OPERATION TOMMYKNOCKER

Test of Survival Equipment

for Underground Refuge Stations

at the

Underground Research Laboratory
Lac du Bonnet, Manitoba

March 04 & 05, 1993

by

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OPERATION TOMMYKNOCKER

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   Letter from R. Sullivan

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Evaluation of the RANA-AIR Mine Refuge Air Centre for Life Support in an Underground Refuge Station

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EXECUTIVE SUMMARY

Operation Tommyknocker was a test to evaluate the Rimer Alco North America Inc. "RANA-AIR Mine Refuge Air Centre," a self-contained system to maintain safe oxygen and carbon dioxide levels for personnel in mine refuge stations under emergency situations.

The evaluation demonstrated that the RANA-AIR system successfully met the test criteria and satisfied the participants and the sponsors. It maintained oxygen at 19.5 to 20.9% (minimum TLV is 18%), and carbon dioxide at less than 2300 ppm (maximum TLV is 5000 ppm) for six volunteers sealed in the refuge station for 24 hours.

The test was conducted in a small station (22 m^3) so gas concentrations would change rapidly. During the first half hour, before the RANA-AIR system was activated, the volunteers were very busy organizing themselves. This activity produced a sharp increase in carbon dioxide concentration. However, shortly after the system was activated, the carbon dioxide was brought under control. The participants found the RANA-AIR system to be "simple and easy" to use. They turned it on, set the oxygen flow, and had no need to make further adjustments.

Carbon dioxide and oxygen gas measurement tubes were used by the volunteers for monitoring. The carbon dioxide tubes worked well, but readings from the oxygen tubes were variable in this application, possibly because of the high humidity. The volunteers also used a Comfocheck instrument developed by AECL Research to measure carbon dioxide, temperature and relative humidity.

The evaluation was performed under the leadership of the Mines Accident Prevention Association of Manitoba (MAPAM) and the Mines Inspection Branch of the Manitoba Department of Labour. They developed functional requirements for the equipment and the evaluation criteria. Rimer Alco developed the RANA-AIR Mine Refuge Air Centre for testing. AECL Research provided a simulated mine refuge station at the 240-metre level in the Underground Research Laboratory facility near Lac Du Bonnet, Manitoba. Six

volunteers from sponsoring MAPAM mining companies used the RANA-AIR system under actual underground conditions.

All the participants were extremely satisfied with the performance of the RANA-AIR Mine Refuge Air Centre. They agreed that it has the potential to enhance mine safety in an emergency situation, and that Rimer Alco should be encouraged to continue development of a production model.

OPERATION TOMMYKNOCKER

Evaluation of the RANA-AIR Mine Refuge Air Centre for Life Support in an Underground Refuge Station

1. INTRODUCTION

Changes in technology and mining methods prompted a review of the requirements for underground refuge stations by the Mines Inspection Branch of the Workplace Safety and Health Division, Manitoba Department of Labour (Mines Inspection Branch), and the Mines Accident Prevention Association of Manitoba (MAPAM). The demand for traditional mine services such as compressed air, water, electricity and communication systems have changed dramatically over the last decade. The introduction of equipment utilizing electric/hydraulic power is rapidly replacing pneumatic equipment, thereby reducing or eliminating the need for compressed-air lines in many workplaces underground. In the absence of compressed-air lines, alternate methods must be established to provide respirable air for refuge stations.

The directors of the MAPAM and representatives from the Mine Inspection Branch defined the operational requirements for an underground refuge station air supply system and developed an evaluation test for the proposed system. The test was to be called Operation Tommyknocker. The name "Tommyknocker" was derived from mining folklore. Tommyknockers are the spirits of trapped miners knocking for food and rescue.

Rimer Alco North America Inc. (Rimer Alco) developed the RANA-AIR Mine Refuge Air Centre according to the directors' requirements. The system was designed to add oxygen and remove carbon dioxide from the atmosphere in an underground refuge station containing trapped personnel. The system was also designed to be rugged, simple and totally self-contained.

Rimer Alco's involvement in Operation Tommyknocker was the result of their interest and awareness of the problem defined by the MAPAM directors and personnel from the Mines Inspection Branch as well as their interest in providing a solution to a potentially dangerous situation.

The directors arranged to have Operation Tommyknocker conducted in a simulated mine refuge station at AECL Research's Underground Research Laboratory (URL) near Lac du Bonnet, Manitoba. AECL developed the URL to carry out geotechnical research relating to the disposal of used nuclear fuel in the plutonic rock of the Canadian Shield. The URL is an important part of the Canadian Nuclear Fuel Waste Management Program and is ideally suited to carry out research projects and tests such as Operation Tommyknocker.

AECL Research's participation in providing a location, professional staff and the many services required for this type of test was done in the true spirit of cooperation. As a member of MAPAM, AECL Research also expressed a keen interest in participation to ensure "safe underground refuge stations."

The simulated refuge station was constructed in a dead-end tunnel in Room 207 on the 240-m level of the URL. The station was approximately 22 m^3 in volume (3.0 x 3.0 x 2.5 m). Six volunteers, representing the types of workers normally found in the mine environment, were isolated in the simulated refuge station and used the RANA-Air Mine Refuge Air Centre for a 24-h period. Technical and medical staff were present in the tunnel outside the refuge station during the test to observe the volunteers and gather environmental and physiological data.

The volunteers were mine personnel from participating MAPAM member companies. MAPAM is a nonprofit organization funded primarily through the Mining Association of Manitoba by the mining companies, mine contracting companies and diamond-drilling companies operating in the Province of Manitoba. Two participants were sent by INCO from Thompson, two were sent by Hudson Bay Mining and Smelting Limited (one from Flin Flon and one from Leaf Rapids), two were provided by The Tantalum Mining Corporation of Canada Limited (Tanco), Lac du Bonnet, and two were provided by AECL Research.

2. SYSTEM REQUIREMENTS

The requirements of the air supply system were defined by the Mines Inspection Branch and MAPAM with the objective of providing a safe respirable refuge environment for confined personnel. It was determined the equipment should:

1. Control oxygen and carbon dioxide concentrations as close to normal levels as possible or at least to nationally accepted safe levels.

   For the evaluation test, the carbon dioxide concentration should be less than the TLV-TWA value of 5000 ppm, and oxygen should be greater than 18%, so the volunteers would not be at risk.

2. Operate without reliance on electric power or compressed air from outside the refuge station for at least 24 h in an emergency situation.

3. Be simple and easy to operate with a minimal training.

4. Be durable and rugged, with a long stand-by life (i.e., years) without use and be able to stand up to the severe environmental conditions present underground, such as cool temperatures, high humidity and concussion from blasting

operations.

5. Affordable cost so the system would be feasible in any mine's safety program.

3. DESCRIPTION OF THE TEST

3.1 Purpose

The purpose of the test was to evaluate how well the RANA-AIR system would meet the requirements defined by the Mines Inspection Branch and the MAPAM directors, and to demonstrate its operation under realistic underground refuge station conditions.

Rimer Alco's objectives going into the test were to:

1. Determine how "simple and easy" the RANA-AIR system is to use.

2. Test the RANA-AIR system's ability to maintain oxygen and carbon dioxide levels as close to atmospheric as possible in underground refuge station conditions.

3. Determine if the monitoring equipment provided with the RANA-AIR system (to measure concentrations of oxygen and carbon dioxide) is effective and appropriate given the experience, training and anxiety of those required to operate it.

The unit had previously been tested by Rimer Alco staff on the surface in a small sealed room simulating a refuge station. To obtain baseline information and to verify the information obtained from the reference literature on rates of oxygen consumption and carbon dioxide production, nine men stayed in the room without adding oxygen or removing carbon dioxide. The results from this preliminary test generally agreed with data from the literature and confirmed the theoretical predictions.

3.2 Selection of Volunteers

Eight volunteers, who were experienced in Manitoba mine rescue procedures, were selected by MAPAM for the test. The volunteers were representative of the type of workers normally found in the underground environment. Prior to the start of the test, six of the eight volunteers were selected for enclosure in the simulated refuge station by the medical doctors during a pre-test medical examination. A briefing was carried out for the participants to explain the purpose of the test. Once they fully understood the operation, the volunteers signed consent forms. The volunteers were briefed on the operation of the monitoring equipment they were to use within the simulated refuge station and the operation of the RANA-AIR system immediately before the start of the test.

3.3 The RANA-AIR Mine Refuge Air Centre

The RANA-AIR system was a prototype unit built to evaluate the simplicity and the effectiveness of this type of equipment under emergency conditions. The system was intended to be rugged and easy to maintain. Measuring 160 mm high, 65 mm wide, and 90 mm deep, it had the capability of sustaining 10 people at rest for 36 h. Systems having a greater capacity can also be made available.

The six volunteer participants were sealed in the simulated refuge station at about 1300 on March 04. They organized themselves and started the RANA-AIR system about half an hour after entering the station.

The oxygen flow rate was set by the volunteers according to their demand. A nominal flow rate of 0.5 L/min per person was set for the test. The oxygen flow from the system was mixed with room air. The room air was circulated by a fan through a built-in carbon dioxide scrubber, which removed carbon dioxide from the atmosphere. Carbon dioxide is a product of breathing and would otherwise build up when the volunteers were confined within the sealed room.

The RANA-AIR system was totally self-contained. The volunteers only have to fill the carbon dioxide scrubber and turn on the oxygen and scrubber. Power was provided by a durable battery that is kept charged when the unit is on standby. The system was designed to be simple and easy to understand so that special skills were not required for its operation. Simple step-by-step instructions requiring a minimum level of training was all that was necessary to operate the system.

Draeger gas measurement tubes were provided as part of the system to monitoring the oxygen and carbon dioxide levels within the refuge station. The volunteer participants were instructed to make adjustments to the oxygen flow of the system based on the oxygen levels measured with the detection tubes. Carbon-dioxide-absorbing material would be changed if the absorber indicated saturation. The object was to maintain oxygen and carbon dioxide levels as close to normal atmospheric conditions as possible (i.e., 20.9% oxygen and less then 0.5% carbon dioxide).

This measurement method was selected because of the long shelf-life of the detection tubes, the ease of use, and measurement tubes are common in underground operations.

Components of the RANA-AIR system were selected for reliability and long standby life. The system was designed for easy maneuvering by personnel with the durability to withstand the ruggedness required for underground transport. It was intended the system would have a minimum 10-year life expectancy, with only periodic checks required.

3.4 Simulated Refuge Station

The simulated refuge station was constructed in a dead-end stub drift on the 240-m level of the URL. It consisted of a room with an excavated volume of 22 m^3 and dimensions of about 3.0 x 3.0 x 2.5 m. An air-tight wall was constructed of nominally 2 x 6 inch lumber, three-quarter inch plywood and plastic film. The room was large enough to accommodate two sets of bunks on either side, thereby providing four beds for sleeping. Two shelves were provided on either end of the room, one above the door. A small Plexiglas window, about 300 x 300 mm, was provided in the wall. A double-door air-lock was provided in the wall to provide an area of about 1 X 1 m.

The normal breathing of the participants resulted in quick changes of oxygen and carbon dioxide levels of the atmosphere within the confined space of the simulated refuge station.

Accessories within the simulated refuge station consisted of blankets, pillows, individually wrapped sandwiches, muffins, chocolate bars, juice, coffee, cards, magazines and TV and video player. A portable toilet was placed within the entrance air lock to provide privacy and control odour.

3.5 Safety

The purpose of the test was to evaluate the performance of the RANA-AIR system, not the reaction of the participants to confinement and isolation. The participants were volunteers who were healthy, free from any medical afflictions, and typical of individuals normally working underground. The following guidelines were used to select the participants:

1. normal vital signs,
2. normal heart and lung function,
3. normal mental psychological status (no phobias),
4. free from need to take medication, and
5. non-smokers.

Pre-test and post-test medical examinations of the volunteers were carried out by the two medical doctors involved in the test.

Technical representatives and a medical doctor were present during the entire test to ensure the necessary monitoring of the simulated refuge station atmosphere was carried out on a continuous basis and that the health of the participants was not jeopardized during the test. Before the test commenced, it was decided that the test would be aborted at any time if the participants felt threatened, wanted to leave the simulated refuge station, or the medical doctor felt the conditions were becoming a threat to their health or otherwise hazardous.

The atmosphere of the simulated refuge station was monitored during the test by the volunteer participants from within the

station and independently by observers located outside the station. The atmosphere was maintained within the Threshold Limit Value (TLV) identified in the Manitoba Mining Regulations. Oxygen levels were not allowed to drop below 18.0% [1] and the carbon dioxide level was not allowed to rise above 0.5% [2] for more than one-half hour during the test. The short-term exposure limit is 5000 ppm [2].

It was intended that the test would not push the equipment to its limit or endanger the safety of the participants. The RANA-AIR system was designed with an oxygen supply for 360 person-hours. For six people, this would be 60 h in the anticipated mine refuge station conditions. The carbon dioxide absorber system had a capacity to operate for 144 person-hours. Enough absorber was placed within the simulated refuge station to fill the system twice, giving a total duration of 288 person-hours. For the purposed of Operation Tommyknocker, the system was set up to accommodate six people for a minimum of 48 h, or twice the maximum duration of the test.

The capacities are based on the selected values of 0.5 L/min oxygen and carbon dioxide per person. The nominal values cited in the literature for astronauts or submariners are 0.42 L/min oxygen and 0.35 L/min carbon dioxide [3]. These values are for people at rest or subject to little physical activity. Strenuous exercise will result in higher values. The selected values are greater than the nominal values to allow for any stress that may have arisen during Operation Tommyknocker because of the confined space.

Individual monitoring of all participants during confinement was carried out by one of the participants who was a Emergency Medical Assistant 1 (EMA-1). The following vital signs were recorded at regular intervals (i.e., about 1-h intervals):

1. blood pressure,
2. pulse, and
3. respiration rate.

A personal log was kept by each of the participants to record changing conditions within the simulated refuge station and his own physical and mental status (e.g., to note such things as drowsiness, odours, fumes, physical changes, mental attitude).

3.6 Atmospheric Monitoring

Continual monitoring of the atmosphere inside the simulated refuge station was provided for the following parameters:

1. oxygen level (%),
2. carbon dioxide level (%, ppm),
3. temperature (°C), and
4. relative humidity (%).

Measuring equipment used inside the refuge station by the volunteers consisted of a Comfocheck instrument for measuring carbon dioxide concentration, temperature and relative humidity, and a sling psychrometer for measuring relative humidity. The Comfocheck unit, which was located on top of the RANA-AIR system near the scrubber outlet, was set to record data every 16 s.

Manual monitoring of oxygen and carbon dioxide concentrations was carried out by the volunteer participants with gas tubes as well. Draeger gas measurement tubes were used to detect oxygen and Gastech tubes were used for carbon dioxide.

In addition, the volunteers provided other equipment from their respective mines, including an Industrial Scientific system (for oxygen concentration measurements) and a Kanomax system (for temperature and relative humidity).

A second Comfocheck instrument, located inside the simulated refuge station on a shelf beside the window, was connected via a cable that passed through a sealed hole to a computer located outside. This Comfocheck unit was set to record carbon dioxide concentration, temperature and relative humidity automatically every 5 min.

Two sampling tubes were passed through sealed bulkhead fittings in the Plexiglas window. The intake for one tube was located adjacent to the Comfocheck instrument on the shelf near the top of the door, while the other sampled from the output of the carbon dioxide scrubber. Valves located at the bulkhead were used to seal the tubes when not in use for measurement. The tubes delivered sample air to two Servomex model 571 oxygen analyzers used to measure oxygen concentrations. The oxygen analyzers were calibrated with tanks of nitrogen (0% oxygen) and 100% oxygen. A Gastech carbon dioxide analyzer (range 0 - 5000 ppm) was used to measure carbon dioxide. The carbon dioxide analyzer was calibrated against a Comfocheck analyzer before the test began.

A third Comfocheck instrument was set up outside the simulated refuge station to monitor the outside atmosphere at the 240-m level. This unit also recorded data every 5 min.

A mercury barometer was installed to record changes in atmospheric pressure outside the refuge station. A water manometer was installed through the window located in the wall of the station to monitor any difference in pressure inside and outside the refuge station. Pressure readings and humidity measurements made with the sling psychrometer were recorded every hour.

Dale thermistors (Model IC-3001-C3) coupled to a switch box and precision ohmeter were used to monitor temperatures at various locations within the simulated refuge station and outside the station. The thermistors were placed as follows:

1. Thermistor T1 was suspended from the back of the simulated refuge station about 150 mm from the rock surface.

2. Thermistor T2 was located 1.5 m above the floor about 150 mm from the back wall of the simulated refuge station.

3. Thermistor T3 was located 150 mm above the floor near the back wall of the simulated refuge station.

4. Thermistor T4 was located at the in-flow port of the RANA-AIR system.

5. Thermistor T5 was located at the out-flow port of the RANA-AIR system.

6. Thermistor T6 was located outside the simulated refuge station, under one of the tables, about 750 mm above the floor.

3.7 Comfocheck System

The Comfocheck Model I101-A system was developed by AECL Research. The system is designed to monitor the climate in an indoor working environment. The system measures the following parameters:

1. Temperature:	range	-10 to 40°C,
	accuracy	+\- 0.5°C,
	resolution	0.2°C.
2. Relative Humidity:	range	10% to 90% RH,
	accuracy	+\- 3.5%,
	resolution	1% RH
3. Carbon Dioxide:	range	0 to 4500 ppm,
	accuracy	+\- 100 ppm,
	resolution	+\- 50 ppm.

The Comfocheck system was designed for users who are not necessarily specialists in this field. The system weighs about 912 g and has dimensions of 215 x 140 x 60 mm. It consists of an instrument case, software for a desk or laptop PC and a cable to link the instruments to a personal computer. This system makes indoor climate monitoring practical and economical.

Temperature is sensed by a platinum resistance temperature device, relative humidity by a capacitance sensor and carbon dioxide concentration by a patented infrared absorption cell. Each sensor and its associated circuit are individually calibrated before the Comfocheck is shipped.

The Comfocheck instrument can be operated in either a "spot-check" or a "data-log" mode. The spot-check mode is used to quickly evaluate the current conditions. The data-logging mode is used to determine how the indoor climate varies over longer periods of time without the need for an operator to record the data.

All three Comfocheck instruments were calibrated on the afternoon

of March 03, the day before the test, using standard calibrating procedures. Carbon dioxide response was calibrated using three standards, 0, 876 and 3950 ppm. Relative humidity readings were calibrated at two levels, 33% and 75% RH. A linear relationship between the output and the RH is specified by the manufacturer. The temperature response was calibrated against thermistors over the range of 5 to 35°C, and was rechecked against a high-precision glass thermometer at room temperature. Immediately prior to the start of the test, the carbon dioxide response was verified at 500 ppm and was varified again at the end of the test using 2000-ppm standards. Instruments inside the refuge station were within specifications both before and after the test. The instrument outside the station showed a slightly lower value (1875 ppm) than expected for the 2000-ppm standard. As these outside data are only of secondary importance, the data were not corrected for what appears to be a very slight drift in the results. The Gastech carbon dioxide analyzer was calibrated to the reading of a calibrated Comfocheck instrument to ensure measurement consistency.

3.8 Supporting Personnel

The following personnel were required to support the test over the 24-h period:

1. Two medical doctors.
2. Two surveyors to record data outside the simulated refuge station.
3. MAPAM representative/test supervisor.
4. Three Department of Labour representatives.
5. Two record keepers/inspectors.
6. Two Rimer Alco representatives.
7. One photographer/video operator.

4. TEST RESULTS

4.1 Oxygen Levels and Measurement

The RANA-AIR system was turned on about 26 min after the start of the test. The volunteer participants set the oxygen flow rate at the value recommended by Rimer Alco in the operating directions at this time (0.5 L/min per person), and after one small adjustment to the flow rate, did not make any further setting adjustments for the duration of the test. Figure 1 shows the oxygen levels over the 24-h duration of the test. The oxygen level remained quite stable, between 19.5% and 20.9%.

Some difficulty with the oxygen detection tubes was experienced during the test. The detection tubes provided reliable readings of oxygen levels at the beginning of the test. However, after about 6 h, the detection tubes indicated oxygen levels as high as 26%. This difficulty may have been related to the humidity inside the simulated refuge station, which reached a very high level

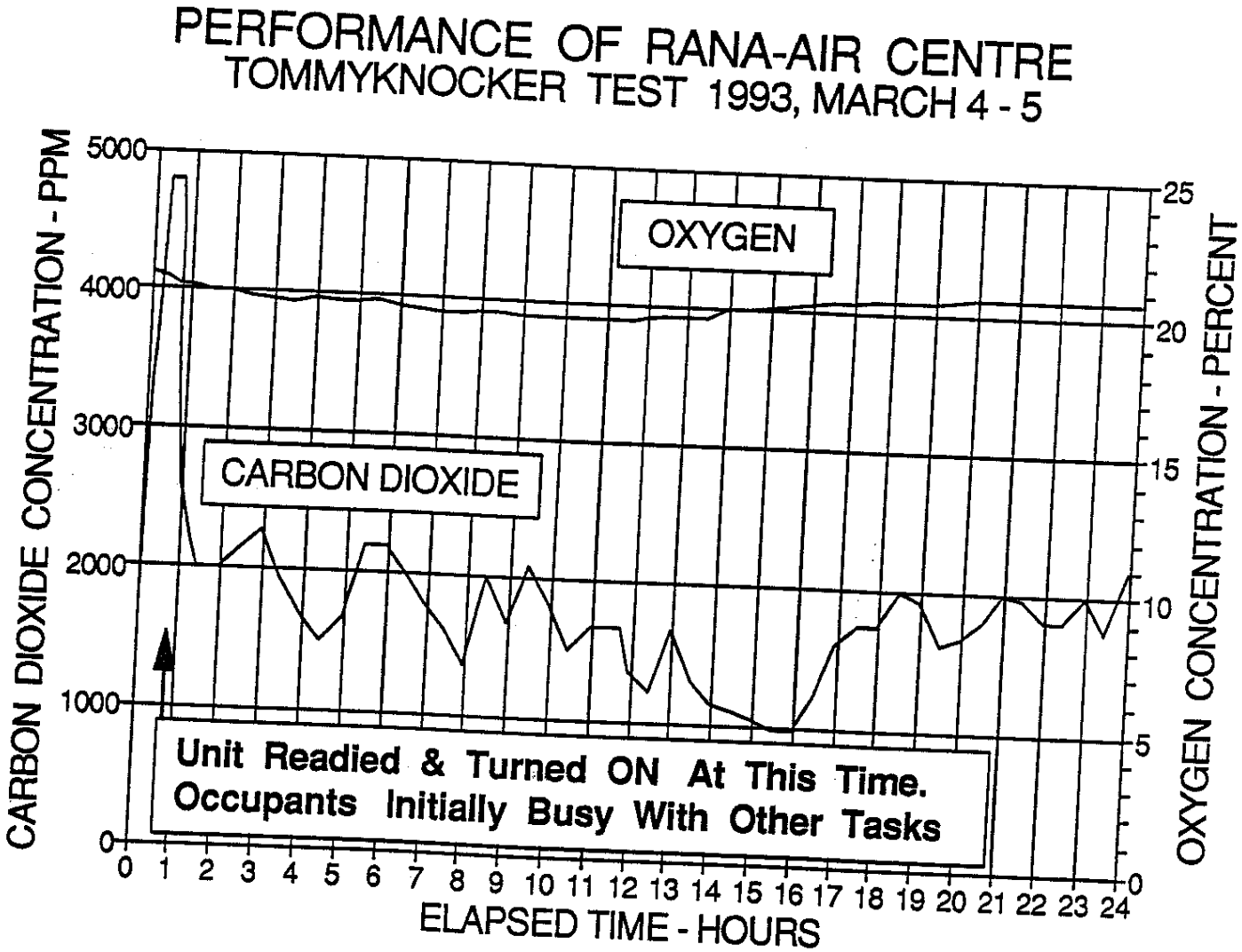
PERFORMANCE OF RANA-AIR CENTRE
TOMMYKNOCKER TEST 1993, MARCH 4 - 5
CARBON DIOXIDE CONCENTRATION - PPM
5000
4000
3000
2000
1000
0
OXYGEN
CARBON DIOXIDE
Unit Readied & Turned ON At This Time.
Occupants Initially Busy With Other Tasks
25
20
15
10
5
0
OXYGEN CONCENTRATION - PERCENT
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ELAPSED TIME - HOURS

Figure 1

(about 90%) after about 2 h. The oxygen measurement was made using a dryer tube connected before the measuring tube. It was intended that each dryer tube be used with four measuring tubes. Initially, the volunteer participants were able to use from one to three measurement tubes with each dryer tube before the oxygen level readings became erratic.

The volunteer participants felt very comfortable during the test and experienced no desire to change the oxygen flow rate on the RANA-AIR system after the initial setup.

4.2 Carbon Dioxide Levels

As shown in Figure 1, carbon dioxide levels increased rapidly upon commencement of the test. The analyzers saturated at about 4800 ppm, but the peak level was actually greater. This was because there was some delay, about 26 min, before the volunteer participants started the RANA-AIR system operating. During this time they were very active while organizing themselves and arranging everything inside the refuge station. Within 7 min after the RANA-AIR system was started, the carbon dioxide level was reduced to 5000 ppm.

The initial high carbon dioxide spike was logged to off-scale readings at 16-s intervals, and these data are plotted in Figure 2. From this plot it is apparent that the carbon dioxide level reached 8000 ppm, which can be attributed to the delay in starting the RANA-AIR system. The value of 8000 ppm was within the short-term TLV of 30 000 ppm [2]. The volunteer participants all reported that they experienced a slight headache at this time. However, once the RANA-AIR system was operating, the carbon dioxide levels quickly reduced to a stable level of about 2000 to 2300 ppm. The volunteer participants reported that their headaches did not persist once the system was turned on.

After about 18 h of operation, about 1 cm of the carbon dioxide adsorbing material started to change its colour to a slightly pinkish tinge.

The carbon dioxide levels fluctuated between 1000 ppm and 2300 ppm during most of the test. It was noted that the levels were lowest 8 to 18 h after the test commenced, at times when some or all of the volunteer participants were sleeping.

The gas detection tubes used to measure carbon dioxide levels worked effectively during the test.

Figures 3 and 4 show the Comfocheck data for the units located beside the window and on top of the scrubber respectively. An absolute agreement between the two instruments inside the simulated refuge station should not be expected because the units were sampling different areas. Occupants exhaling in the vicinity of one instrument or the other would cause local maxima. However, as seen in the two figures, the two instruments do track each other very closely, rarely differing by more than 200 ppm.

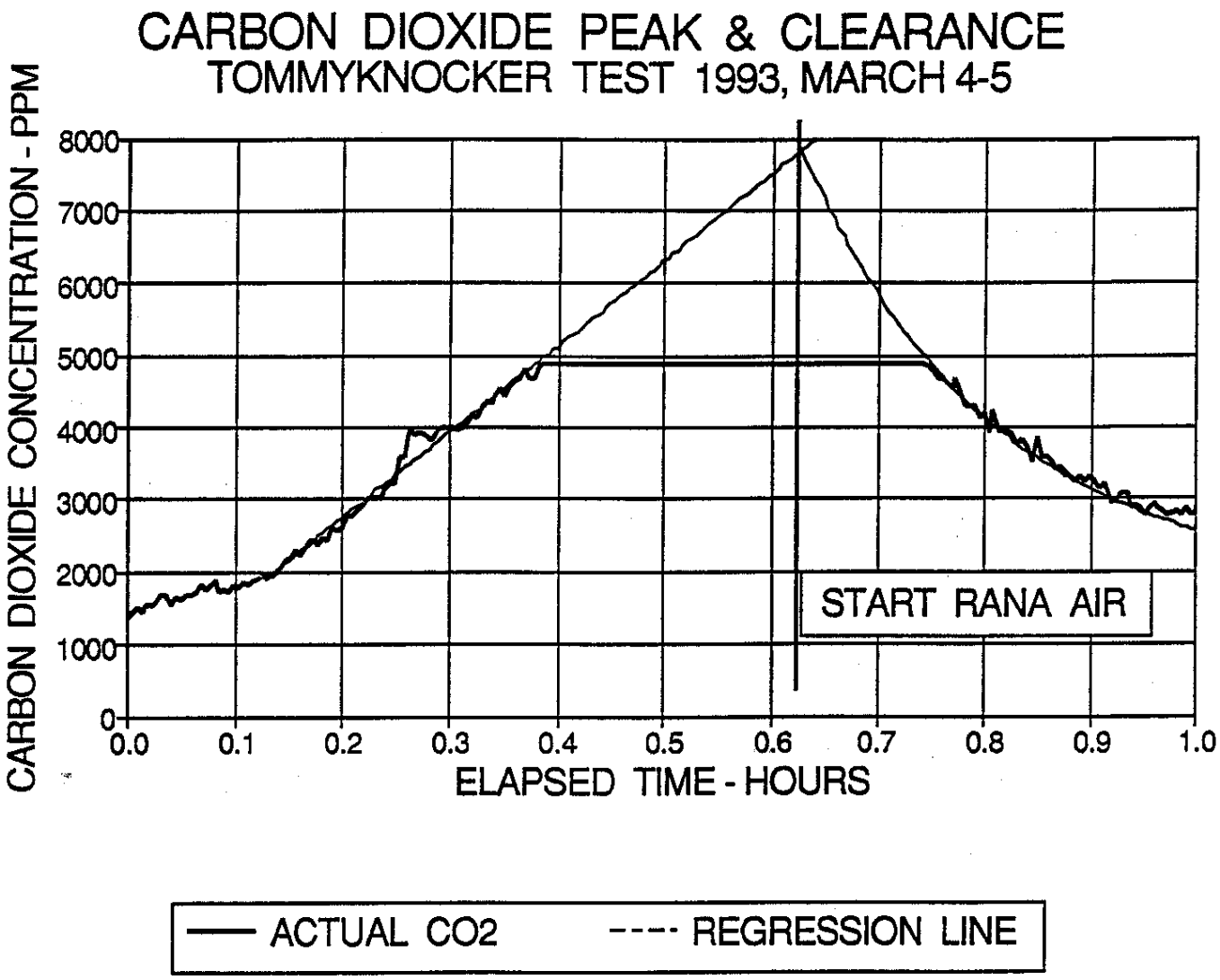
CARBON DIOXIDE PEAK & CLEARANCE
TOMMYKNOCKER TEST 1993, MARCH 4-5
CARBON DIOXIDE CONCENTRATION - PPM
8000
7000
6000
5000
4000
3000
2000
1000
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
ELAPSED TIME - HOURS
START RANA AIR
ACTUAL CO2
REGRESSION LINE

Figure 2

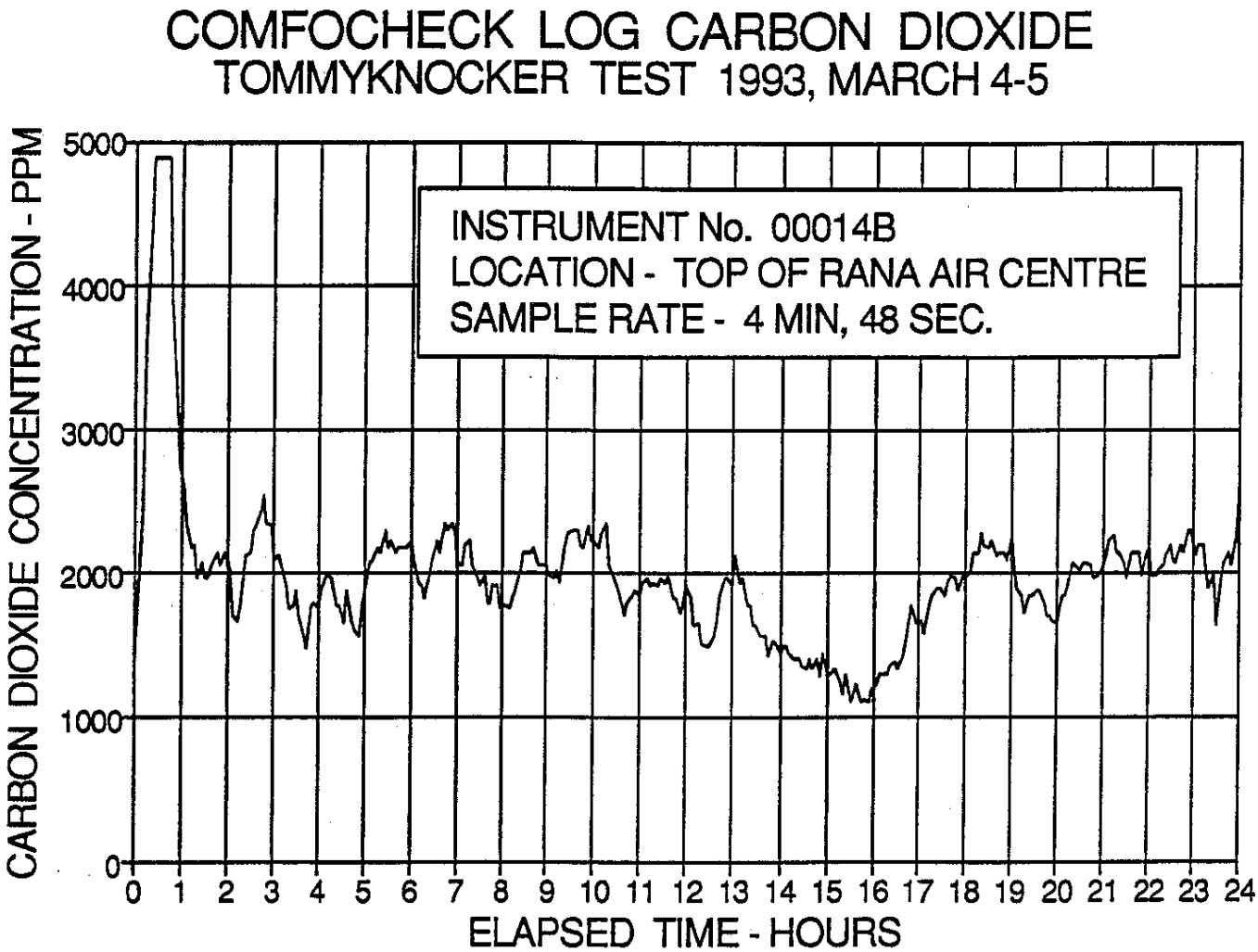
COMFOCHECK LOG CARBON DIOXIDE
TOMMYKNOCKER TEST 1993, MARCH 4-5
INSTRUMENT No. 00014B
LOCATION - TOP OF RANA AIR CENTRE
SAMPLE RATE - 4 MIN, 48 SEC.
CARBON DIOXIDE CONCENTRATION - PPM
5000
4000
3000
2000
1000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ELAPSED TIME - HOURS

Figure 3

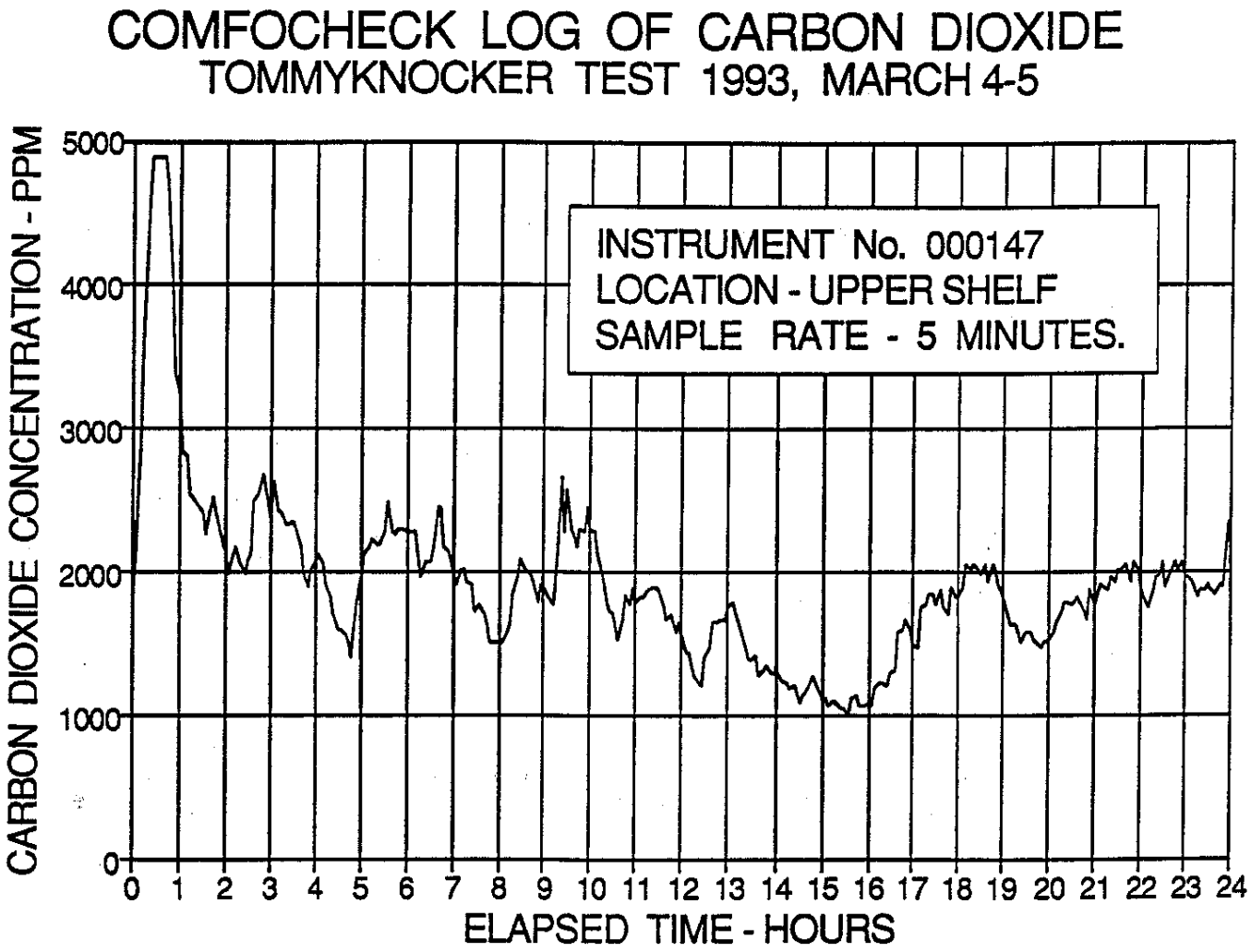
COMFOCHECK LOG OF CARBON DIOXIDE
TOMMYKNOCKER TEST 1993, MARCH 4-5
INSTRUMENT No. 000147
LOCATION - UPPER SHELF
SAMPLE RATE - 5 MINUTES.
CARBON DIOXIDE CONCENTRATION - PPM
5000
4000
3000
2000
1000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ELAPSED TIME - HOURS

Figure 4

The carbon dioxide levels outside the simulated refuge station were about 800 ppm, as shown in Figure 5. This is somewhat higher than normal atmospheric air, which is less than 300 ppm. This higher than usual level occurred because the URL ventilation air is heated with "in-stream" propane heaters located in the fresh-air intake at the surface. The carbon dioxide combustion product is mixed with the incoming air.

The carbon dioxide concentration outside the station just before the volunteers entered the station was slightly higher, likely because there were many people active in the area to assist with the preparations for the test.

The carbon dioxide concentrations outside the refuge station showed a minimum around 1800 on March 04 at the start of the test, and a steady rise to a maximum near 0800 the next morning, corresponding inversely with surface daily maximum and minimum temperatures. This was because of the thermostat setup on the surface propane heaters, which will increase the heater output as the outside temperature decreases.

A sharp peak outside the station approximately 15.5 h into the test is attributed to someone leaning over the Comfocheck instrument at that moment to examine it.

4.3 Relative Humidity

Figure 6 show the relative humidity outside the station. The outside humidity varied between 70% and 80%. This is normal for the URL underground atmosphere during the winter months when the propane heaters are in use. The combustion products of propane are carbon dioxide and water vapour.

The relative humidity measured by the two Comfocheck units inside the simulated refuge station is shown in Figures 7 and 8. Both units indicated that the relative humidity increased rapidly within the first hour of the test to a maximum value. The Comfocheck was not calibrated to 100% humidity and in fact the RH sensor is only guaranteed to a 90% calibration level. Values above 90% can only be interpreted as tracking humidity changes in a qualitative way. Since the volunteers exhaled considerable amounts of water vapour, it may be expected that the actual relative humidity was approximately 100%.

The Comfocheck unit located on the shelf beside the window was positioned with its sensor within 30 to 50 mm of the rock surface, which was cooler than the air. As the scrubber also removes water from the air to a limited degree, one would expect the unit located on top of the RANA-AIR unit would show somewhat lower values, as it did.

The humidity, as described by the volunteer participants, became very apparent a few hours into the test. Clothing that was taken

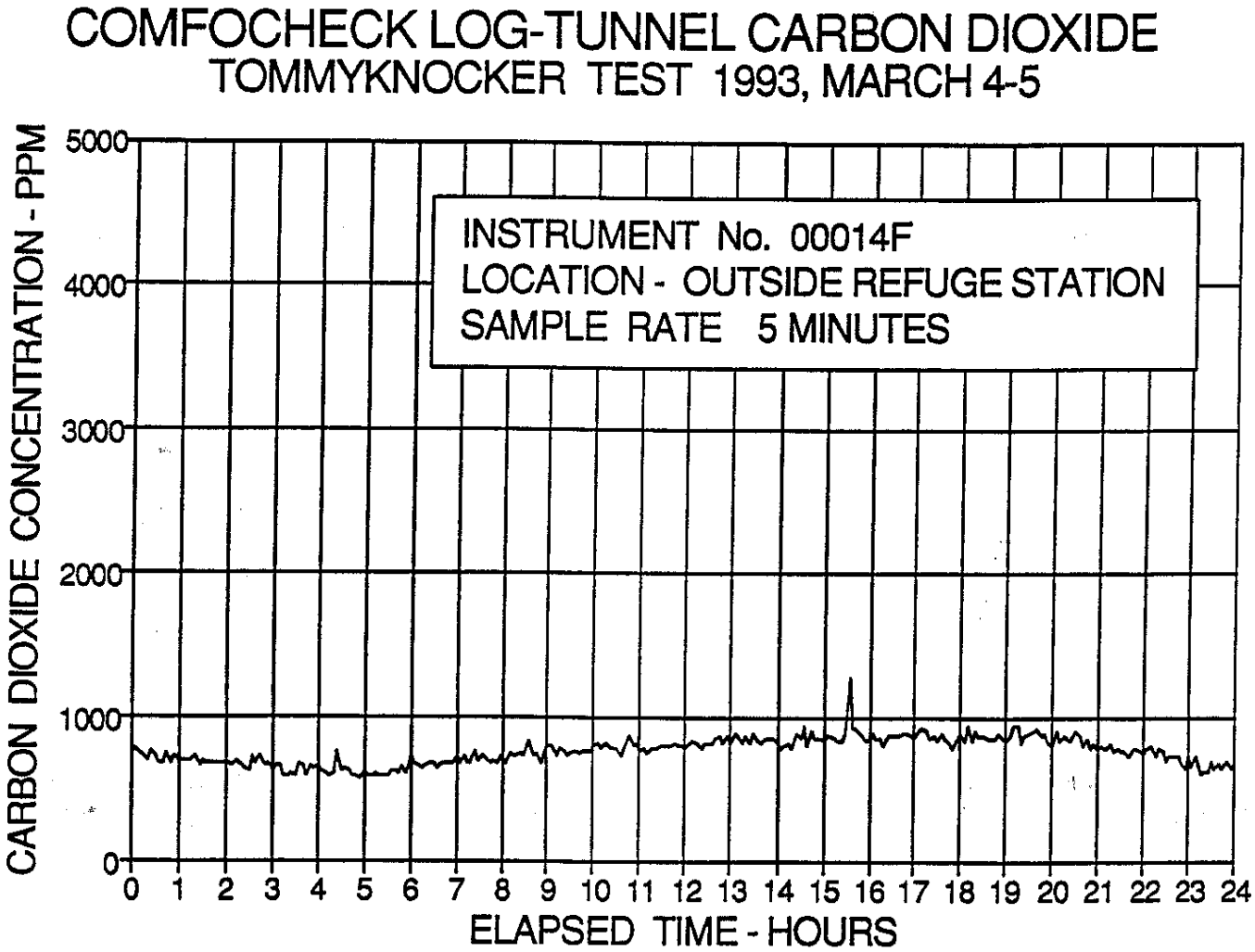
COMFOCHECK LOG-TUNNEL CARBON DIOXIDE
TOMMYKNOCKER TEST 1993, MARCH 4-5
INSTRUMENT No. 00014F
LOCATION - OUTSIDE REFUGE STATION
SAMPLE RATE 5 MINUTES
CARBON DIOXIDE CONCENTRATION - PPM
5000
4000
3000
2000
1000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ELAPSED TIME - HOURS

Figure 5

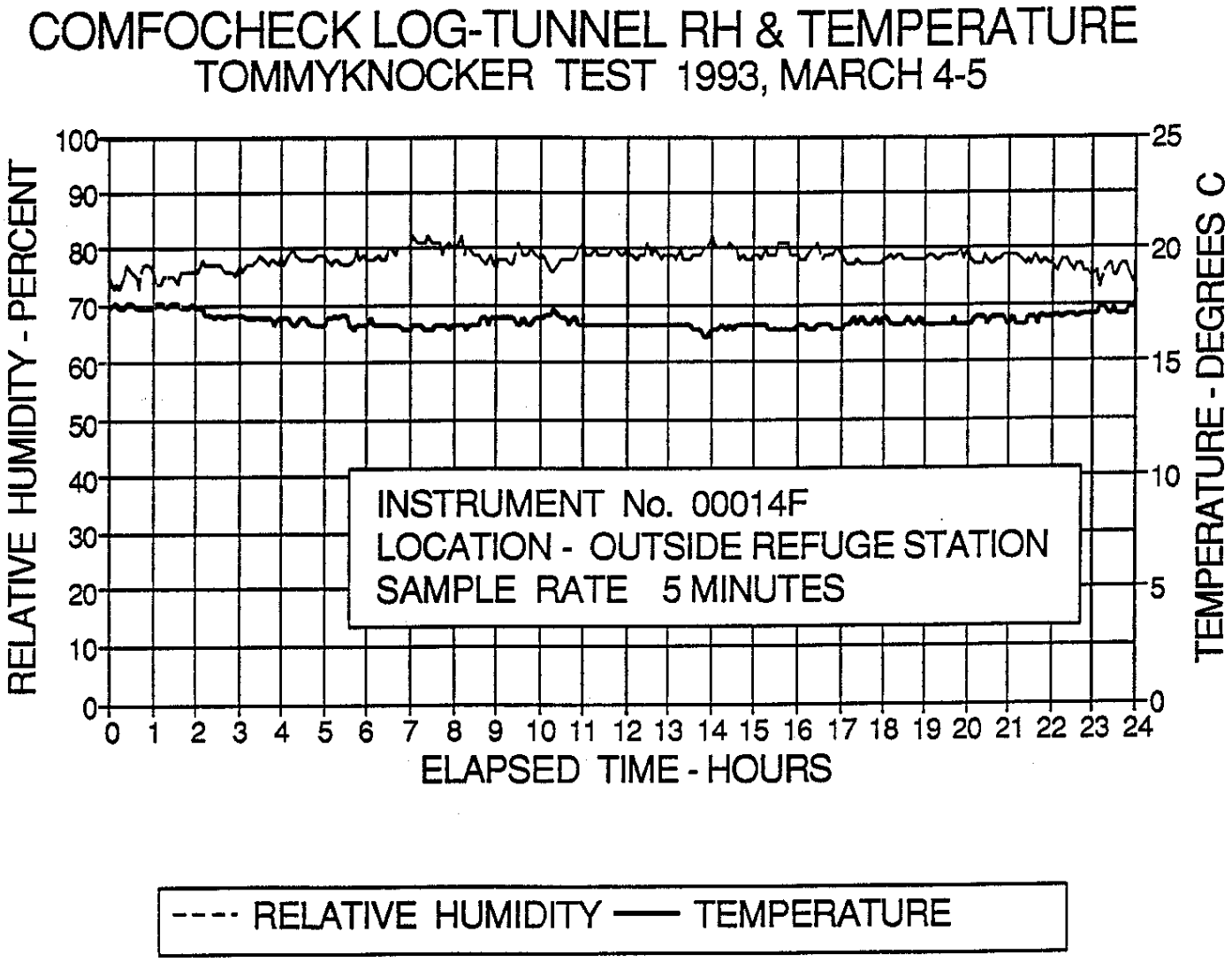
COMFOCHECK LOG-TUNNEL RH & TEMPERATURE
TOMMYKNOCKER TEST 1993, MARCH 4-5
RELATIVE HUMIDITY - PERCENT
TEMPERATURE - DEGREES C
ELAPSED TIME - HOURS
INSTRUMENT No. 00014F
LOCATION - OUTSIDE REFUGE STATION
SAMPLE RATE 5 MINUTES
---- RELATIVE HUMIDITY —— TEMPERATURE

Figure 6

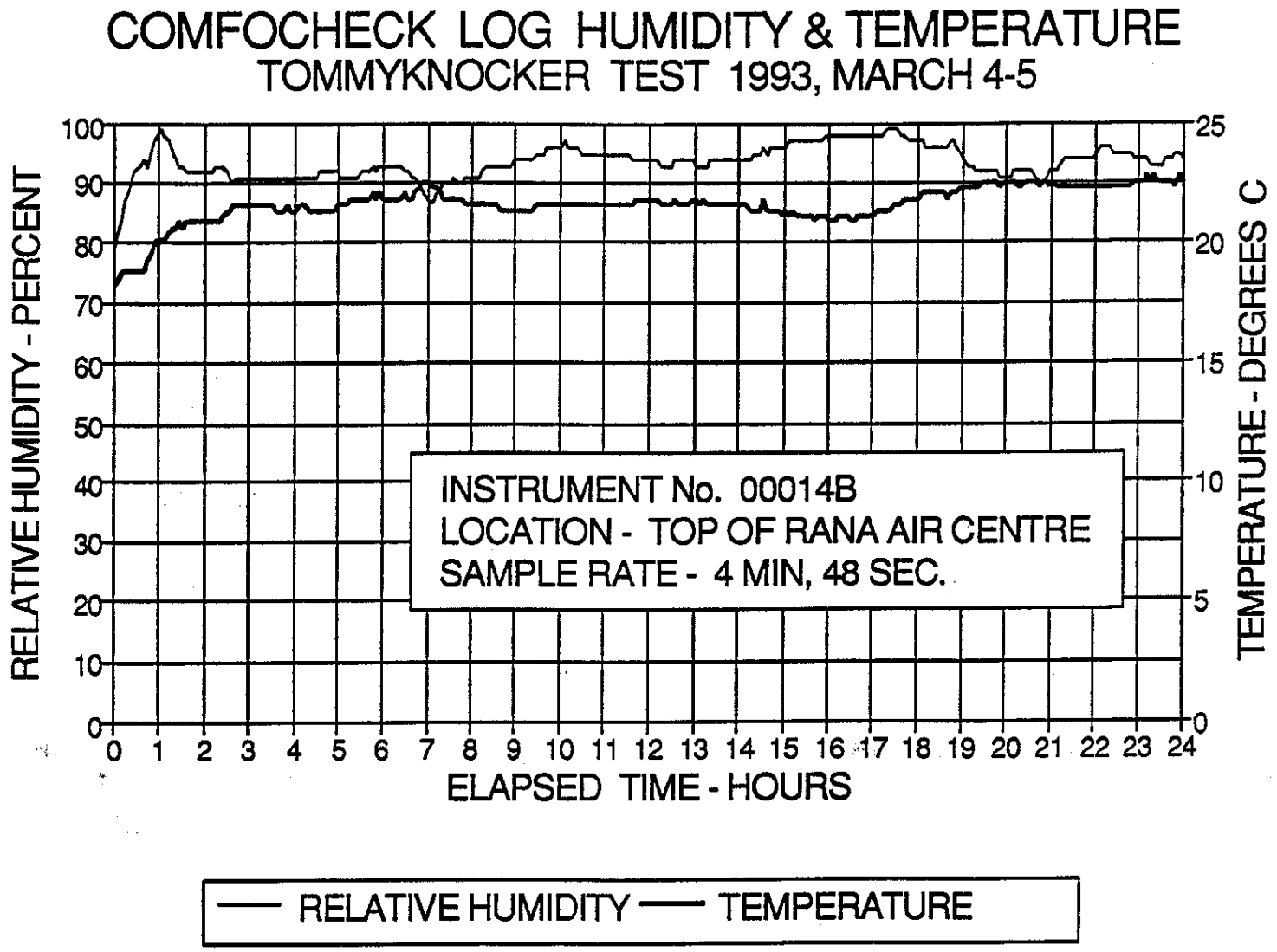
COMFOCHECK LOG HUMIDITY & TEMPERATURE
TOMMYKNOCKER TEST 1993, MARCH 4-5
RELATIVE HUMIDITY - PERCENT
TEMPERATURE - DEGREES C
ELAPSED TIME - HOURS
INSTRUMENT No. 00014B
LOCATION - TOP OF RANA AIR CENTRE
SAMPLE RATE - 4 MIN, 48 SEC.
RELATIVE HUMIDITY
TEMPERATURE

Figure 7

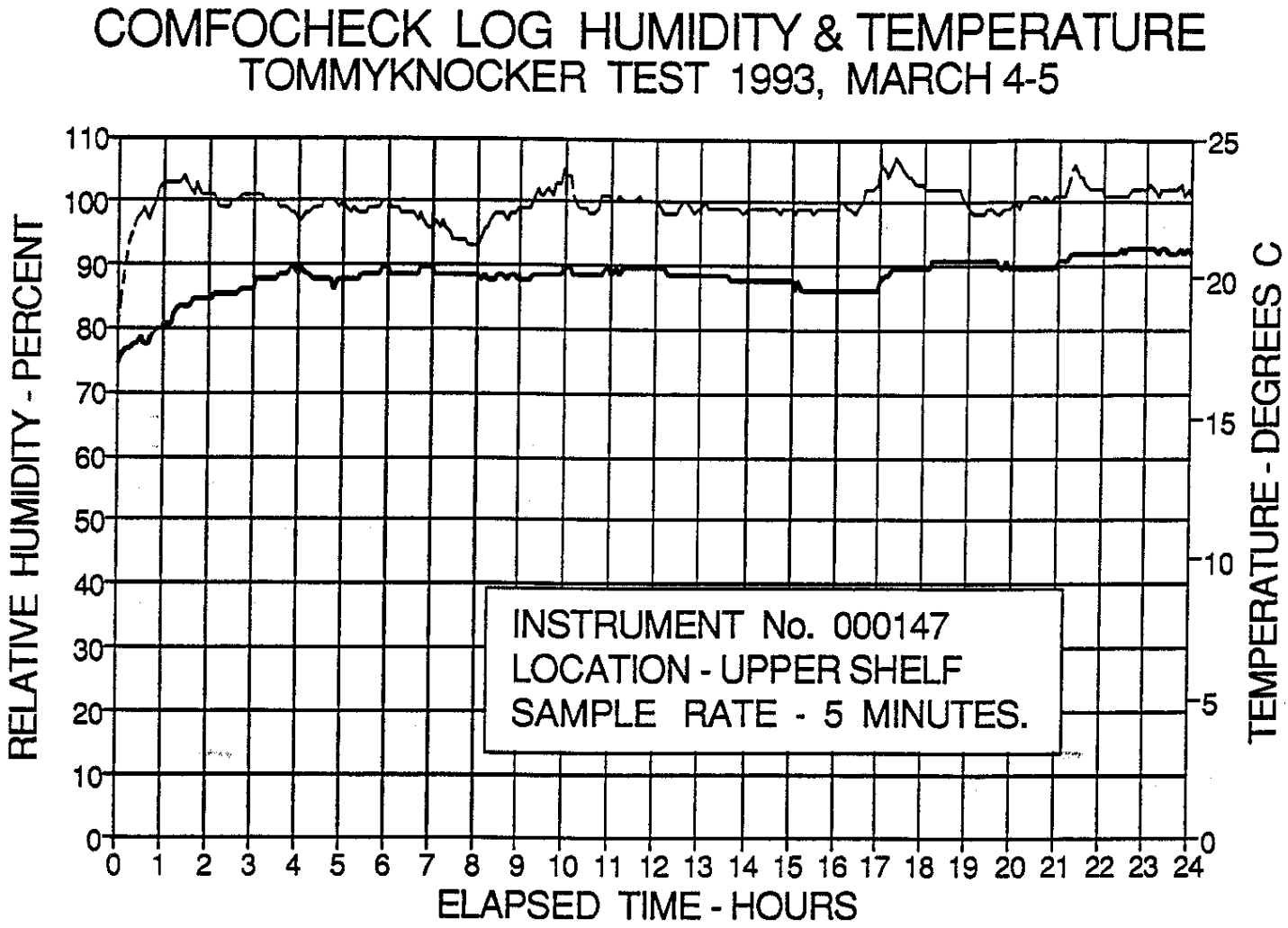
COMFOCHECK LOG HUMIDITY & TEMPERATURE
TOMMYKNOCKER TEST 1993, MARCH 4-5
RELATIVE HUMIDITY - PERCENT
TEMPERATURE - DEGREES C
ELAPSED TIME - HOURS
INSTRUMENT No. 000147
LOCATION - UPPER SHELF
SAMPLE RATE - 5 MINUTES.
110
100
90
80
70
60
50
40
30
20
10
0
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Figure 8

off and placed on the benches became damp and felt very clammy when put back on. The sandwiches became "soggy" if not kept within closed containers. The back of the station became moist, but not enough water was present for droplets to form and fall.

The sling psychrometer used by the volunteers inside the refuge station produced totally variable readings because the humidity was so high. The sling psychrometer used outside the refuge station was quite reliable in the 70-80% RH range.

4.4 Temperature

The outside temperature is shown in Figure 6. It varied between 16.5 and 18.5°C. Temperatures were lower during the evening and night hours because of decrease in surface air temperature.

Temperatures measured by the two Comfocheck units located inside the simulated refuge station are shown in Figures 7 and 8. The temperatures recorded by both units are essentially identical, with no unusual features. Figure 9 shows that the temperature inside the room climbed from about 16°C at the beginning of the test to about 20°C after about 3 h, while the outside temperature remained fairly steady around 15°C.

Figure 10 shows the temperatures measured by the thermistors located at the back, wall and floor inside the simulated refuge station. The temperatures measured by the thermistors located above the floor level were similar to those determined by the two Comfocheck units. The temperature at the floor level was 2°C lower throughout the test.

Thermistors were placed on the air inlet and outlet of the RANA-AIR system. The data collected are shown in Figure 11. As would be expected, once the carbon dioxide absorber had stabilized, the air coming out of the system was at a somewhat higher temperature then the ambient air because of the chemical action of the carbon-dioxide-adsorbing material. The outlet air temperature stabilized at about 24°C, whereas the inlet air temperature was similar to that measured by the other thermistors inside the station, 20°C. The outlet temperature tracks the inlet temperature. This indicates that the carbon dioxide absorber did not have a significant effect on the temperature in the refuge station.

Figure 9 shows a plot of the air temperatures measured by the thermistors inside and outside the room. The thermistor located outside the room indicated a temperature of 15°C. This is about 1-2°C lower then the temperature indicated by the Comfocheck unit located outside the station (Figure 6). This difference is most likely attributable to the different measurement positions. The thermistor was located underneath a table, exposed to the cool floor, while the Comfockeck instrument was located on top of an adjoining table and was better exposed to the circulating air.

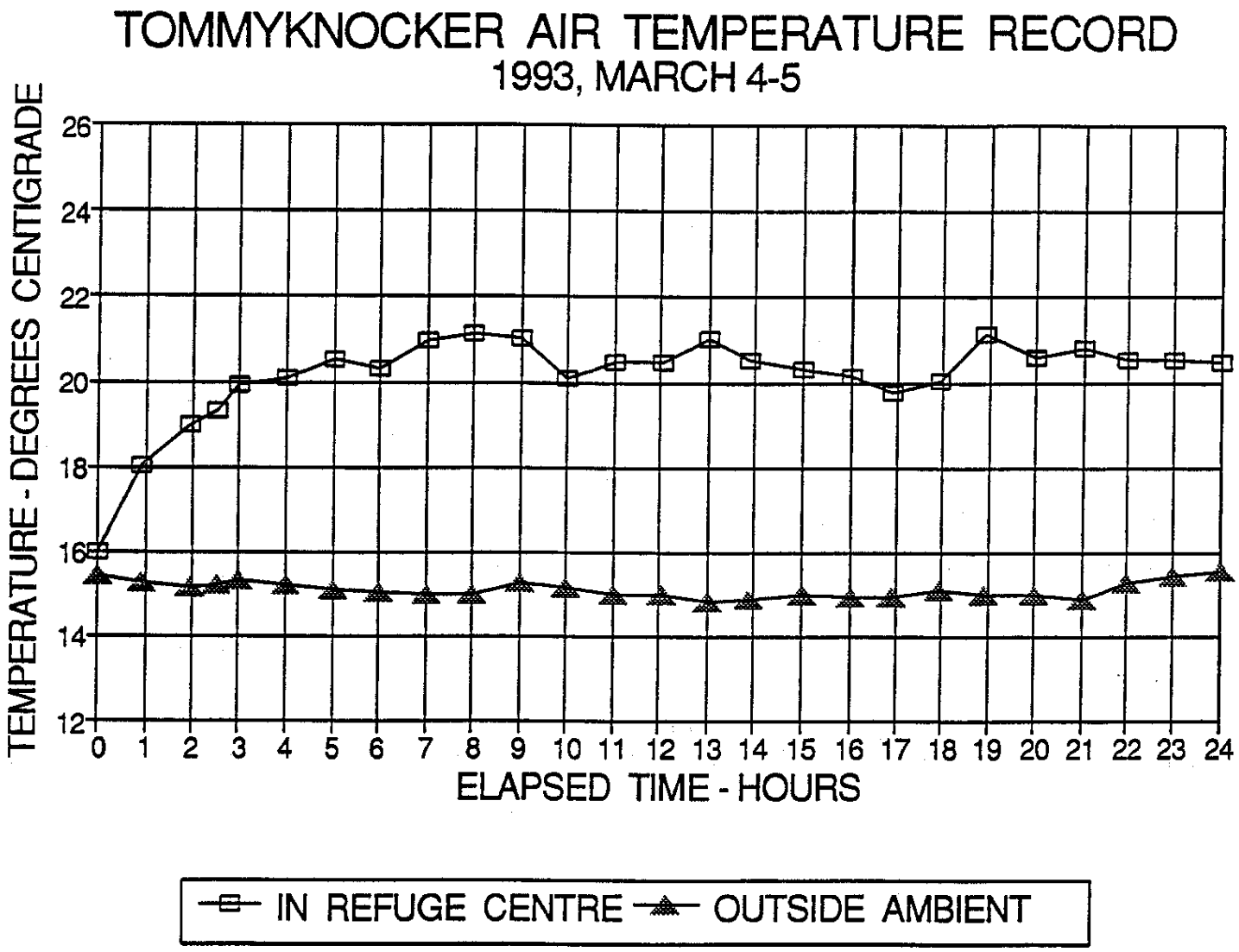
TOMMYKNOCKER AIR TEMPERATURE RECORD
1993, MARCH 4-5
TEMPERATURE - DEGREES CENTIGRADE
26
24
22
20
18
16
14
12
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ELAPSED TIME - HOURS
IN REFUGE CENTRE
OUTSIDE AMBIENT

Figure 9

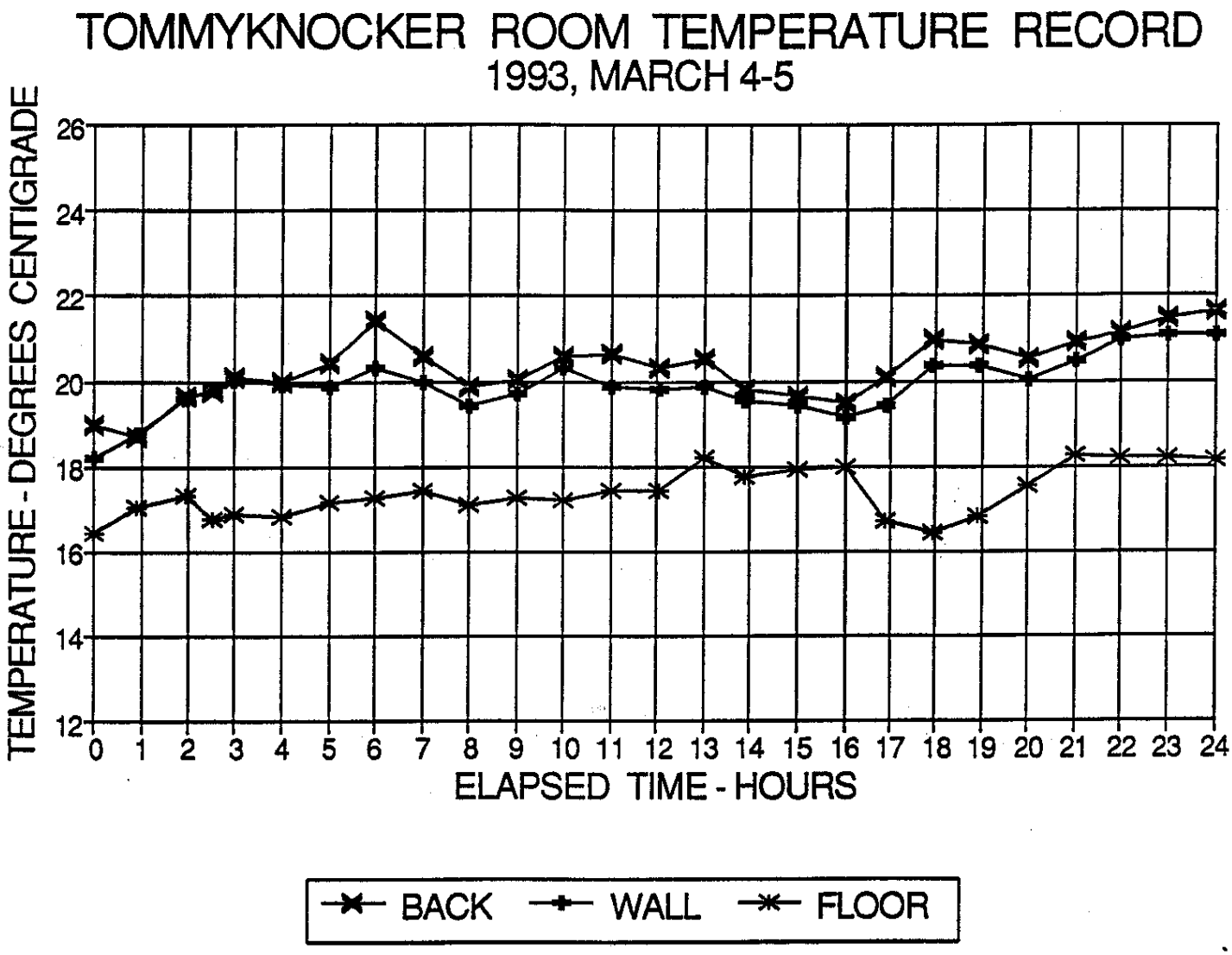
TOMMYKNOCKER ROOM TEMPERATURE RECORD
1993, MARCH 4-5
TEMPERATURE - DEGREES CENTIGRADE
26
24
22
20
18
16
14
12
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ELAPSED TIME - HOURS
BACK
WALL
FLOOR

Figure 10

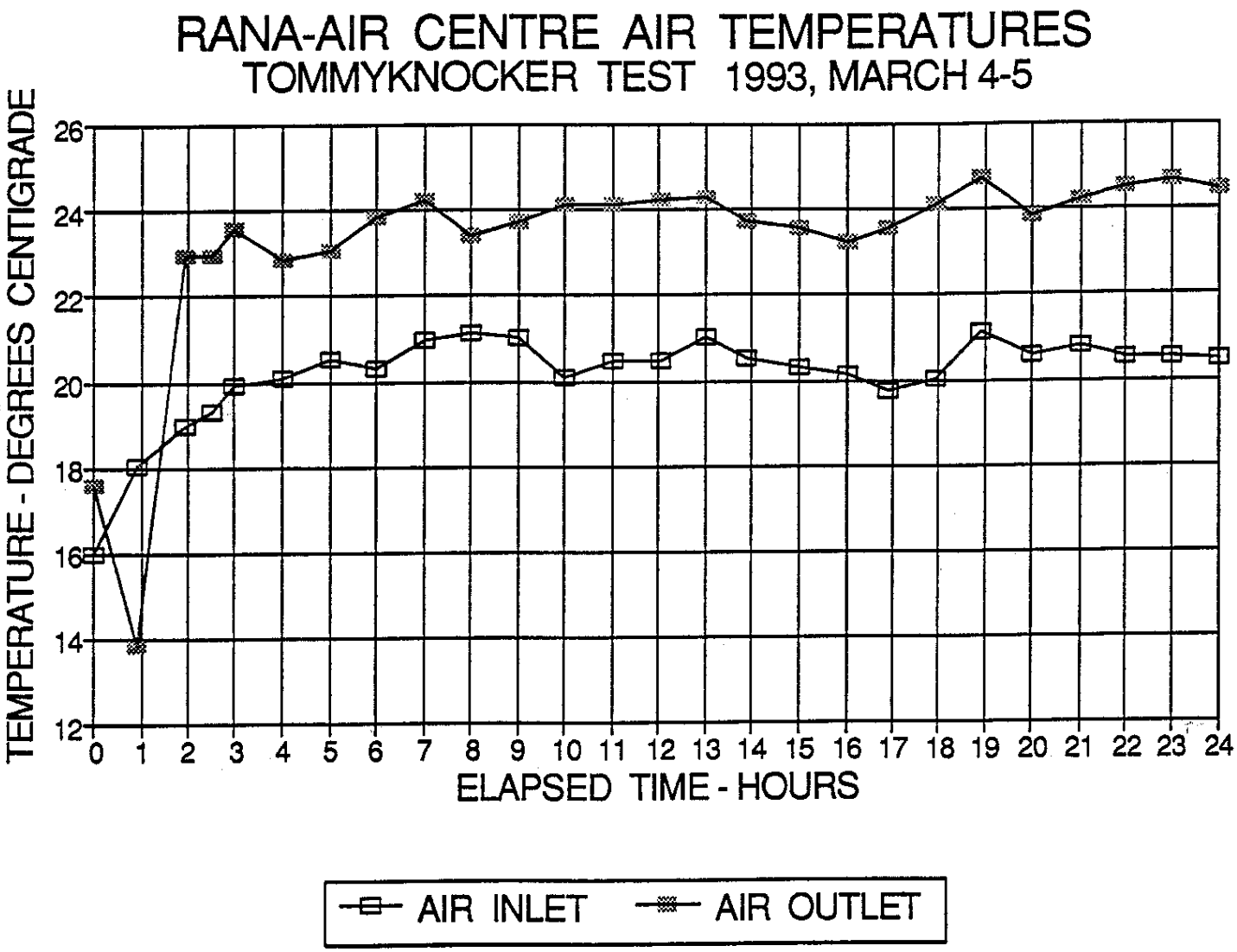
RANA-AIR CENTRE AIR TEMPERATURES
TOMMYKNOCKER TEST 1993, MARCH 4-5
TEMPERATURE - DEGREES CENTIGRADE
26
24
22
20
18
16
14
12
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ELAPSED TIME - HOURS
AIR INLET
AIR OUTLET

Figure 11

4.5 Barometric Pressure

There was no significant change in the barometric pressure measured with a mercury barometer on the 240-m level during the test. The pressures recorded were in the 758 mm Hg range, +/- 4 mm. The manometer installed through the window of the station showed no relative difference in pressure inside and outside of the room, except for a brief period at the end of the test. During the last few minutes of the test, the volunteer participants were asked to increase the oxygen flow to produce a slight pressure increase. The manometer registered an increase of 24.6 mm of water inside the room, which took 36 s to equalize. This suggests that the simulated refuge station was effectively sealed during the test.

4.6 Performance of the RANA-AIR System

The volunteer participants recorded their opinions on performance and ease of use of the RANA-AIR system. These comments are presented in Appendix B, Participant Comments and Evaluation. Briefly, they thought the system was simple and easy to use. The measurements of carbon dioxide and oxygen levels indicate that the system maintained safe levels successfully.

4.7 Medical Surveillance

During the morning of March 04, Dr. R. Hawkins, Medical Director, AECL Research, examined eight volunteers and declared six men to be fit for 24-h confinement in the simulated refuge station.

At 1300 on March 05 the men were re-examined by Dr. T. D. Redekop, Chief Occupational Medical Officer, Manitoba Ministry of Labour, after completion the Operation Tommyknocker. All six men were asymptomatic and had no complaints about their reaction to the 24-h confinement, except that they had all experienced mild headaches early on before the oxygen-generating equipment was functioning and the carbon dioxide level in the room exceeded 5000 ppm for a brief duration. Their headaches subsided relatively quickly as the carbon dioxide level dropped to an acceptable level.

The men monitored their own blood pressure during this time period. The results did not indicate any level of concern.

Either Dr. Redekop or Dr. Hawkins was present to monitor the participants from outside the simulated refuge station during the 24-h test period.

The oxygen level in the refuge station was maintained at around 20.5% while the carbon dioxide level fluctuated around 2000 ppm. This level of carbon dioxide, well above the ambient air level, was quite acceptable for such circumstances, and in general one would not expect people to have any symptoms. The temperature in the room remained stable at about 20°C. The relative humidity rose to nearly 100%, which was not surprising considering six adults

were confined in a small space. The volunteer participants did not complain about this to any extent. They did notice that they felt slightly chilly at night time when they were trying to sleep, even though the temperature remained at about 20°C.

A letter from Dr. T. D. Redekop, dated 1993 March 9, provided a medical opinion on the status of the volunteers participants and the levels of carbon dioxide and oxygen maintained during the test. To summarize, the gas concentrations were kept well within safe limits and the volunteers were healthy and unaffected by the test.

4.8 Feedback from the Participants

The volunteer participants generally felt comfortable during the test. There were no offensive odours from the RANA-AIR system or other conditions that threatened the disruption of the test. The participants were able to sleep during most of the late night hours. Appendix B contains a letter from R. Sullivan, volunteer participant from Hudson Bay Mining and Smelting, which is a summary of his views.

The volunteer participants indicated that the location of the toilet within the door lock area was in fact very important. It likely would not have been possible to continue the test if this provision had not been made. This fact is very relevant to the design of actual underground refuge stations. Provisions should be made for toilet facilities separated from the rest of the space.

4.9 Debriefing Notes

A debriefing was carried out after the test. The following points were noted during the debriefing.

1. It was suggested that the RANA-AIR system could be made smaller.

2. A Plexiglas cover could be placed over the gauges for better mechanical protection.

3. The battery charge alarm light came on shortly after the start of the test. The volunteer participants were somewhat confused by this until they read the manual. Some instruction concerning the light could be written on the panel.

4. The oxygen levels were less then normal, 20.9%. The volunteer participants said they had no great urge to increase the oxygen level delivery rate on the basis of this. There was a strong tendency to go along with the way they felt. Once their headaches went away after the RANA-AIR system was started, they felt happy to leave the oxygen settings alone.

5. There were some problems with the oxygen gas detection tubes. They were not working towards the end of the test. Oxygen readings over 26% were being obtained, which did not agree with the Kanomax unit within the station.

6. The Kanomax oxygen analyzer worked well during the test, however, the batteries went dead about 1930, and the unit was useless after this time. It was believed that this length of battery operation is typical for this type of self-contained unit.

7. It was suggested that the classical symptoms of carbon dioxide poisoning and oxygen deficiency be included in the manual. In the event of failure of gas detection tubes or gas analyzers, one could use these symptoms as a means of monitoring the carbon dioxide and possibly the oxygen levels within a refuge station.

8. A hand-operated blower could be considered as a standby unit for the electric fan.

9. The colour change of the carbon dioxide level was apparent after 18 h of operation. The colour change is intended to be a pre-warning only. It is reliable but not accurate. It was intended that the absorbing material would be changed on the basis of carbon dioxide levels determined by the gas detection tubes.

10. The noise made by the RANA-AIR system did not bother the volunteer participants.

11. The level of carbon dioxide in the simulated refuge station varied with the level of activity of the volunteer participants. The levels were lowest when the activity was low.

12. There were no unusual odours noticed. The unit blew cool air all the time.

13. The humidity was acceptable. It tended to get somewhat cool in the simulated refuge station. Water constantly dripped off the walls, but not the back of the unit.

14. The toilet would have been unbearable if kept in the same room. The toilet had an ammonia smell at the beginning, and a refuse smell later on.

15. The difference in temperature of up to 6°C between to top and bottom of the simulated refuge station was noticeable.

16. The participants felt that the design of the RANA-AIR system was simple enough and easy to use. The unit should be reliable and easy to repair.

17. It was generally felt that the Manitoba code for refuge stations could incorporate some of the information gathered by the test. Such things as considerations for separated toilet facilities and air locks could be considered.

18. It would be most beneficial if the RANA-AIR system incorporated a means of removing noxious gases and smoke from an underground refuge station as well. The station may be contaminated with gases such as carbon dioxide, nitrous oxides and smoke that may be present as a result of a fire.

19. A flame safety lamp could possibly be used to test for oxygen levels. This may not be a good idea when oxygen under pressure is used.

5. CONCLUSIONS

Operation Tommyknocker demonstrated that the RANA-AIR system was "simple and easy" to use. The volunteer participants operated the system for a full 24-h period with a minimum amount of instruction. The operating manual was acceptable and sufficient to operate the equipment.

It was clearly demonstrated that the RANA-AIR system maintained oxygen and carbon dioxide levels to safe values within the sealed, simulated refuge station for the duration of the test. Activity and delay in turning on the RANA-AIR system produced a high carbon dioxide level of 8000 ppm. Consequently, the carbon dioxide levels rose to levels above 0.5% for a short period. The volunteer participants experienced typical minor headaches as a result of this. This indicates that immediate control of the carbon dioxide levels is very important in underground refuge stations once they become isolated.

The monitoring system, which consisted of gas detection tubes for determining the levels of oxygen and carbon dioxide, was tested. The equipment was appropriate given the experience and anxiety level of those required to use it. The gas detection tubes for determining the carbon dioxide levels were effective. However, the gas detection tubes for measuring oxygen were unreliable, giving erroneous readings. Another method should be used to determine the oxygen levels if monitoring is required.

6. RECOMMENDATIONS

1. The RANA-AIR system should be developed for use in underground refuge stations.

2. A method other than gas detection tubes should be used to determine the levels of oxygen for monitoring the atmospheric conditions within the refuge station.

3. A system to remove noxious gases that may be present as a result of a fire underground should be incorporated within the design of the RANA-AIR system.

ACKNOWLEDGMENT

The authors wish to thank the Manitoba Department of Labour, the Mine Accident Prevention Association of Manitoba, AECL Research, INCO Thompson, Hudson Bay Mining and Smelting, Tantalum Mining Corporation of Canada, Croda Canada Ltd., Molecular Products Ltd., and the volunteer participants who kindly dedicated their time and effort to ensure Operation Tommyknocker was planned and carried out to achieve the objectives and goals. Through the efforts of these organizations, companies and individuals, we believe the RANA-AIR Mine Refuge Air Centre, being developed by Rimer Alco North America Limited to improve safety in underground mining and civil operations, is a great step closer to being a marketable commodity.

REFERENCES

1. Labour Canada Occupational Safety and Health Code.

2. Threshold Limit Values for Chemical Substances and Physical Agents, 1992-1993. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

3. U.C.Luft, Aerospace Environments, Chapter 10 of Environmental Physiology, N.B. Slonim, Editor, C.V. Mosby Co., 1974.

APPENDIX A

List of Participants

OPERATION TOMMYKNOCKER

List of Participants

Organizers

Greg Kuzyk	Engineer, AECL Research, Underground Research Laboratory
Earl Gardiner	President, Rimer Alco North America
Barrie Simoneau	Safety Coordinator, Mines Accident Prevention Association of Manitoba
Ray Lambert	AECL Research, Radiation and Industrial Safety
Ron Glassford	Director, Mines Inspection, Workplace Environment, Safety and Health, Manitoba Department of Labour
Bill Schubert	Mine Rescue Instructor, Workplace Environment, Safety and Health, Manitoba Department of Labour
Dr. Ray Hawkins	AECL Research, Medical Services Branch
Dr. Ted Redekop	Chief Occupational Medical Officer, Workplace Safety, Health and Support Services Division, Manitoba Department of Labour

Test Participants

Vern Steiner	AECL Research, Underground Research Laboratory
Ed Chuckrey	INCO Thompson
Ron Sullivan	Hudson Bay Mining and Smelting
Tim Haverlock	Tanco
Don Daymond	AECL Research, Underground Research Laboratory
Jamie Law	Tanco
Dennis Wilson	Hudson Bay Mining and Smelting
Wayne Mattson	INCO Thompson

Supporting Staff

Barney Kovacs	Manitoba Mining Association
Monte Raber	Rimer Alco North America
Gary Wallace	AECL Research
Paul Barnsdale	AECL Research
Don Hladki	AECL Research
Andy Gerwing	AECL Research
Jane Sargent	AECL Research
André Salloum	AECL Research
Larry Shewchuk	AECL Research
Rich Corman	AECL Research
Mitch Ohta	AECL Research, Underground Research Laboratory
Harry Backer	AECL Research, Underground Research Laboratory
Dwayne Onagi	AECL Research, Underground Research Laboratory
Glen Karklin	AECL Research, Underground Research Laboratory
Walter Schmidt	AECL Research, Underground Research Laboratory
Glen Snider	AECL Research
Richard Simcoe	J.S. Redpath Limited
Rolly Simard	Tanco
Ron Casson	Manitoba Department of Labour

Visitors

Darren Praznik	Minister of Labour and MLA Lac du Bonnet
Ben Sveinsen	MLA La Verendrye
Dave Marion	Reeve, RM of Lac du Bonnet
Robert Vachon	RCMP, Lac du Bonnet
Gille Lafreniere	RCMP, Lac du Bonnet
Nick Ostash	Bond Gold

APPENDIX B

Technical Information

Participant Comments and Evaluation

Letter from Dr. T.D. Redekop

Letter from R. Sullivan

RIMER ALCO NORTH AMERICA

MINE REFUGE AIR CENTRE TESTS

"PARTICIPANT COMMENTS AND EVALUATION"

Determine how "simple and easy" it is to use.

- Fairly straight forward.
- Very simple and easy. Directions on the system are very self–explanatory. It may be difficult for some non–mine rescue people to understand.
- Very simple and easy. RANA–AIR could be used by anyone without any prior knowledge of the system.
- Very simple. Instructions on the unit itself are clear and concise. I would venture to say, even an engineer could operate this equipment. (Maybe this is a rash statement.)
- The machine was easy to fill and simple to start according to the directions.
- Easy to start and easy to refill. Door should be removed, or replaced with a screen.

Prove it's ability to maintain Oxygen and Carbon Dioxide levels as close to atmospheric as possible.

- So far it has done a very good job.
- It has done its job, 20 minutes after it was turned on our headaches were gone.
- Our records will show unit works perfectly without any adjustments.
- CO_2 levels were increasing as we started the test. (There was a lot of pre–test action in the refuge station and a number of people in the room.) Within half an hour, the O_2 and CO_2 levels were within acceptable values.
- According to our records, the machine works very good. We had no problems with the levels once it was started.
- CO_2 levels were up. After starting up RANA–AIR, CO_2 dropped down.

Determine if the monitoring equipment provided with the system (to measure concentrations of O_2 and CO_2) are effective and appropriate, given the experience, training and anxiety of those required to operate it.

- Definite problems with O_2 tubes. Need to make sure expiry dates are current. Expiry 1992 tubes for CO_2 were not very good. 1992 CO_2 were N=1 while 1995 tubes were N=1+5. Need barometric pressure gauge and chart of O_2 barometric readings for quick and easy O_2 conversions.

- Bulb works well.

- We are familiar with Draeger tubes, but non–mine rescue people should have better instructions. Equipment supplied with the RANA–AIR would not be complete without a barometer. This should be built into the machine so the value can be seen.

- CO_2 tubes work effectively. O_2 tubes can only be sued once when the humidity gets high. Without a barometric pressure, the O_2 value cannot be calculated. A barometer on the RANA–AIR system would be a definite requirement. A graph of barometric pressure versus tube readings would eliminate calculations.

- The equipment supplied was sufficient and easy to use, but non–mine rescue personnel might need better instructions.

- Problems with O_2 tubes (3 tests to tube at beginning). Towards the end of the test, O_2 tubes were not reading accurately. Some readings as high as 23%

Size, Colour and Shape of System:

- Size seems bulky; appears to be a lot of wasted inside space. Possibility of having external O_2 bottles?

- Size seems a bit large, lots of wasted space where O_2 bottles are. By reducing size, the unit would be more portable.

- Bottom storage compartment door should be made to be removed. In our situation, it takes up floor space being open. We removed door. O_2 cylinders should be easier to put into the unit. Cylinders should go in from the side, not top.

- Colour OK. Shape OK. Size could be reduced by half if the O_2 bottles were external. Could then be cascaded with more O_2. A screen in the front door would negate having to open the front door.

- Size & Shape: The unit could be smaller. Colour: This has no bearing other than making instruction stand out more.

- Size could be reduced by half. Colour OK. Shape of system OK.

Noise Level:

- Not too bad, at least for me. Others find it irritating now especially after sleeping. Possibility of putting some type of muffler on to reduce the noise level some.

- The noise level is tolerable, even when sleeping.

- Low. Tolerate very easy.

- Tolerable. Can be aggravating in a small area when right next to system.

- There is no problem with the noise. If anything, it helps me sleep.

- OK if in a bigger Refuge Station.

Labelling and Manuals:

- Labelling is clear and easy to read. Should have "No Smoking" sign. O_2 instructions should be in RED.

- Small point: "Replace soda lime when colour change (purple) rises to arrows." There are no arrows. You should say "dashed line".

- O_2 warning should be in red. Manual is self explanatory. "No Smoking" signs should be on the system. Because of possible illiteracy on the part of someone who would use this system, a set of pictorial instructions in the manual might be useful.

- The labelling could stand out more. Example: Black letters on white. Manual should be simpler for non mine rescue users.

- O_2 warning should be in red.

Actual potential of Mining Companies to install these units in underground refuges:

- Good, especially if units could be made portable so that they could be used in temporary refuge locations (transported easily).

- I would say the potential for underground use is quite good, taking into consideration cost, portability and durability.

- My vote "YES".

- This system would be very adaptable in a permanent refuge station or portable refuge station if the size were reduced.

- I think personally, the system would work excellent in a refuge. Other than the size, it would be perfect for a mine refuge.

- Yes, this system would be good to have in a refuge station.

Other:

- – Should come with monitoring equipment (O_2, CO, RH).
  – Storage door should be of screen.
  – Should also have a side door for removing O_2 bottles, or make the unit smaller by having the bottles stand outside.
  – O_2 & Litre Flow Indicator should be protected by some sort of see–through cover.

- – Test start – Unit is producing cool air from exhaust.
  – Test middle – above.
  – Gloves could possibly be supplied in unit.

- – Difficult to see colour change in soda lime. 6 a.m. – 0.5 cm first time really visible.
  – Gauges should be protected.

Manitoba

Labour

Workplace Safety, Health
and Support Services Division

1000 — 330 St. Mary Avenue
Winnipeg, Manitoba, CANADA
R3C 3Z5

(204) 945-3446

March 9, 1993

Mr. Barrie D. Simoneau CRSP
Mines Accident Prevention
Association of Manitoba
700-305 Broadway Avenue
Winnipeg, Manitoba
R3C 3J7

Dear Mr. Simoneau:

RE: OPERATION TOMMYKNOCK MEDICAL REPORT

Number of Men Examined = 8

Number of Men Declared Fit for the 24 hour confinement in the mine refuge station = 6

Examiner Dr. R. Hawkins, AECL Medical Director (2 people were rejected for medical reasons - these 2 individuals supplied monitoring activity throughout this demonstration project).

Average age of participants was 37 years old; male - age ranged from 29 to 44.

All men were examined for fitness prior to entering the room. They were re-examined by me at 1:00 p.m. on March 5, 1993. All were asymptomatic and had no complaints about their reaction to the 24 hour confinement, except that they had all experienced mild headaches early on before the oxygenator was functioning and when the carbon dioxide level in the room reached at least 5000 ppm. Their headaches subsided relatively quickly as the carbon dioxide level dropped to an acceptable level.

The men monitored their own blood pressure during this time period, the results did not indicate any level of concern.

The oxygen level in the refuge station was maintained at around 20.5% while the carbon dioxide level fluctuated around 2000 ppm level. This level of carbon dioxide, well above the ambient air level, is quite acceptable for such circumstances and in general one would not expect people to have any symptoms. The temperature in the room remained stable at around 20°C. The relative humidity rose to near 100 % which is not surprising considering 6 adults in a small confined space but the participants did not complain about this to any extent. They did notice that they felt slightly chilly at night time when they were trying to sleep even though the temperature remained at about 20°C.

....2

SUMMARY:

The six participants did not experience any adverse health effects except at start up when the carbon dioxide level rose to about 5000 ppm and prior to the oxygenator function.

Sincerely,

Dr. T. D. Redekop
Chief Occupational Medical Officer

PS: I think this was a very well run demonstration with optimum cooperation from the many participants. You are to be congratulated on organizing this so professionally.

Dr. Hawkins should be commended for steering the project through the ethics committee hurdle. This created some last minute "angst" but it did not impact on the timing nor the smooth running of this project.

cc: Dr. R. Hawkins, AECL
Ron Glassford

TDR/AR

COMON-Z:TOMMYKNOCKER

Hudson Bay Mining & Smelting Co., Ltd.
Ruttan Operations

OPERATION TOMMYKNOCKER

Submitted by Ron Sullivan

Six men entered the Refuge Station at 1:00 pm, March 04, 1993.

After being in the station for approximately one half hour, the CO_2 went up to over 5000 ppm. All individuals started to get a headache.

At this time we started up the Rana-air unit, filling it with approximately 60 lbs. of soda lime. We then turned on the two oxygen bottles and set the oxygen flow to three litres per hour.

After the Rana-air unit was started, the CO_2 went back to normal.

All individuals in the station helped with the testing. We had to test for O_2, CO_2, temperature and "R" humidity. We also had our vital signs taken every hour for the first eight to ten hours, and during the last two hours we were in the Refuge Station.

The oxygen stayed at approximately 20.5% and the temperature was constant at 20.5° to 22.9° at the end of the twenty-four hour period. The "R" humidity levels were 80° to 90°, towards the end of the twenty-four hour period, it went up to over 100°.

There were photographs and videos taken during our confinement in the Refuge Station.

In conclusion, the Rana-air unit will provide the oxygen needed for breathing, and will remove the carbon dioxide produced by the miners during a period of entrapment.

Ron Sullivan
Advanced Mine Rescue
Ruttan Mine
March 16, 1993
/cs