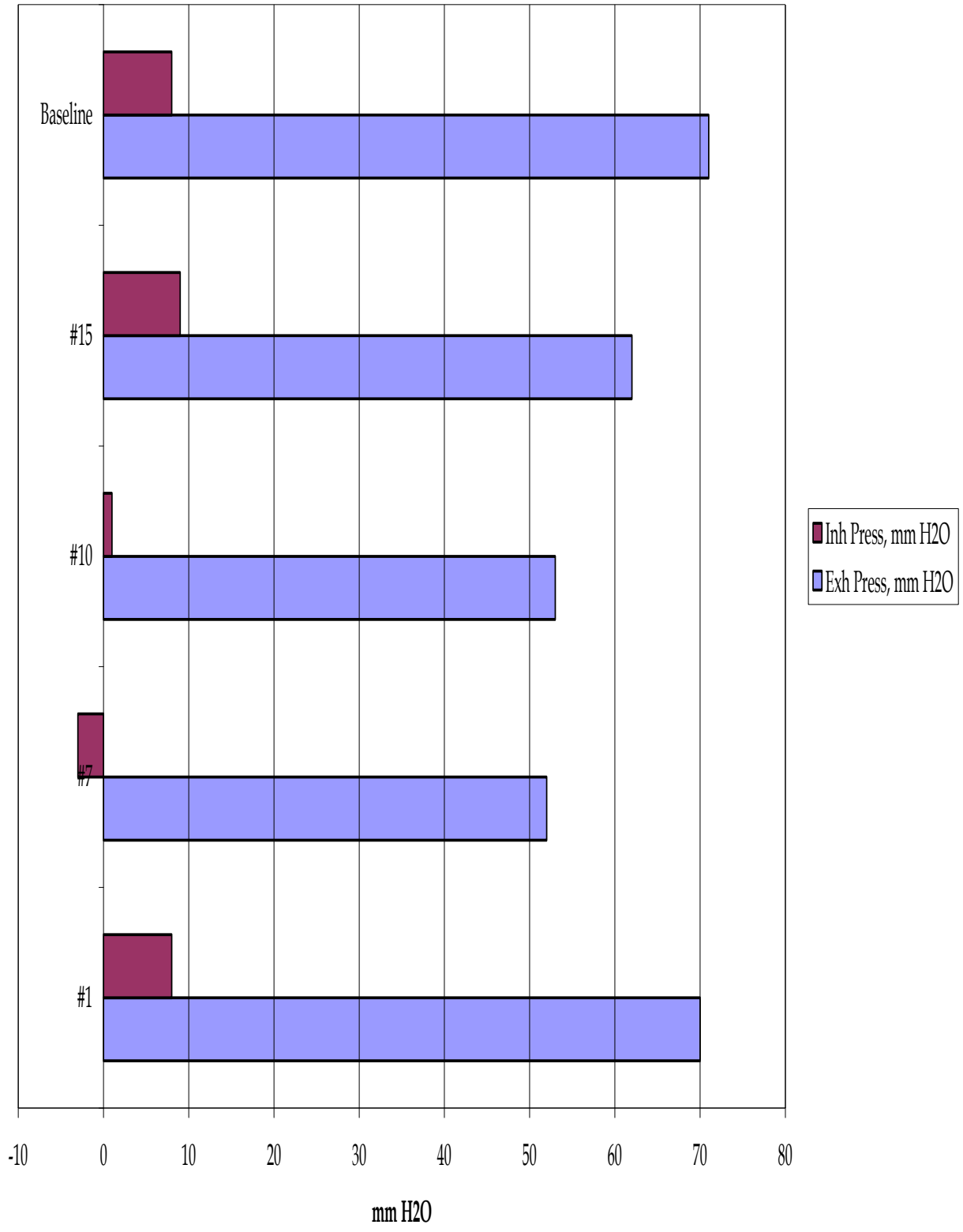

Chart 3b: Oxygen

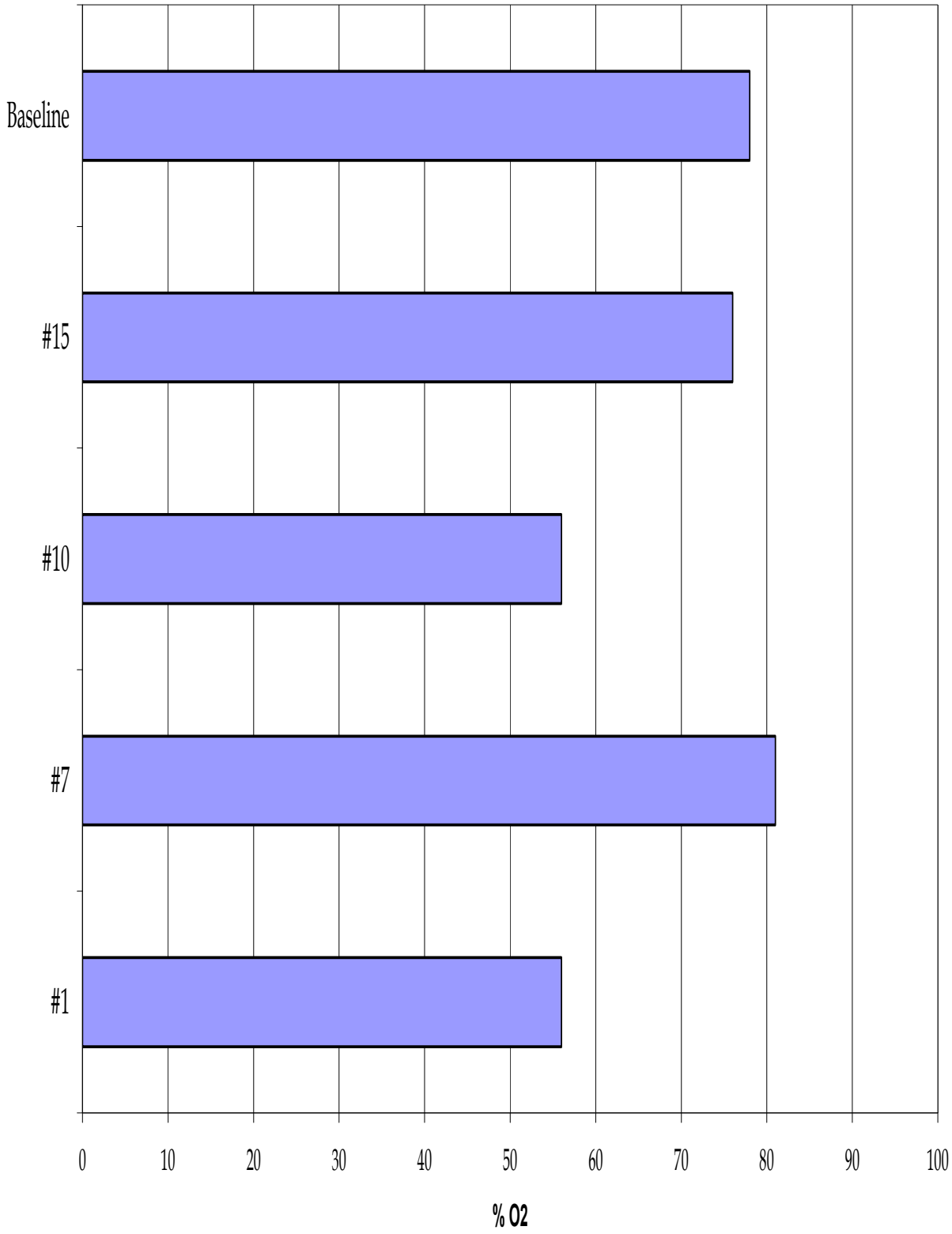

Chart 3c: Scrubber Performance

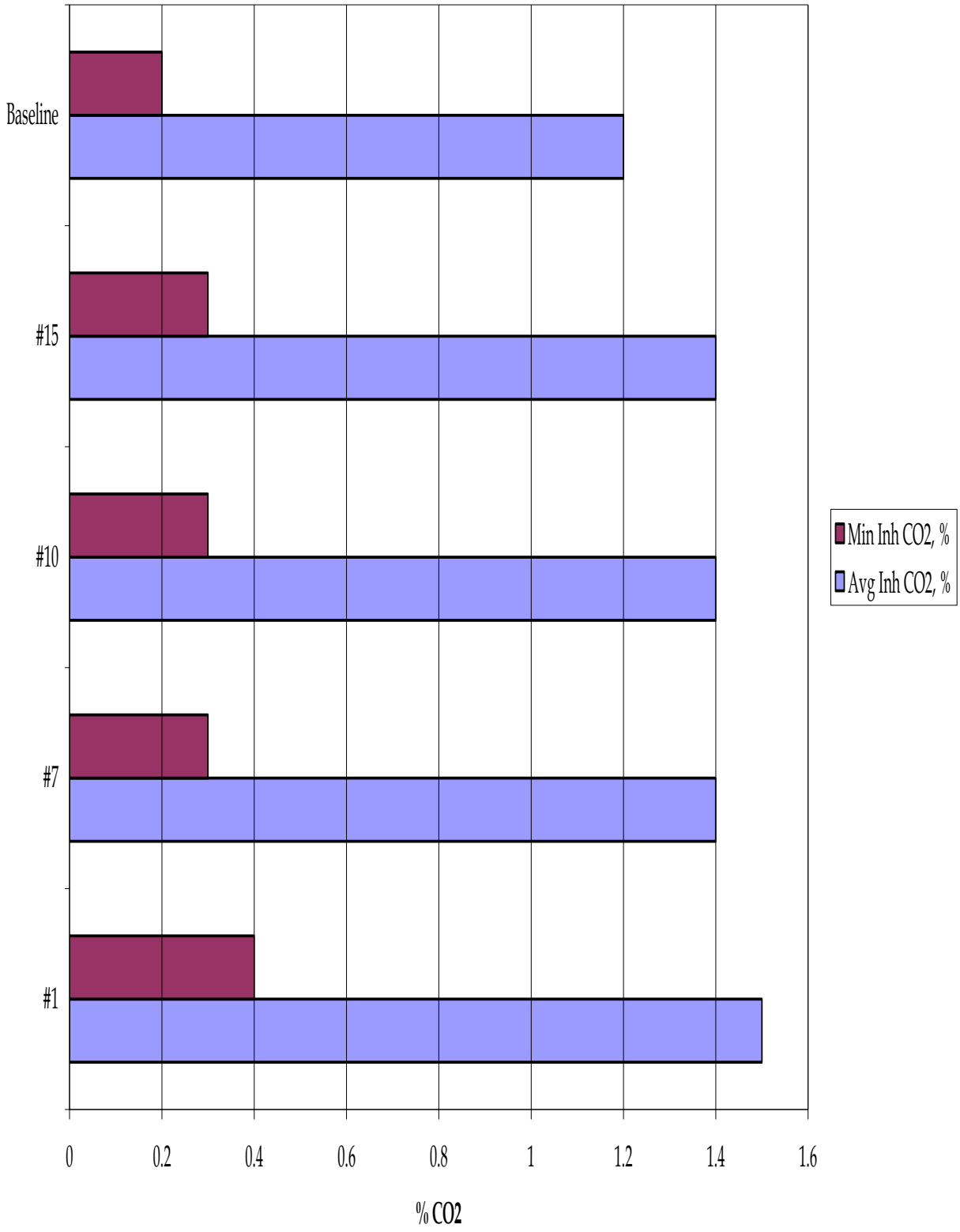

Chart 3d: Inhalation Temperature

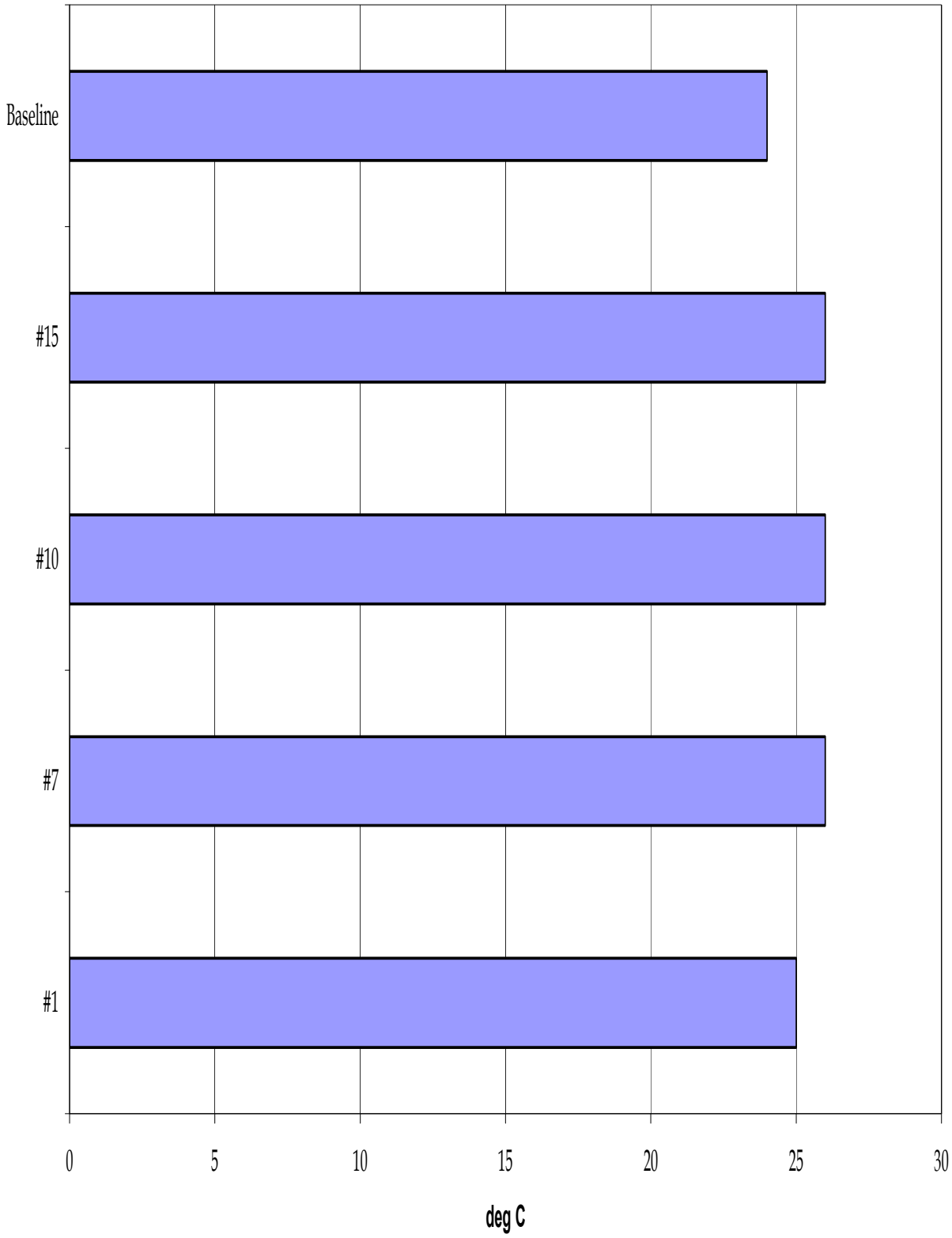

Chart 5a: Breathing Resistance

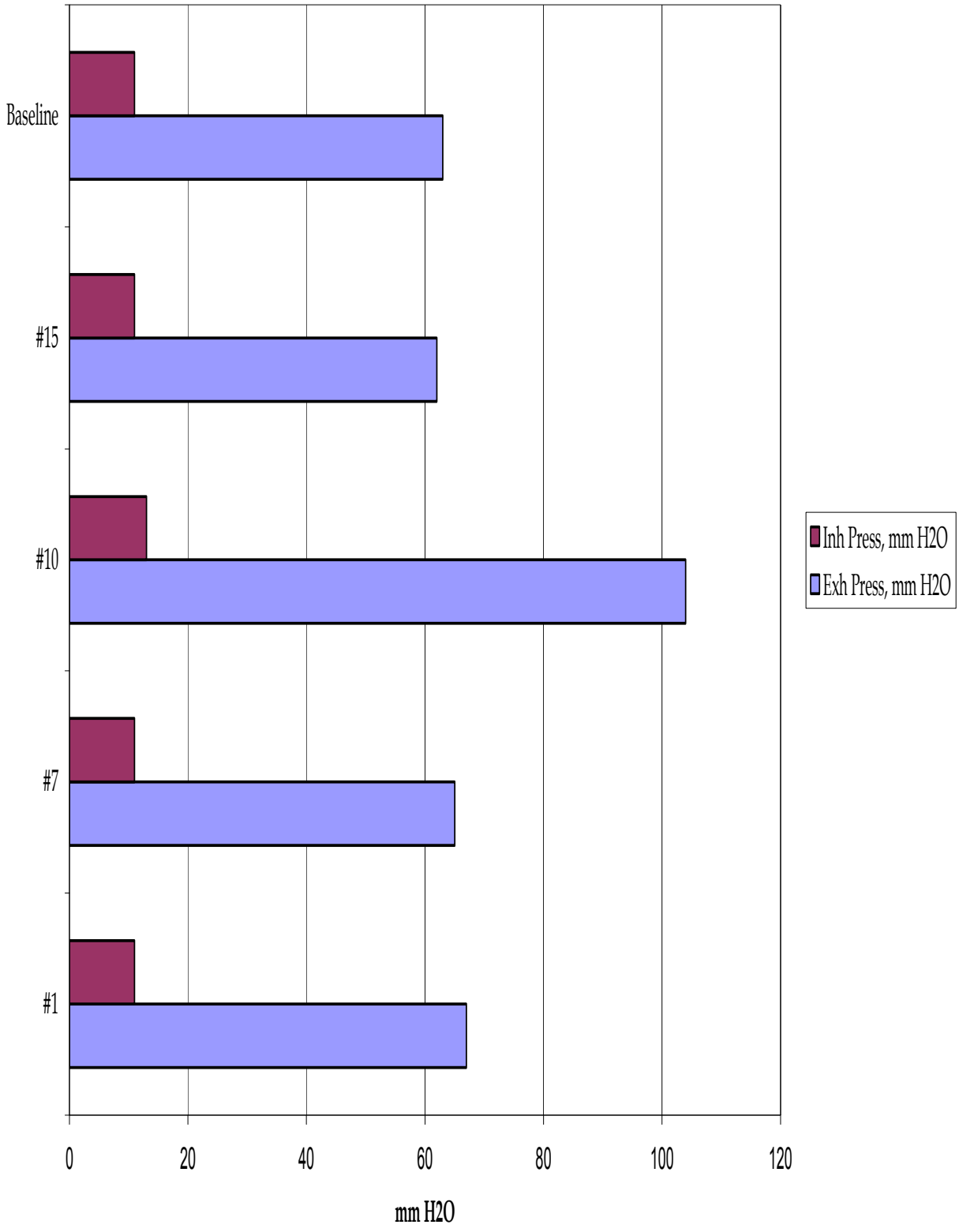

Chart 5b: Oxygen

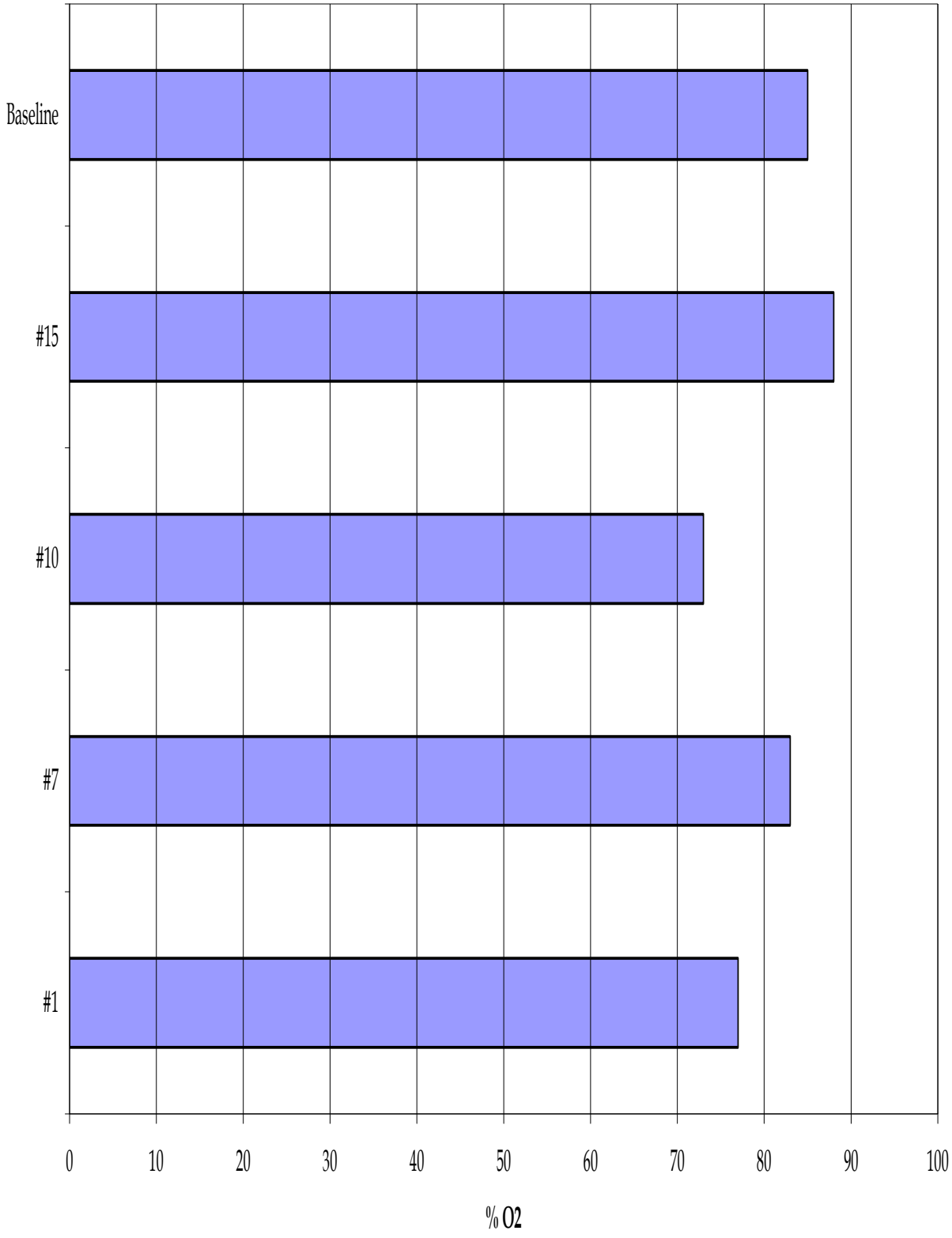

Chart 5c: Scrubber Performance

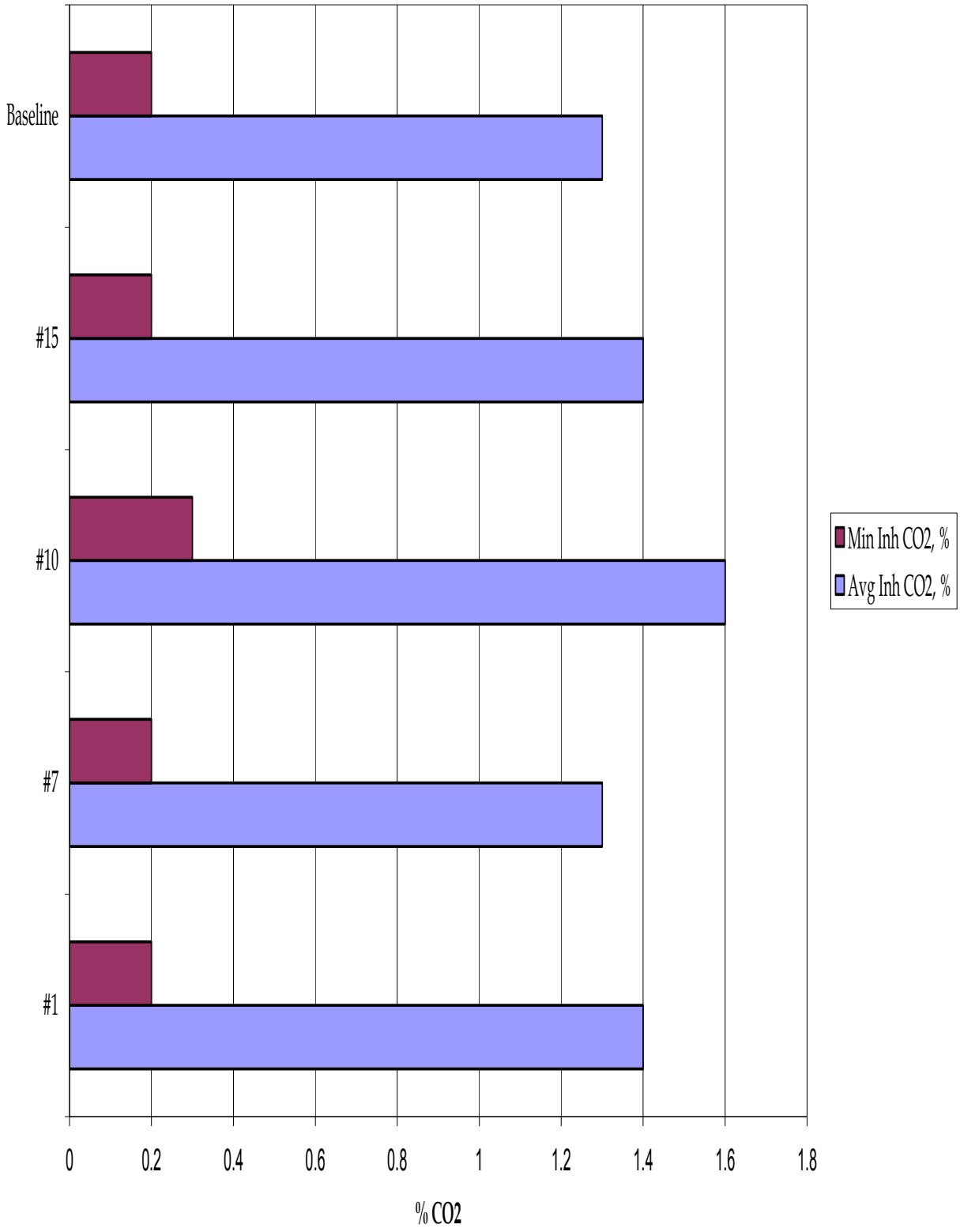

Chart 5d: Inhalation Temperature

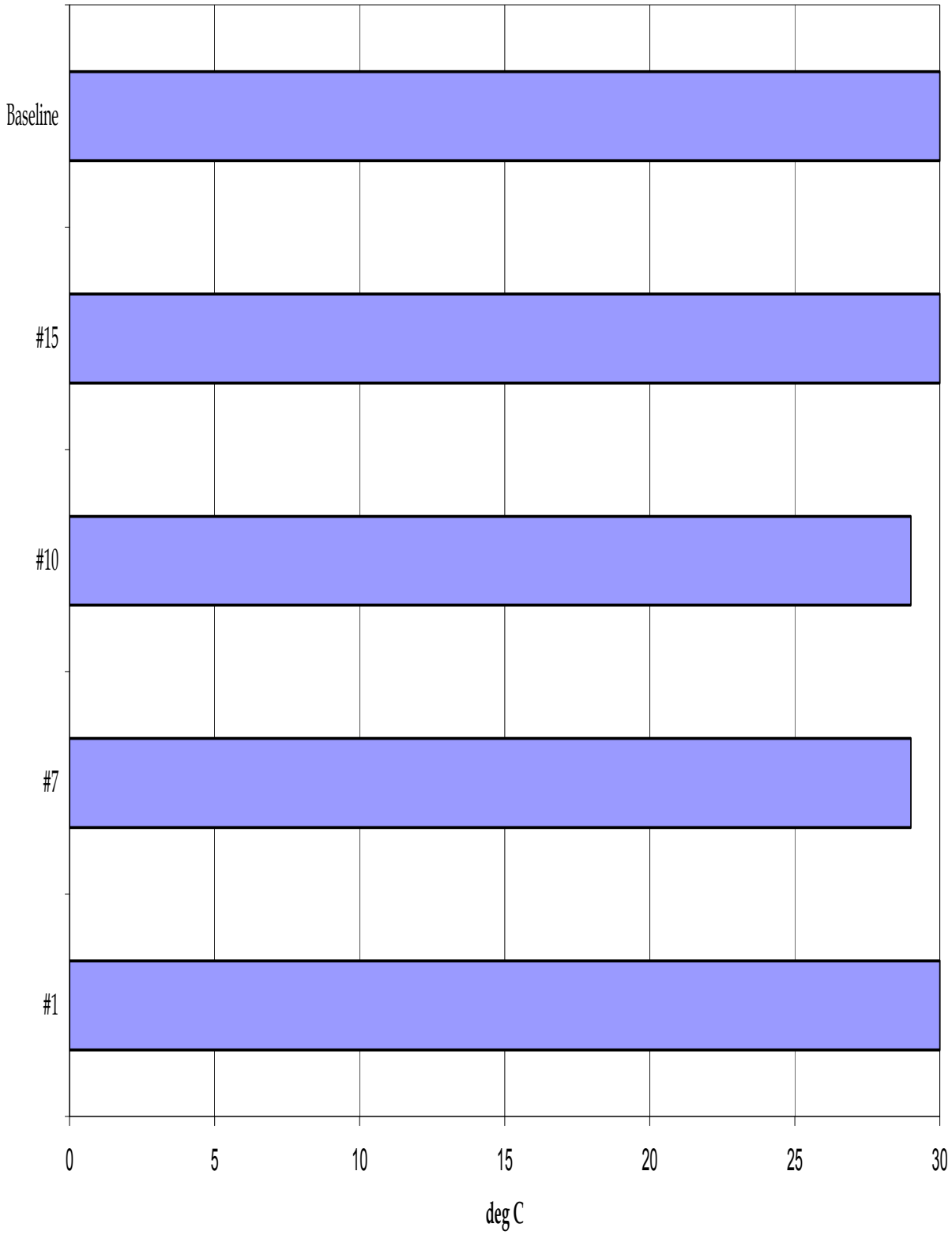

Chart 8a: Breathing Resistance

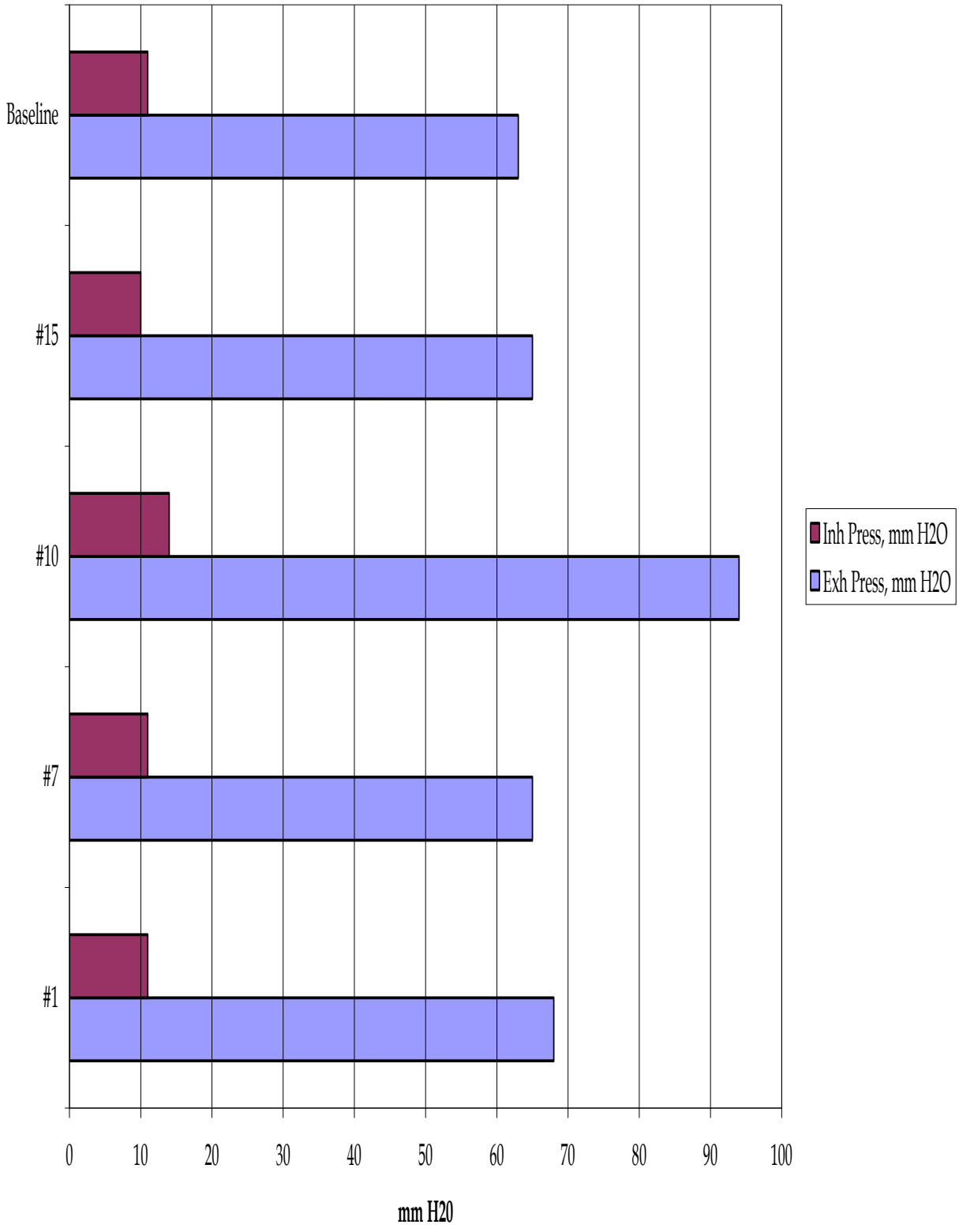

Chart 8b: Oxygen

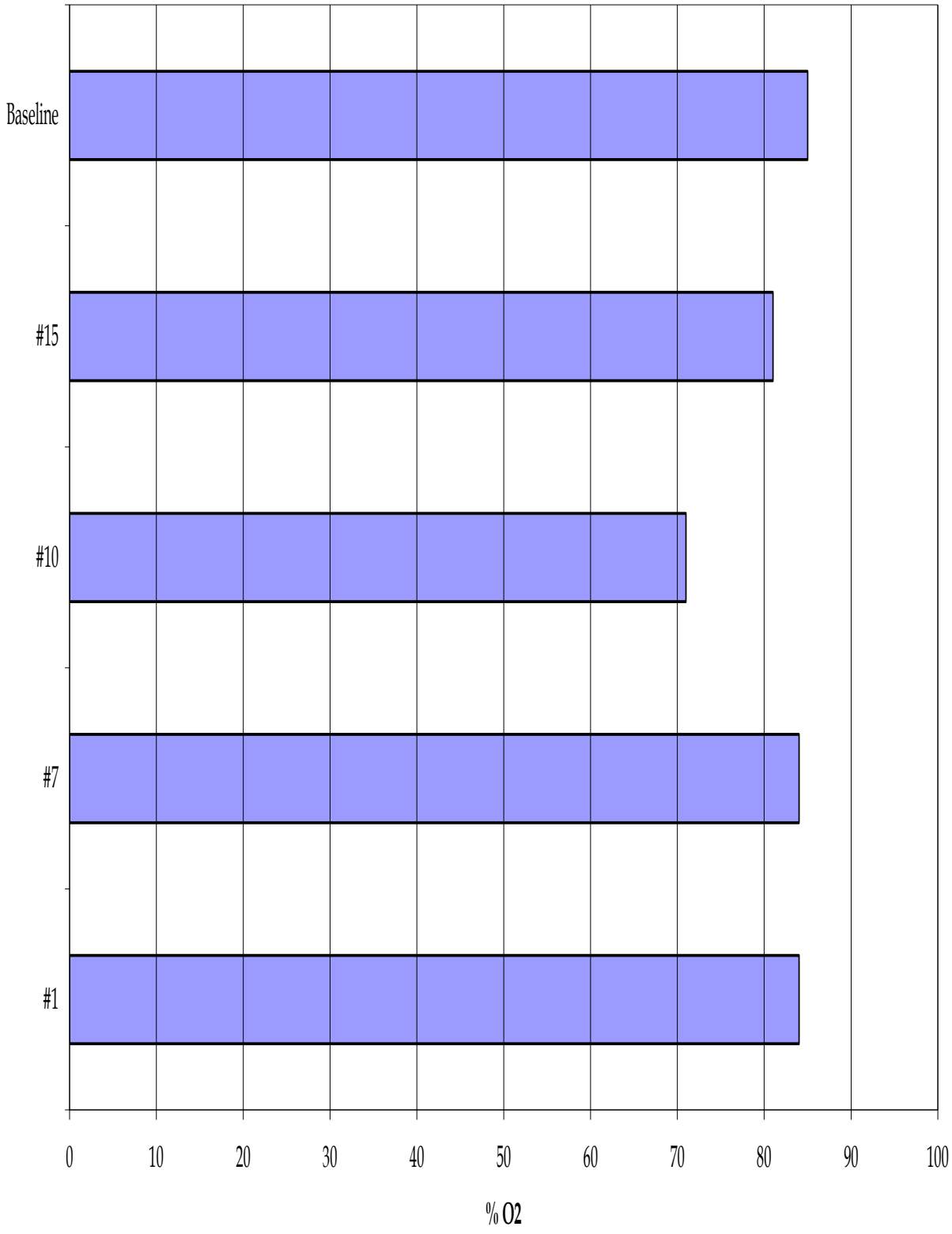

Chart 8c: Scrubber Performance

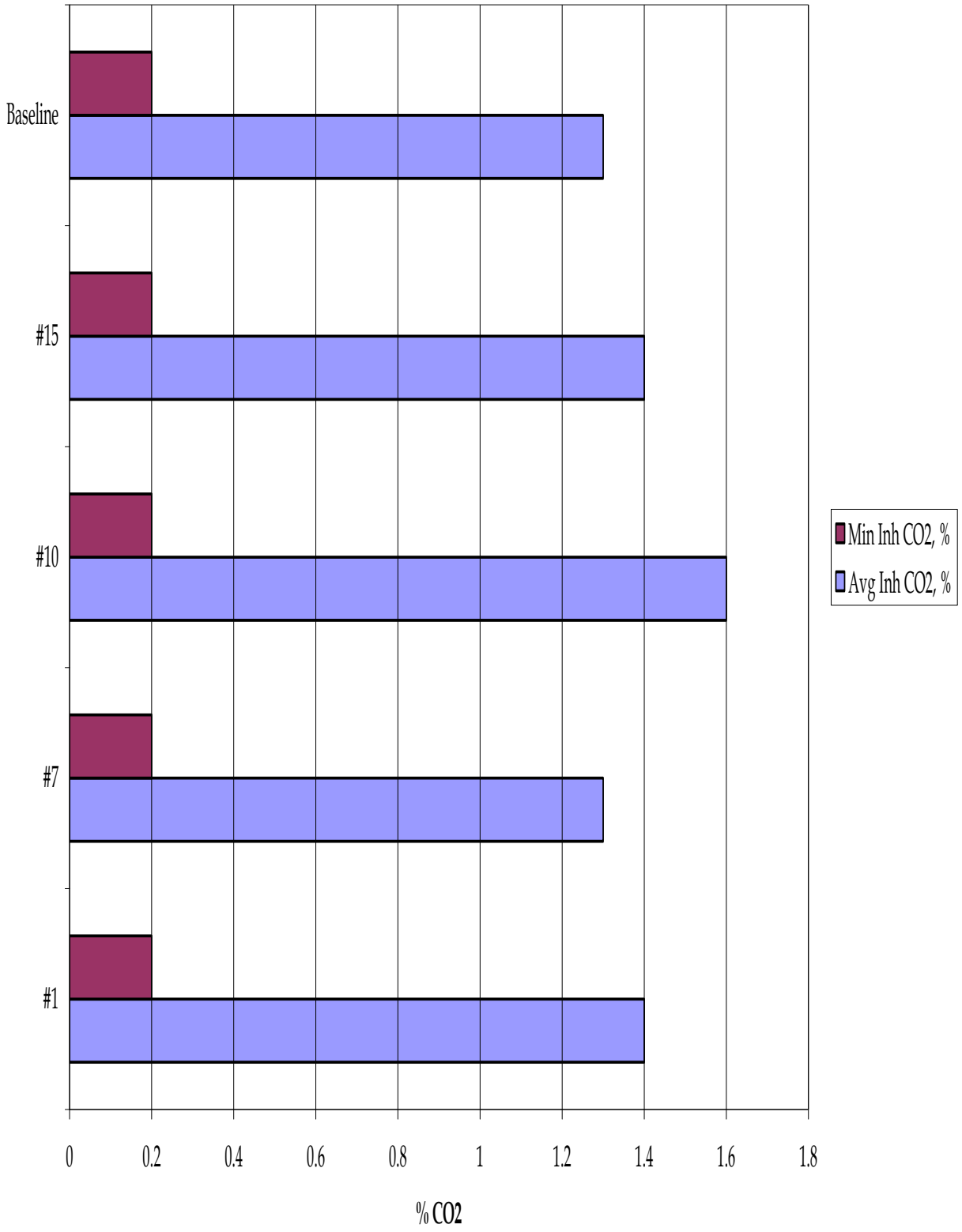

Chart 8d: Inhalation Temperature