Workplace Safety North

Health and Safety Report

Mine Rescue Heat Stress Report

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A Health & Safety Ontario Partner

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Workplace Safety North recognizes that individual companies must develop health and safety policies and programs which apply to their workplaces and comply with appropriate legislation. The information contained in this reference material is distributed as a guide only to assist in developing those policies and programs.

While WSN cannot guarantee the absolute accuracy or sufficiency of this information, we will be pleased to respond to individual inquiries about this information at any time.

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Mine Rescue Heat Stress Report

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Introduction

Mine rescue volunteers are considered elite miners, the best at performing difficult tasks under difficult conditions underground, but they are no less susceptible to the dangers that all workers face under extreme heat exposure. In fact, because of the nature of mine rescue work, mine rescuers may be considered at greater danger of heat stress than any other job, certainly within the mining industry.

In Poland in 1998, 10 mine rescuers under oxygen were overcome by heat during an exploration activity and on several subsequent rescue attempts. Temperatures peaked only at 31.5°C (88.7°F), but the relative humidity was in the high 95 to 98 per cent range. Six died and one suffered severe injuries.

Several years later, in October 2002, two members under oxygen of a mine rescue team collapsed in the heat while exploring an abandoned mine stope in Nevada. They encountered temperatures exceeding 39.4°C (103°F). One of the members died on site, while the second died a week later in hospital.

In 2011, three mine rescuers died of heat stroke while fighting a coal mine fire in China's Shandong province, and heat exposure was a factor in the deaths of two South African mine rescuers during an emergency in 2012.

Incidents such as these and a growing awareness of the issue as Ontario mines encounter hotter mineral formations and reach deeper depths, prompted Ontario Mine Rescue to join others in supporting research by the University of Ottawa into heat exposure and heat stress in mining and mine rescue. Several significant reports into workload, heat stress management, and the effect of garments in mine rescue, have been completed and further research is ongoing.

Understanding how the body responds to heat, the dangers posed by heat stress, recognizing the factors that contribute to heat stress, and taking preventive measures, should not only safeguard mine rescue volunteers, but also the mine rescue team, and allow the best opportunity for safe and successful missions.

Acknowledgements

The Mine Rescue Heat Stress Report was developed in consultation with Ontario Mine Rescue's Technical Advisory Committee, and with the assistance of mine rescue organizations in Australia, the Czech Republic, Germany, South Africa, Poland, and the United Kingdom.

Physiological Response to Heat

Normal core body temperature is 37°C (98.6°F), though there is slight variation among individuals of about half a °C. This temperature must remain relatively constant for the body to work well. As body temperature rises, the body automatically takes a combination of steps to cool or lose heat to maintain a relatively constant temperature.

Vasodilation – The circulatory system—blood vessels, heart—acts as a human radiator. Blood vessels and capillaries near and in the skin increase in size, and the heart beats faster to increase blood flow. This encourages heat dissipation and body cooling. As blood warmed by the metabolic rate nears the skin surface, it transfers heat to the skin, which in turn, attempts to dissipate the heat through radiation and conduction to the cooler air. If the air is moving and skin exposed or lightly covered, body heat passes more easily to the environment than if the air is still and skin less exposed or more fully covered. When air temperature exceeds body temperature, vasodilation ceases to cool the body.

Sweat – As blood circulation to the skin fails to adequately cool the body, sweat glands in the skin produce sweat to allow for evaporative cooling, the most effective mechanism the body has for cooling itself. The evaporation of the sweat cools the skin. If too much sweat is lost, the body can become dehydrated and lose the ability to cool itself. Dehydration also reduces the volume of blood in the body, resulting in lower blood pressure and increased strain on the heart. The rate of cooling depends on the rate of evaporation based on temperature, humidity, and skin exposure. Lightly covered and exposed skin allows greater evaporation, but when relative humidity exceeds 70 per cent, the air has a limited ability to absorb moisture and cooling is minimal. The body, however, will continue to produce sweat until it is dehydrated.

Decreased heat production – Meanwhile inside the body, the increased blood flow to the skin, as much as 25 per cent of the cardiac output, and a rising body temperature causes blood flow to internal organs to decrease to produce less heat. The diminished blood flow, however, can place the internal organs and the brain at risk.

When the individual is required to work in hot, humid conditions, the working muscles also have an additional need for blood. In the resulting competition for blood between the muscles and the body's cooling system, blood pressure drops and the heart works even harder. Blood flow to organs diminishes further. The body places a higher priority on supplying blood to the muscles, so not only does physical activity increase body temperature through increased metabolism, but it can slow and prevent cooling.

Though all people will react to heat, the rate at which they react and how they will react will vary based on a number of individual factors, including:

Hydration – Since the body's most effective response to heat is to cool itself through sweat, the most effective defence against heat exposure is adequate hydration, principally through drinking water. The consumption of excessive caffeine, carbonated soft drinks, fruit juices and alcohol can slow rehydration or even reduce hydration. Inadequate hydration reduces and limits the body's ability to produce sweat and to cool itself.

Nutrition – A regular, balanced diet can help prevent the depletion of salts that could lead to early heat stress. If the majority of meals are dry or dehydrated, the risk of dehydration is greater. A diet of junk food, high fat and caloric foods can also increase the risk of dehydration.

Fitness – Fitter individuals tolerate work and heat better. Their bodies have higher water content, use energy more efficiently, and are better able to stay hydrated. Heavier, less fit individuals reach their maximum level of activity more quickly than their lighter, fitter counterparts, and experience an increased susceptibility to heat stress disorders.

Health – Health problems, large and small, can compromise the body's ability to cool itself. Even temporary acute problems—mild fever, runny nose, hangover, constipation—can compound and be compounded by heat stress. Healthy individuals tolerate work and heat better.

Acclimation – The more often an individual works in the heat, the better his or her body becomes at keeping cool. A body requires one to two weeks of acclimation to fully adjust to work in a hot environment.

Age – Younger individuals tend to tolerate heat better than older individuals, as the body tends to be less responsive to heat exposure with age.

Rest – Adequate rest prior to heat exposure, during heat exposure, and between work periods allows the body to cool and recover.

When the rate of "heat gain" exceeds the rate of "heat loss", the body temperature begins to rise. A rise in the body temperature results in heat stress, and may lead to heat stress disorders. Although people react differently to heat, even mild heat discomfort can create problems for many people. Workers who are hot are less productive and less attentive, and that may affect the safety of themselves and the entire work group.

It is important to note that workers can experience a heat stress disorder in a hot environment without any significant escalation in the environmental heat load.

Heat Stress Disorders

Heat stress disorders can be considered a spectrum of health issues from mild to severe with potentially fatal results as the body attempts to control a rising core temperature.

Heat Rash is a red, bumpy skin rash with severe itching caused by excessive sweating. It is most likely to occur on the neck and upper chest, in the groin, under the breasts, and in elbow creases. Though uncomfortable, heat rash does not pose a danger to life and health.

Heat Cramps are painful cramps in arms, legs, or stomach that occur suddenly during strenuous activity due to low salt and electrolyte levels in muscles caused by sweating. Though painful, heat cramps do not pose a danger to life and health. They are, however, a strong indication the body is experiencing difficulty adjusting to a rising core temperature. Heat cramps may be a symptom of heat exhaustion.

Heat Syncope (fainting) is the loss of consciousness or passing out while doing or after doing physical work in a heated environment. Dehydration and the lack of acclimation may contribute to heat syncope. Symptoms include cool, moist skin, weak pulse, light-headedness and dizziness. Heat syncope is an indication the body's cooling efforts are failing. It may not occur before heat exhaustion or heat stroke.

Heat Exhaustion is the body's response to an excessive loss of water and salt, usually through excessive sweating, and indicates the body's cooling system is breaking down. Symptoms include heavy sweating, cool moist skin, body temperature greater than 38°C (100°F), weak pulse, low blood pressure, fatigue, as well the person may be weak, clumsy, upset or confused; very thirsty; panting or breathing rapidly; vision may be blurred. Not all these symptoms will occur or be evident.

Heat Stroke is difficult to recognize even under ideal circumstances, but it is the most serious heat-related disorder and indicates the body's cooling system has broken down, causing the body temperature to rise to a deadly level. Symptoms include a high body temperature greater than 41°C (106°F), a confused mental state, headache or dizziness, fast pulse, and hot, dry, red skin. In late stages, a person may pass out and have convulsions. This condition will quickly kill. Heat stroke has an 80 per cent mortality rate if not treated immediately. If not fatal, the central nervous system, kidneys and liver are most likely to be injured.

Incidents of heat syncope, heat exhaustion and heat stroke in the workplace are reportable. Workers who experience them must receive immediate medical attention.

Heat Stress in Mining

Heat stress is the heat burden on the body from the combination of environmental sources, as well as the body's metabolism as determined by workload, and clothing requirements. In mining, as in other industries, the exposure of workers to very hot conditions is unhealthy and unproductive. In several Ontario mines, usually but not exclusively deep mining operations, employees face high heat exposure levels that can lead to heat stress during their regular work duties.

General environmental factors that play a role in heat stress in mining include:

- Heat sources
    - Auto-compression is the major contributor to underground heat load. For every kilometre in depth underground, the air temperature can increase by approximately 10°C due to auto-compression. However, as the underground air is almost totally enclosed by a poor thermal conductor in rock, heat dissipation is inhibited.
    - Rock temperature increases with depth and can contribute to heat load, but is a minor contributor and is dependent on the rock properties and geothermal gradient.
    - Flowing ground and standing water cause the humidity in the air to increase. If the water is warm or hot, it will contribute to heat load.
    - Powered-equipment and machinery generate significant heat load to a localized area with minor heat being added by recently backfilled areas, blasting, and lights.
- High air temperatures may not only reduce the ability of the body to cool itself, but once higher than body temperature, will contribute to body heating.
- Little or no air movement reduces the body's ability to dissipate heat through convection, and the evaporation of sweat. Clothing also inhibits the body's ability to dissipate heat and restricts the evaporation of sweat.
- As relative humidity increases, the air gradually loses its ability to evaporate sweat from the skin, and help cool the body. Above 70 per cent relative humidity, body cooling through the evaporation of sweat is minimal.

Mines in Canada and around the world use a range of control measures to eliminate and reduce the risks posed by heat exposure. See Appendices.

Training workers to be knowledgeable about the risks, causes, symptoms, and prevention of heat stress is a necessary and common administrative control used in most industries, particularly those in which heat exposure is a more seasonal hazard. Trained workers are also most likely to take effective personal control measures, including hydration, good nutrition and exercise, against heat exposure.

Ventilation can reduce the effects of factors that create a heat exposure hazard and the risk of heat stress disorders. Increased air velocity removes the heat from the source and facilitates evaporative cooling. Ventilation, however, cannot always adequately create environmental conditions under which workers can perform a traditional or standard work shift. When this occurs, cooled and conditioned air is provided to lower temperatures and reduce humidity.

Drinking water to prevent dehydration and maintain adequate hydration is a key control measure, since the body's most effective response to heat is to cool itself though sweat. Drinking water replaces the fluids lost through sweating and other bodily functions, and helps maintain blood pressure when the body's circulatory system is under stress. Estimates of the amount of water required to maintain adequate hydration vary based in part on exposure, but consumption of small quantities (a cup) at regular intervals (20 minutes) is preferable to large quantities at extended intervals. It is important to arrive at work hydrated, as it can take time to hydrate and re-hydrate the body.

Exposure time limits in the form of work/rest regimens, provide workers with relief from high temperatures, and allow the body to cool and recover. Time limits are based on wet bulb temperatures, air velocity, workload, clothing and/or personal protective clothing, worker acclimation, shift length and other factors.

Self-pacing is an effective method to allow the body to rest when appropriate. Recovery should be in an area that is three to five degrees cooler than the working environment and where air flow can be directed over the person. "Active recovery", a low level of activity without increasing metabolic heat, is important to prevent the blood pressure from dropping so the body's cooling system does not stop working.

Heat acclimation refers to the physiological adjustments induced by repeated prolonged exposure to hot environmental conditions. When the body is heat acclimated, there is:

- Reduced cardiovascular strain through increased plasma volume and decreased heart rate
- Improved fluid balance
- Increased sweating
- Increased skin blood flow
- Lower core and skin temperature
- Reduced perceived exertion

A body requires one to two weeks of acclimation to fully adjust to work in a hot environment. Acclimation can be lost in as few as three or four days.

Other controls include measures to isolate the worker from heat exposure; to contain or isolate heat sources, possibly with barriers or insulation; personal protective equipment such as cooling vests; regular monitoring of workers' health; and identifying workers who may be more, or conversely less, susceptible to heat stress.

Heat Stress in Mine Rescue

Mine emergency and emergency training situations tend to place mine rescue team members at a higher risk of heat stress than ordinary mining activities. Team members can face extreme heat loads not only due to environmental factors that will be less than ideal, but also due to their metabolic work output and clothing.

In a rescue environment, existing engineering controls—fans, ventilation, heat shields and barriers, may have limited effectiveness or no longer work. Environmental factors may be subject to new influences—fire and flooding, that pose increased variables and dangers.

Mine rescuers may have already have put in partial or full work shifts when called to action, contributing to fatigue and dehydration. The emotional urge and psychological stress to respond quickly to an emergency may inhibit a rescuer's ability to self-assess his or her personal situation.

During rescue operations, mine rescuers may travel long distances on foot over uneven terrain, wearing breathing apparatus and under oxygen. They usually carry heavy loads, and do extreme physical and often psychologically demanding work. Muscular work can increase the heat production in the body 10 to 20 times that of when at rest.

The breathing apparatus and additional protective clothing worn by mine rescuers can add to the heat burden by increasing a rescuer's metabolism, containing the perspiration, and preventing or reducing cooling. Protective equipment and clothing can also make it difficult for mine rescuers to recognize heat stress symptoms in each other until heat stress reaches a critical level.

Ontario Mine Rescue has a number of sets of the recently developed Dräger hydration masks for use with Dräger BG4s, which may not be available therefore mine rescuers may have no opportunity during an assignment to drink fluids to rehydrate their bodies. As well during an assignment, rest conditions are often less than ideal.

Since work in a hot, humid environment will create a higher heat stress level than the same work in a normal environment, occupational health authorities, industrial hygienists and researchers in different jurisdictions have developed work level/time exposure guidelines and standards to limit the likelihood of people suffering heat stress disorders while working.

Ontario Mine Rescue Heat Exposure Standard

Within Canada, provinces and various agencies have established guidelines and standards to regulate heat exposure in the workplace, including mines (See Appendix B – Canadian Heat Stress Guidelines/Standards, Pg. 20). For example, to fulfil their health and safety responsibility to workers as required under the Occupational Health and Safety Act (OHSA), Ontario mines use a range of measures, principally ventilation, exposure time limits, training and acclimation to hot environments to control heat exposure for workers.

None of these guidelines/standards, however, are directly and easily applicable to the dynamic conditions and situations faced by mine rescuers, but would require relatively complex adjustments, most involving multiple subjective evaluations unique to the emergency situation and specific mine site, to be adapted for use in mine rescue.

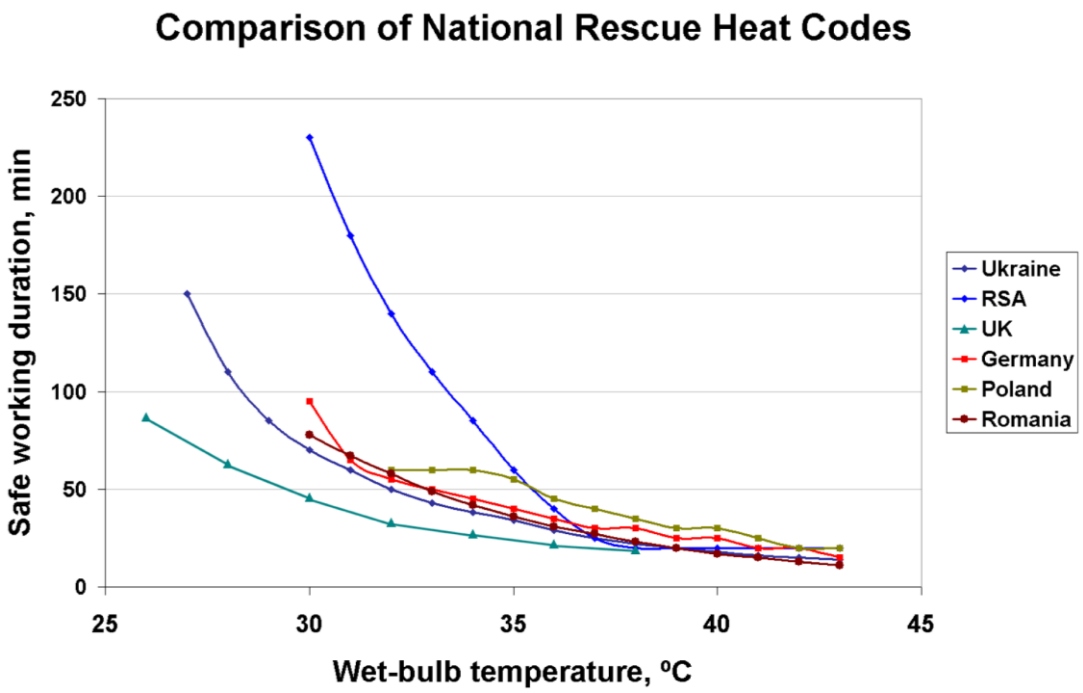
In contrast internationally, different countries, several of which have conducted substantial research into heat exposure and heat stress in mine rescue activities, have developed standards and protocols specific to their own legislative requirements, and the occupational health and safety needs of mine rescuers (See Appendix C – International Mine Rescue Guidelines/Protocols, Pg. 28).

A straight comparison of standards among international mine rescue organizations is difficult due to different approaches and methods used in research efforts. Various standards are often expressed using different combinations and formulas of dry bulb and wet bulb temperature, relative humidity and dry bulb, wet bulb globe temperature (WBGT), and other environmental measurements.

As well, some jurisdictions have attempted to target their research and subsequent heat exposure limits or tolerance times to be appropriate for their "standard" of mine rescuers, such as fitness level, age, and heat acclimation, as well as other jurisdiction-specific criteria such as breathing apparatus, cooling vests, protective clothing, and type of mine.

Mine Rescue Services Ltd. (MRSL), which administers mine rescue in the United Kingdom, had a comparison prepared in 2008 by the Institute of Occupational Medicine (IOM), a leader in heat exposure research in mining and mine rescue activities in the U.K. since the 1950s (see Comparison of National Rescue Heat Codes, Pg. 10).

Though the comparison revealed a variance in approved safe working durations among the surveyed jurisdictions at relatively lower wet bulb temperatures (25 to 30°C), the variance quickly diminishes in the mid-range and upper range of wet bulb temperatures. It should be noted that South Africa, which has the longest safe working duration limits for most of the temperature range, has specific age, fitness and acclimation requirements for its mine rescuers.



Various national guidelines for permissible work duration at high temperatures (100% RH)

Source: Note on UK and German Breathing Apparatus Safe Wearing Time Guidelines under Hot and Humid Conditions, Prepared by Mines Rescue Service Limited, November 2008.

IOM also determined its standard, the most conservative of the six national standards reviewed, is suitable for mine rescuers using the Dräger BG4, the apparatus used by MRSL and Ontario Mine Rescue. The British standard cross-references dry and wet bulb temperatures to determine the mission maximum time limit in minutes. Maximum time limits are strictly followed. MRSL continues to use the standard.

After reviewing the international mine rescue standards, as well as the Canadian guidelines, Ontario Mine Rescue, recognizing that mine rescuers at Ontario mines are at growing risk of heat stress incidents, has adopted the standard developed by IOM and used by MRSL in the U.K.

The maximum time limits under the Ontario Mine Rescue Heat Exposure Standard, Pg. 11, must be strictly followed.

Ontario Mine Rescue Heat Exposure Standard

Wet Bulb Temp.	24	26	28	30	32	34	36	38	40	42	44	46	48	50
38	-	-	-	-	-	-	-	19	19	19	19	0	0	0
37	-	-	-	-	-	-	-	20	19	19	19	19	19	0
36	-	-	-	-	-	-	22	22	21	20	20	19	19	19
35	-	-	-	-	-	-	24	23	22	22	22	21	20	20
34	-	-	-	-	-	27	26	25	24	23	23	22	22	22
33	-	-	-	-	-	29	28	27	27	26	25	24	23	23
32	-	-	-	-	33	32	31	30	29	28	27	26	26	25
31	-	-	-	-	38	36	35	33	32	31	30	29	28	27
30	-	-	-	46	44	42	40	38	36	34	33	32	30	30
29	-	-	-	53	50	48	45	43	41	39	38	36	34	32
28	-	-	63	60	57	55	52	50	47	45	43	41	39	37
27	-	-	72	69	66	63	60	57	54	52	49	47	45	43
26	-	87	83	79	75	72	68	65	62	59	56	54	51	49
25	-	99	95	90	86	82	78	75	71	68	65	62	59	56
24	119	114	108	103	99	94	90	85	81	78	74	71	67	64
23	120	120	120	118	113	108	103	98	93	89	85	81	77	73

Dry Bulb Temp.

Cross referencing the Wet Bulb and Dry Bulb temperatures indicates the maximum time exposure in minutes.
Exposure limits include time for entry, exit, and rest breaks.
Exposure limits must not be exceeded.
Wet Bulb temperature cannot exceed Dry Bulb temperature.

Control and Prevention

All personnel involved in mine rescue activities, as well as mine management, should be aware of the risk of heat stress, and take appropriate control and preventive measures to identify, evaluate and reduce the hazards that may lead to an incident of heat stress disorder during all mine rescue activities, including training and callouts. Any control measures, such as hydration testing, used for regular mining operations, should be available for mine rescue activities.

Mine Managers/Operators Responsibilities

- Be knowledgeable of the risk, causes, symptoms, and prevention of heat stress
- Maintain up-to-date mine and ventilation plans that include:
  - Identified hot zones or areas where heat exposure is an issue and control measures are required under normal operating conditions
  - Identified potential hot zones where heat exposure may be an issue if normal operating conditions and controls, such as ventilation, fail or are inoperative
  - Air temperature ranges at various locations (i.e. levels, headings, ventilation points, etc . . .) with and without ventilation
  - Relative humidity ranges at various locations (i.e. levels, headings, ventilation points, etc . . .) with and without ventilation
  - Air flow ranges at various locations (i.e. levels, headings, ventilation points, etc . . .) with and without ventilation
  - The location of potential advanced fresh air bases, refuge stations, potential safe refuges and cooling areas particularly those located in or near hot zones or potential hot zones
- Ensure that these plans are readily available to the Emergency Control Group during an incident
- Have sufficient trained mine rescue volunteers in excess of the minimum required, so that:
  - Overall emergency operations, especially those involving the possible loss of life, need not be delayed by mission time limits or work/rest regimens
  - If circumstances warrant (distance, heat exposure level, type of incident, etc…), two standby teams are available to assist a mine rescue team in distress
  - An expanded team rotation is possible for incidents in which heat exposure is a hazard
  - Mine rescuers and teams are assured of adequate rest and recovery, at least 24 hours when exposed to heat in a hot zone or heat exposures that reach that level, between assignments
  - Mine rescuers who experience heat stress symptoms can be readily replaced upon the next team rotation
- Ensure that potential respondents to a mutual aid agreement, in which one or more mine has a hot zone or potential hot zone, train in identified zones of concern
- Address potential heat exposure hazards in all emergency response plans, including work/rest regimens and limiting mission times

Control Groups, Briefing Officers, and Supervisors with Mine Rescue Responsibilities

- Be knowledgeable of the risk, causes, symptoms, prevention and treatment of heat stress
- Have ready access to work/rest regimens, mission time limits, the Ontario Mine Rescue heat exposure standard, and other resources
- Have ready access to up-to-date mine and ventilation plans that include:
  - Identified hot zones where heat exposure is an issue and control measures are required under normal operating conditions
  - Identified potential hot zones where heat exposure may be an issue if normal operating conditions and controls, such as ventilation, fail or are inoperative
  - Rock temperature measurements at specific depths and locations
  - The general geothermal gradient
  - Air temperature ranges at various locations (i.e. levels, headings, ventilation points, etc . . .) with and without ventilation
  - Relative humidity ranges at various locations (i.e. levels, headings, ventilation points, etc . . .) with and without ventilation
  - Air flow ranges at various locations (i.e. levels, headings, ventilation points, etc . . .) with and without ventilation
  - The location of potential advanced fresh air bases, refuge stations, safe refuges and cooling areas particularly those located in or near hot zones or potential hot zones
- Include potential heat exposure hazards and operations in emergency simulations and training scenarios, such as:
  - Working in extreme heat
  - Multiple teams (two or more) on the same task
  - Mine rescue volunteer in distress
  - Mine rescue team in distress
- Ensure that potential respondents to a mutual aid agreement, in which one or more mine has a hot zone or potential hot zone, train in those identified zones of concern
- Establish a protocol to ensure all mine rescuers are rested, fit, healthy, and hydrated before any mine rescue activity (training exercise or emergency callout)
- Identify team members as acclimated or not acclimated, based on their regular and recent work duties, to work in hot environments
- Ensure that prior to assignment, the mine rescue team has access to and is encouraged to drink water

- During the briefing, advise the mine rescue team of:
  - Whether the incident is a potential heat exposure incident (fire, explosion, loss of ventilation, unknown nature, etc…)
  - Hot zones or potential hot zones
  - An estimate of the temperature range that may be encountered in those zones
  - A tentative work/rest regimen as they approach/enter that environment
  - Mission time limits that apply because of the heat exposure
  - Potential rest or cooling areas that may assist the team in recovery from heat exposure
- Monitor and record temperature and time exposures, as well as work/rest regimens, as reported by the team captain
- Require mine rescuers to follow the appropriate work/rest regimens and/or mission time limits for the environment in which they are operating
- When making operational decisions, always consider:
  - Potential control measures for heat exposure, such as transportation options, alternate routes, cooling areas, rest options, etc. . .
  - The Ontario Mine Rescue heat exposure standard
  - A team's heat exposure level
  - Rescue needs (standby teams, equipment, etc…) and options (safe areas, nearby teams, etc…) should a team report itself in distress
- Locate the fresh air base, with backup teams, as close as possible to an incident to avoid unnecessary travelling time and effort to and from the site
- Ensure that all mine rescuers have adequate water and cooling facilities following an activity
- Ensure that mine rescuers are assured of adequate rest and recovery, at least 24 hours when exposed to heat in a hot zone or heat exposures that reach that level, between assignments
- Ensure that medical aid is immediately available for mine rescuers suffering from heat stress
- Ensure that environmental conditions at fresh air bases are such that teams can recuperate

Team Captain Responsibilities

The mine rescue team captain has the undisputed discretion, based on the condition of team members and the work environment, to increase the rest period or terminate the assignment. Rest breaks should be in a location where body cooling and recovery can take place. Breaks must be long enough for cooling to occur. The more stressful the heat load, the longer the break required. Rest breaks are an ideal time for assessment. Heat stress symptoms will be difficult to recognize in a fully clothed and apparatus-wearing individual and even more to an observer (the captain) also wearing an apparatus.

- Be knowledgeable of the risk, causes, symptoms, prevention and treatment of heat stress
- Ensure that prior to assignment, the team has access to and is encouraged to drink water

- Prior to going underground, confer with each team member to ensure:
  - He/she is healthy (no cold, flu, hangover, headache, etc…)
  - He/she is adequately rested
  - He/she has not taken any prescription drugs, non-prescription drugs or alcohol that may inhibit his/her abilities to withstand heat stress
  - He/she is adequately hydrated (when did he/she last drink, how much, what was it?)
- Once underground, regularly monitor and confer with each team member to ensure:
  - He/she is hydrated
  - He/she is not suffering any symptoms of minor heat stress disorder (excessively sweating, cramps, dizziness)
  - He/she is not suffering any symptoms of major heat stress disorder (dizziness, disorientation, cool and moist skin, loss of breath)
  - He/she can respond coherently to simple questions – names, time, day, date, location
  - His/her pulse rate is at an acceptable rate while at rest
  - He/she is mentally alert (ask simple questions about names, the day, date, location . . .)
- If a team member is suffering from a heat stress disorder or excessive pulse rate, report to the briefing officer and return to the fresh air base or nearest safe location as advised by the briefing officer
- While underground regularly monitor and record temperature and time exposures, and report those findings to the briefing officer
- Should the temperature increase by 3°C or more while the team is at one location, report the change to the briefing officer and consider removing the team
- Ensure that the team follows the work/rest regimen and/or mission time limit set out by the control group or briefing officer
- Ensure the team's heat exposure does not exceed the Ontario Mine Rescue heat exposure standard
- Stay aware of the environment and if possible, avoid exposing the team to high temperatures, during the course of the mission
- Increase rest periods, if in the captain's consideration, it is necessary to allow adequate cooling and recovery to occur
- Ensure that work is done at a steady, even pace with a minimum of movement
- Ensure that the burden of the work is evenly distributed over the team members, so as not to over burden any individual
- Do as little physical work as practical, but observe the team, regulate the work/rest regimen and plan for the return trip

Mine Rescue Volunteer Responsibilities

- Be knowledgeable of the risk, causes, symptoms, prevention and treatment of heat stress
- Prior to assignment, drink water
- Prior to assignment self-assess their risk level for heat stress by asking themselves:
  - Am I physically fit and healthy?
  - Am I rested?
  - Am I taking any prescription or non-prescription drugs that may inhibit my abilities?
  - When did I last drink water? How much? Am I hydrated, do I feel thirsty?
- Accurately and honestly report their status to the briefing officer and team captain
- Prior to beginning an assignment in a hot zone or potential hot zone, or involving an actual or potential heat incident, wear a minimum amount of clothing underneath mine rescue coveralls
- During assignment self-assess their risk level for heat stress on an on-going basis, including by monitoring their pulse rate, and accurately and honestly report their status to the team captain. They should ask themselves:
  - Is my heart rate/pulse rate too fast?
  - Am I short of breath?
  - Am I hydrated, do I feel thirsty?
  - Am I sweating excessively or not at all?
  - Am I hydrated, do I feel thirsty?
  - Am I weak, dizzy or disoriented?
- During assignment monitor team members for symptoms of heat stress and report concerns to the team captain

Mine rescue volunteers should remember that heat stress can cloud judgment and make self-assessment more difficult. As well, heat stress symptoms will be difficult to recognize in a fully clothed and apparatus-wearing individual and even more to observers also wearing an apparatus. Mine rescuers must work together to keep a protective eye on each other.

As a matter of course, mine rescue volunteers should be advised and encouraged to maintain a lifestyle that supports and sustains a level of physical fitness that reduces the likelihood of experiencing a heat stress disorder, and enables them to better perform all mine rescue activities.

APPENDICES

Appendix A – Glossary

Appendix B – International Mine Rescue Guidelines/Protocols

Appendix C – International Mine Rescue Guidelines/Protocols

Appendix D – Additional Reading

Appendix E – Additional Ontario Mine Rescue Resources

Appendix A – Glossary

Absolute Humidity – The mass of water vapor present in a unit volume of moist air.

Acclimation – The physiological changes that occur in response to several days of heat exposure and make the body accustomed to a hot environment.

Brigadesman – A common term in many countries and jurisdictions for a mine rescuer.

Conduction – The process of heat exchange between materials that contact each other. Heat passes from the warmer material to the cooler material.

Convection – The process of heat exchange between the body and the surrounding air or fluid as a result of the flow of that air or fluid.

Cool Mine – According to the South African mine rescue authorities, a mine with a wet bulb temperature of <27.5°C (81.5°F) with the dry bulb temperature not exceeding 37.0°C (98.6°F).

Dehydration – The loss or deficiency of water in body tissues caused by sweating, vomiting or diarrhea. Symptoms include excessive thirst, nausea, and exhaustion.

Emergency Heat Stress Index (EHSI) – Protocol used by South Africa's mine rescue services to limit emergency workers' exposure in hot environments.

Evaporative Cooling – The process of cooling that takes place when sweat evaporates from the skin. High humidity reduces the rate of evaporation and thus reduces the effectiveness of the body's primary cooling mechanism**.**

Heat Cramps – The painful and, at times, incapacitating cramps in muscles. Heat cramps are caused by depletion of salt in the body as a result of heavy sweating, and ingestion of water without replacing salt.

Heat Exhaustion – Weakness, lassitude, dizziness, visual disturbance, feeling of intense thirst and heat, nausea, vomiting, palpitations, tingling and numbness of extremities after exposure to a hot environment.

Heat Rash (prickly heat) – An itchy rash of small raised red spots on the face, neck, back, chest and thighs caused by exposure to a hot, humid environment..

Heat Strain – The overall physiological response resulting from heat stress (ACGIH).

Heat Stress – The net heat load to which a worker may be exposed (ACGIH).

Heat Stroke – An acute illness caused by overexposure to heat. Symptoms are dry, hot skin, high body temperature (usually over 40°C) and mental dysfunction.

Heat Syncope – The temporary loss of consciousness induced by insufficient blood flow to the brain, due to the body being overheated. Recovery is normally prompt and without any long-term ill effects.

Hot Work Site – According to the Mine Safety and Health Administration in the United States, any combination of air temperature, humidity, radiation and wind speed that exceeds a wet bulb globe temperature of 79°F (26.1°C)

Hot Zone – Locations in a mine where heat stress is an issue and control measures are required under normal operating conditions.

Hygrometer – An instrument used for measuring the moisture content, humidity, in the air.

Metabolic Rate – The rate of energy (heat) production of the body which varies with the level of physical activity.

Natural Wet Bulb Temperature – Air temperature measured using a thermometer in which the bulb is covered with wet cotton wick and cooled by the natural movement of air.

Heat Exposure Incident – An incident involving fire, explosion, loss of ventilation, or other factor that could result in a heat exposure hazard. Incidents of an unknown nature should be considered potential heat exposure incidents.

Potential Hot Zone – Locations in a mine where heat exposure may be an issue if normal operating conditions and controls, such as ventilation, fail or are inoperative.

Psychrometer – A device consisting of two thermometers, one dry and one kept moist with distilled water on a sock or wick, used to measure relative humidity. Also referred to as a wet and dry bulb thermometer. See Sling Psychrometer/Whirling Psychrometer.

Prickly Heat – See Heat rash.

Sling Psychrometer – A psychrometer attached to a handle or length of rope and spun around in the air for a few minutes to measure relative humidity, used for field measurements**.** See Psychrometer/Whirling Psychrometer.

Radiation (heat) – Transfer of heat between hot and cold bodies without contact between them. Heat passes from the warmer body to the cooler body.

Relative Humidity – The ratio of the water vapour content of air to the maximum possible water vapour content of air at the same temperature and air pressure.

Vasodilation – The body's initial response to an increase in body temperature. Blood vessels and capillaries near and in the skin increase in size and the heart beats faster to increase blood flow. This encourages heat dissipation and body cooling.

Wet Bulb Globe Temperature (WBGT) – A composite temperature used to estimate the effect of temperature, humidity, wind speed (wind chill), and solar radiation on humans. It is used by industrial hygienists to determine appropriate exposure levels to high temperatures**.**

Whirling Psychrometer – A psychrometer attached to a ratchet that is spun in the air. See Psychrometer/Sling Psychrometer.

Appendix B – Canadian Heat Stress Guidelines/Standards

In Ontario and across Canada, no specific guidelines or standards have been established to limit heat exposure in mining or mine rescue activities, though various workplace limits and guidelines do apply to mining activities.

Within Canada, provinces and agencies have created heat indices that are available for using to establish work in heat guidelines. These indices are developed for specific conditions and assumptions that may not have relevance to mine rescue activities.

Knowledge, however, of these standards can help Ontario mine rescuers gain understanding of heat exposure risks and take appropriate control measures.

Ontario and Canadian Work Standards

Under Section 25(2) (h) of Ontario's Occupational Health and Safety Act, employers have a duty to take every precaution reasonable in the circumstances for the protection of workers. This includes developing hot environment policies and procedures to protect workers in hot environments due to hot processes or hot weather.

For compliance purposes, the Ministry of Labour recommends employers use the Threshold Limit Values (TLVs) for Heat Stress and Heat Strain published by the American Conference of Governmental Industrial Hygienists (ACGIH). These values are based on preventing unacclimated workers' core body temperatures from rising above 38°C.

The only specific reference in Ontario legislation to restrictions on work in a hot environment is in Regulation 213 Construction Projects, which reads:

> **384.** (1) Subject to subsection (2), no worker shall work or be permitted to work in a work chamber in which the temperature exceeds the greater of,
> (a) 27 degrees Celsius; and
> (b) the temperature at the entrance to the service shaft above ground. O. Reg. 213/91, s. 384 (1).
> (2) No worker shall work or be permitted to work in a work chamber in which the temperature exceeds 38 degrees Celsius. O. Reg. 213/91, s. 384 (2).

No other specific standards regarding work in hot environment exist in the Occupational Health and Safety Act or its associated regulations. Most other Canadian jurisdictions rely on the ACGIH standards for heat stress guidelines.

Canadian Health & Safety Regulations with respect to Thermal Conditions in the Workplace (source - Canadian Centre for Occupational Health & Safety)		
Jurisdiction	**Regulation**	**Temperature**
British Columbia	Heat Stress Regulations Indoor Air Quality Regulation, ASHRAE 55-1992 Standard	Limits in WBGT units similar to ACGIH TLV
	Summer Indoor Winter Indoor	23.3 - 27.2°C or 74 - 81°F 20.5 - 24.4°C or 69 - 76°F
Alberta	(Guidelines only)	similar to ACGIH TLVs for heat stress and cold stress
Saskatchewan	Thermal environment	Reasonable and appropriate to nature of work
Manitoba	Thermal environment	ACGIH TLVs for heat stress, cold stress
Quebec	Safety in mines: Dryhouse temperature Occupational exposure limits	22°C min. WBGT similar to ACGIH TLVs
Nova Scotia	Construction safety regulations: Working chamber	27°C (80°F) max. ACGIH TLVs for heat stress and cold stress
Prince Edward Island	Occupational exposure limit	ACGIH TLVs for hot and cold environment
Newfoundland & Labrador	Occupational exposure limit	ACGIH TLVs for hot and cold environment

American Conference of Governmental Industrial Hygienists

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends Threshold Limit Values (TLVs) for working in hot environments. These limits are given in units of wet bulb globe temperature (WBGT) degrees Celsius (°C). The WBGT unit takes into account environmental factors namely, air temperature, humidity and air movement, which contribute to the perception of heat by people. Some Canadian jurisdictions have adopted these TLVs as occupational exposure limits and others use them as guidelines to control heat stress in the workplace.

ACGIH Screening Criteria for Heat Stress Exposure for eight-hour work day five days per week with conventional breaks

(source - Canadian Centre for Occupational Health & Safety)

Allocation of Work in Work/Rest Cycle	**Action Limit – Acclimated** (°C WBGT)				**Action Limit – Unacclimated** (°C WBGT)			
	Light	Moderate	**Heavy**	**Very Heavy**	Light	Moderate	**Heavy**	**Very Heavy**
75-100%	31.0	28.0	**--**	**--**	28.0	25.0	**--**	**--**
50-75%	31.0	29.0	**27.5**	**--**	28.5	26.0	**24.0**	**--**
25-50%	32.0	30.0	**29.0**	**28.0**	29.5	27.0	**25.5**	**24.5**
0-25%	32.5	31.0	**30.5**	**30.0**	30.0	29.0	**28.0**	**27**

Notes:

Assumes eight-hour workdays in a 5-day workweek with conventional breaks.

TLVs assume that workers exposed to these conditions are adequately hydrated, are not taking medication, are wearing lightweight clothing, and are in generally good health.

Examples of workloads:

Rest - sitting (quietly or with moderate arm movements)

Light work - sitting or standing to control machines; performing light hand or arm work (e.g. using a table saw); occasional walking; driving

Moderate work - walking about with moderate lifting and pushing or pulling; walking at moderate pace; e.g. scrubbing in a standing position

Heavy work - pick and shovel work, digging, carrying, pushing/pulling heavy loads; walking at fast pace; e.g. carpenter sawing by hand

Very Heavy - very intense activity at fast to maximum pace; e.g. shovelling wet sand

The ACGIH Heat Stress TLVs make assumptions regarding acclimation and worker fitness. Since the body's main cooling mechanism, however, is the evaporation of sweat from the skin, the ACGIH specifies the following clothing adjustment factor to its standard.

Clothing Type	WBGT Addition
Work clothes (long-sleeved shirt and pants)	0
Cloth (woven material) overalls	0
Double-layer woven clothing	3
SMS polypropylene coveralls	0.5
Polyolefin coveralls	1
Limited-use vapour-barrier coveralls	11

The adjustments are not for completely encapsulating suits, while the coverall adjustment assumes only modest clothing is underneath, not a second layer of clothing. For example, an acclimated worker wearing double-layer woven clothing doing moderate work would have a corrected exposure level of: 30.0 + 3 = 33ºC, which would lower his or her allowable exposure to 0-25 per cent work (from 25-50 per cent work).

OHCOW's Humidex-Based Heat Response Plan

The Occupational Health Clinics for Ontario Workers (OHCOW) developed the Humidex-Based Heat Response Plan as a simplified method for employers and workers to assess heat stress in the workplace. Rather than use the Wet Bulb Globe Temperature, the Humidex-Based Response Plan requires workplaces to use a thermal hygrometer to measure temperature and humidity. A chart or pocket-sized paper/plastic calculator can be used to easily determine a workplace humidex value.

The plan correlates humidex values with the ACGIH WBGT values, and proposes two response plans, Humidex 1 for unacclimated workers at a moderate work level wearing light clothing and Humidex 2 for acclimated workers at a moderate level wearing light clothing. Both response plans require general controls such as annual heat stress training, encouraging adequate fluid replacement, permitting self-limitation of exposure, encouraging watching out for symptoms in co-workers, and adjusting expectations for workers returning to work after an absence.

Humidex 2 additionally requires job specific controls such as engineering controls to reduce physical job demands, shielding of radiant heat, increased air movement, reduction of heat and moisture emissions at the source, adjusting exposure times to allow sufficient recovery, and personal protective equipment that provides for body cooling.

Adjustments to the humidex value are required for additional or heavier clothing – for example, cotton overalls on top of summer clothes adds 5 to the humidex value, and for exposure to radiant heat – for example, outdoor work in direct sunlight between 10 a.m. and 5 p.m. adds between 2 and 3 to the humidex value. The resulting reading is referenced according to the appropriate humidex response plan for suggested actions.

Humidex-Based Heat Response Plan – Actions		
Humidex 1	**Action**	**Humidex 2**
25–29	supply water to workers on an "as needed" basis	32–35
30–33	post Heat Stress Alert notice; encourage workers to drink extra water; start recording hourly temperature and relative humidity	36–39
34–37	post Heat Stress Warning notice; notify workers that they need to drink extra water; ensure workers are trained to recognize symptoms	40–42
38–39	work with 15 minutes relief per hour can continue; provide adequate cool (10-15°C) water; at least 1 cup (240 mL) of water every 20 minutes workers with symptoms should seek medical attention	43–44

Humidex-Based Heat Response Plan – Actions		
Humidex 1	**Action**	**Humidex 2**
40–41	work with 30 minutes relief per hour can continue in addition to the provisions listed previously;	45–46*
42–44	if feasible, work with 45 minutes relief per hour can continue in addition to the provisions listed above.	47–49*
45 or over	only medically supervised work can continue	50 or over*
***at Humidex exposures above 45, heat stress should be managed as per the ACGIH TLV**		

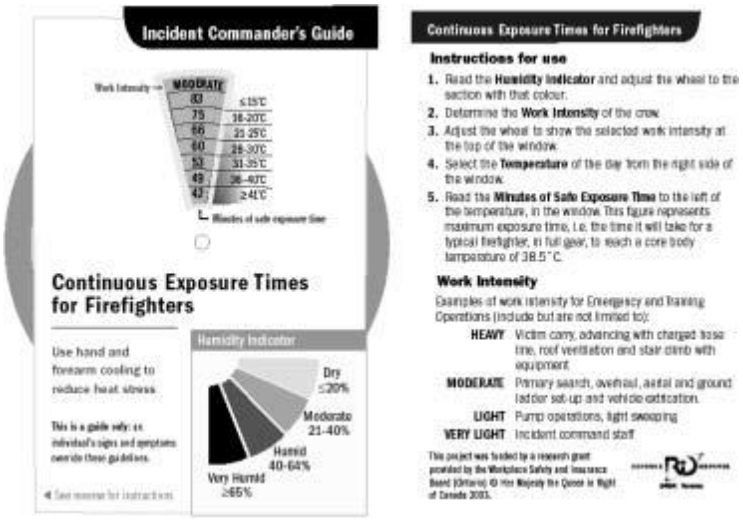
Humidex-Based Heat Response Plan – Humidex Values

°C	Relative Humidity (in percent)																		
	100	95	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10
49																			50
48																			49
47																		50	47
46																		49	46
45																	50	47	45
44																	49	46	43
43																49	47	45	42
42															50	48	46	43	41
41															48	46	44	42	40
40														49	47	45	43	41	39
39													49	47	45	43	41	39	37
38												49	47	45	43	42	40	38	36
37											49	47	45	44	42	40	38	37	35
36									50	49	47	45	44	42	40	39	37	35	34
35								50	48	47	45	43	42	40	39	37	36	34	33
34							49	48	46	45	43	42	40	39	37	36	34	33	31
33					50	48	47	46	44	43	41	40	39	37	36	34	33	32	30
32			50	49	48	46	45	44	42	41	40	38	37	36	34	33	32	30	29
31	50	49	48	47	45	44	43	42	40	39	38	37	35	34	33	32	30	29	28
30	48	47	46	44	43	42	41	40	39	37	36	35	34	33	31	30	29	28	27
29	46	45	43	42	41	40	39	38	37	36	35	33	32	31	30	29	28	27	26
28	43	42	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25
27	41	40	39	38	37	36	35	34	33	32	31	30	29	28	27	26	25		
26	39	38	37	36	35	34	33	33	32	31	30	29	28	27	26	25			
25	37	36	35	34	33	33	32	31	30	29	28	27	26	26	25				
24	35	34	33	33	32	31	30	29	28	28	27	26	25						
23	33	32	31	31	30	29	28	28	27	26	25								
22	31	30	30	29	28	27	27	26	25	25									
21	29	29	28	27	26	26	25												

Ontario Firefighter Guideline

In the mid-2000s**,** the Municipal Health and Safety Association, now a part of Health and Safety Ontario, in partnership with the Workplace Safety and Insurance Board, the Ontario Fire Marshal, the Toronto Fire Service, and others, developed a heat stress management tool to help incident commanders on fire calls safely manage the heat stress of wearing firefighting protective clothing.

The guide allows incident commanders to determine a firefighter's maximum safe exposure time by assessing the local temperature, humidity and work intensity.



Controls recommended by the research include, if possible, varying the workload intensity by rotating or alternating responsibilities, withdrawal from the heat zone to permit on-site recovery and cooling, immediate access to water for rehydration, removal of personal protective equipment and clothing, as well as the active cooling methods of hand and forearm submersion in water, and cooling mists.

Appendix C – International Mine Rescue Guidelines/Protocols

Australia

Australian mine rescue authorities recommend a series of precautions be taken when brigadesmen or mine rescuers are required to work or train in hot and humid environments. The precautions include the use of well-rested personnel, a preference for light clothing, the regular determination of temperature and humidity, and advice to personnel to inform the leader of any sign or symptoms of heat stress.

Additionally, authorities have set standard deployment times for mine rescue activities based on the wet bulb temperature and the difference between wet and dry bulb temperatures (see chart, Pg. 28). Teams are equipped with a whirling hygrometer/sling psychrometer as minimum temperature/humidity testing equipment, and are instructed to test on initial entry of areas to determine operational time constraints. They also test temperature and humidity when environmental conditions noticeably change or on suspicion conditions are changing.

After any period of duty in a hot and humid atmosphere approximating the permissible deployment times, brigadesmen are normally rested for 24 hours before they are again called on to perform another period of duty.

The following measures are recommended for mine rescue work in hot and humid conditions:

Before entering:

- Team members should have rested, preferably in a cool place and be properly hydrated by drinking water. The drinking of coffee should be avoided.
- Team members having a cold or cough or other infection should not be allowed to work in hot and humid conditions.
- Team members must be reminded of the signs and symptoms of heat illness or hyperventilation and instructed to inform the captain at the first sign or symptom.
- Team members who have consumed a significant quantity of alcohol in the previous 24 hours may suffer from dehydration and should not be allowed to work in hot and humid atmospheres.

In the hot location:

- Work should be done at a slow, even pace with a minimum of movement.
- Rest pauses should be frequent and taken in turn.
- All team members should watch each other for heat illness or hyperventilation signs and symptoms.
- The leader should not engage in physical work. He should observe his team members, regulate the work, allocate rest periods and plan for the return trip.
- The use of personal cooling devices should be considered.

After exposure:

- Team members should not cool down too quickly and should wait until sweating ceases before having a shower. They should lie down while waiting and rest after the shower.
- Team members should rest as much as possible, not do heavy work and avoid driving.
- Lost sweat should be replaced by drinking fluids.
- Dry clothes or blankets should be made available at the fresh air base.
- Consideration of electrolyte levels.

Deployment Times For Rescue Brigadesmen Wearing Drager BG4					
Per cent Relative Humidity	100-85	84-73	75-62	67-53	60-45
Temperature °C*	0-2	3-4	5-6	7-8	9-10
Wet Bulb Temperature	Duration of Exposure (in minutes)				
26	95	100	105	110	115
27	85	85	90	95	100
28	75	75	80	80	85
29	65	65	70	70	75
30	55	60	60	65	65
31	50	50	55	55	60
32	45	45	50	50	50
33	40	40	45	45	45
34	35	35	40	40	40
35	30	35	35	35	35
36	30	30	30	30	30
37	25	25	30	30	30
38	25	25	25	25	25
39	20	20	20	25	25
40	20	20	20	20	20
41	15	20	20	20	20
42	15	15	15	15	20
43	15	15	15	15	15
44	15	15	15	15	15
45	10	10	10	15	15
***Temperature = Difference between wet and dry bulb temperatures**					

Czech Republic

The Czech Republic Mine Rescue has set working time standards for mine rescue activities in hot and humid environments that are similar to the standards used by German mine rescue authorities. Czech mine rescuers, however, use the dry bulb temperature and the temperature difference between wet and dry bulb temperatures, rather than relative humidity, to help set working time limits (see charts, Pgs. 30 & 31).

Mine rescuers are equipped with Kestrel personal anemometers capable of measure air movement, temperature and relative humidity, to gauge their heat exposure. They are also equipped with Thermal Wear II Magnum cooling vests, which weight about 1.3 kilograms, approximately three pounds.

Prior to responding to an incident in a known hot environment, Czech mine rescuers are examined by a rescue doctor, who records each rescuer's temperature, blood pressure, and heart rate, as well as assesses their general state of health before the assignment. Each rescuer is also examined following the assignment. Records are kept and the doctor must report "serious findings to the base commander."

When approaching and working in a hot environment, the mine rescue team captain must monitor the environment temperature and the heart rate of team members at intervals no longer than 10 minutes. While the temperature is allowed to increase as the team approaches the work assignment, if the temperature at the work site rises by more than 3°C in 10 minutes, the team must return to the fresh air base.

Similarly, should at any time, any team member have a pulse exceeding 160 heartbeats per minute, the team must return to the fresh air base. Heart rate is measured by team members counting their pulse rate either on their wrist or carotid artery while the captain times them for 15 seconds. If any member counts a pulse of 40 or higher (the equivalent of a 160 pulse per minute), the team must turn back.

Captains are also required to monitor team members for hyperthermia or heat stress symptoms, including general faintness, sickness, urge to vomit, stopping of perspiration, a heart rate that does not calm, loss of muscle coordination and movement, cramps, pulmonary or cardiac arrests. The captain is required to return the team to the fresh air base should any member show a symptom of heat stress.

Following an assignment, mine rescuers must have suitable conditions for their recovery at the mine site, including showers, a rest room with a suitable temperature range below 25°C, vitamins, and beverages, "particularly ion (Gatorade-like) drinks which are dosed after agreement with the rescue doctor." After an assignment in a hot environment, a mine rescuer cannot be reassigned for a minimum of two hours.

4.3.5/II. Response time in the worsened microclimatic conditions

(adapted according to BZ I)

Shoot-proof clothes without and with cooling vest - response time in minutes (depending on $\Delta t_s - t_v$]

DRY TEMPERATURE [^{0}C]	Temperature differences between dry and wet thermometers																								DRY TEMPERATURE [^{0}C]
	0		1		2		3		4		5		6		7		8		9		10				
22	80	90																					22		
23	75	90	80	90																			23		
24	70	90	75	90	80	90	85	9															24		
25	65	90	70	90	75	90	80	90	85	90													25		
26	60	90	60	90	65	90	70	90	80	90	85	90											26		
27	55	90	55	90	60	90	65	90	70	90	75	90	85	90									27		
28	50	80	55	85	55	90	60	90	65	90	70	90	75	90	80	90							28		
29	45	75	50	80	50	85	55	90	60	90	65	90	70	90	75	90	80	90	85	90			29		
30	45	65	45	70	50	80	50	85	55	90	60	90	65	90	70	90	75	90	80	90	85	90	30		
31	40	60	40	65	45	70	50	75	50	85	55	90	60	90	65	90	65	90	75	90	80	90	31		
32	35	55	40	60	40	65	45	70	50	75	50	80	55	90	60	90	60	90	65	90	70	90	32		
33	35	50	35	55	40	60	40	65	45	70	45	75	50	80	55	90	55	90	60	90	65	90	33		
34	35	45	35	50	35	55	40	60	40	65	45	70	45	75	50	80	55	85	55	90	60	90	34		
35	30	45	30	45	35	50	35	55	40	60	40	60	45	65	45	70	50	80	50	85	55	90	35		
36	30	40	30	45	30	45	35	50	35	55	40	55	40	60	45	65	45	70	50	75	50	85	36		
37	25	35	30	40	30	45	30	45	35	50	35	50	40	55	40	60	40	65	45	70	50	75	37		
38	25	35	25	35	30	40	30	40	30	45	35	50	35	50	35	55	40	60	40	65	45	70	38		
39	25	30	25	35	25	35	30	40	30	40	35	50	30	45	35	50	35	55	40	60	40	65	39		
40	25	30	25	30	25	35	25	35	30	40	30	40	30	40	35	45	35	50	35	55	40	60	40		
41	20	30	25	30	25	30	25	35	25	35	30	40	25	40	30	45	30	45	35	50	35	55	41		
42	20	25	20	30	25	30	25	30	25	35	25	35	25	35	30	40	30	45	30	45	35	50	42		
43	20	25	20	25	20	30	20	30	25	30	25	35	25	35	25	35	30	40	30	40	30	45	43		
44	20	25	20	25	20	25	20	25	20	30	25	30	25	30	25	35	25	35	30	40	30	40	44		
45	20	20	20	25	20	25	20	25	20	25	20	30	20	30	25	30	25	35	25	35	30	40	45		
46	15	20	20	20	20	25	20	25	20	25	20	25	20	25	25	30	25	30	25	35	25	35	46		
47	15	20	15	20	15	20	20	20	20	25	20	25	20	25	20	30	25	30	25	30	25	35	47		
48					15	20	15	20	20	20	20	25	20	25	20	25	20	30	25	30	25	30	48		
49							15	20	15	20	20	20	20	20	20	25	20	25	20	25	20	30	49		
50									15	20	15	20	15	20	20	25	20	25	20	25	20	25	50		
51											15	20	15	20	20	20	20	25	20	25	20	25	51		
52													15	20	15	20	20	20	20	25	20	25	52		
53																	15	20	15	20	20	20	53		
54																			15	20	15	20	54		
55																					15	20	55		

RESPONSE AREA UP TO 90 MINUTES

RESPONSE AREA ONLY WITH APPROVAL OF RESCUE CREW COMMANDER

ČÁST 2. **Light clothes - without a d** **with cooling vest** **- response time in minutes**

		Temperature differences between dry and wet thermometers																							
		0		1		2		3		4		5		6		7		8		9		10			
	30	95	*																					30	
	31	65	*	90	*																			31	
	32	55	60	60	*	85	*																	32	
	33	50	60	55	60	60	*	80	*	115	*													33	
	34	45	60	45	60	50	60	60	*	75	*	105	*											34	
D	35	40	55	40	60	45	60	55	60	55	60	70	*	100	*									35	D
R	36	35	45	40	55	40	60	45	60	50	60	55	60	65	*	95	*							36	R
Y	37	30	40	35	45	35	50	40	60	45	60	50	60	55	60	60	*	90	*					37	Y
	38	20	35	30	40	35	45	35	50	40	55	45	60	50	60	55	60	60	*	80	*			38	
	39	25	30	25	35	30	40	35	45	35	50	40	55	45	60	50	60	55	60	60	*	75	*	39	
T	40	25	30	25	30	25	35	30	40	30	45	35	50	40	55	45	60	45	60	50	60	60	*	40	T
E	41	20	25	20	25	25	30	25	35	30	40	30	45	35	50	40	55	40	60	45	60	50	60	41	E
M	42	20	20	20	25	20	25	25	30	25	35	30	35	30	40	35	45	40	55	40	60	45	60	42	M
P	43	15	20	20	20	20	25	20	25	25	30	25	35	30	35	30	40	35	45	15	50	40	60	43	P
E	44	15	15	15	20	20	20	20	25	20	25	25	30	25	30	30	35	30	40	35	45	35	50	44	E
R	45	15	15	15	15	15	20	20	20	20	25	20	25	25	30	25	30	25	35	30	40	35	45	45	R
A	46	15	15	15	15	15	15	15	20	15	20	20	20	20	25	20	30	25	30	25	35	30	40	46	A
T	47	10	10	10	15	15	15	15	15	15	20	15	20	20	20	20	25	20	25	25	30	25	35	47	T
U	48					10	15	15	15	15	15	15	15	15	20	20	20	20	25	20	25	25	30	48	U
R	49							10	15	15	15	15	15	15	15	15	20	20	20	20	25	20	25	49	R
E	50									10	10	15	15	15	15	15	15	15	20	20	20	20	25	50	E
	51			RESPONSE AREA								10	10	15	15	15	15	15	15	15	20	20	20	51	
[0C]	52			ONLY WITH APPROVAL OF RESCUE CREW										10	10	15	15	15	15	15	15	15	20	52	[0C]
	53			COMMANDER														10	15	15	15	15	15	53	
	54																			10	15	15	15	54	
	55																					10	15	55	

RESPONSE AREA UP TO 120 MINUTES
* VEST ISN´T USED

Germany

German mine rescue authorities have done extensive research on mine rescue teams working in hot, humid conditions during the past 15 years and developed two working-time standards based on dry bulb temperature (trockentemperatur) and relative humidity (relative Freuchte) for rescue teams (see charts, Pgs. 33 & 34). The first is for mine rescue teams wearing flame protective clothing (flammenschutzkleidung), and the second for teams wearing shirts and shorts (leichte Bekleidung). Both standards also have different limits for teams with and without cooling vests (kuhlveste).

The researchers, G. Bresser (Central Mine Rescue Station, German Coal Co., Herne,Germany) and B. Kampmann (Institut für Arbeitswissenschaften, RAG, AG, Dortmund, Germany) proposed the following "general rules" for using the standards and for working in hot environments:

- Calculate the maximum exposure time using the highest climate data (temperature and relative humidity) measured during the activity. Using continuous measuring devices offers advantages.
- The calculated exposure time should include time required to return to a safe refuge (fresh air base). It might be necessary to start the return trip, even if the assignment is not completed.
- The return time to a safe refuge should take into consideration the difficulty of the return trip.
- Mine rescue team members should be aware of the effects of heat stress on their bodies and watch for signs of heat exhaustion.

Teams use a psychrometer to measure relative humidity and temperature while on assignment.

Though the standards were established in 1990, the subsequent research indicates that German training procedures place their mine rescuers at the upper level of tolerable strain. The researchers endorse that level as reasonable during training.

German mine rescuers are encouraged to participate in aerobic training (low intensity, long duration), such as long distance running to maintain a high level of fitness, which should reduce the likelihood of experiencing heat stress. As well, German mine rescuers must pass an annual medical screening test and leave active mine rescue at age 50.

Einsatztabelle für Flammenschutzkleidung ohne und mit Kühlweste Einsatzdauer in Minuten

Trockentemperatur (°C)	relative Feuchte (%) 100		95		90		85		80		75		70		65		60		55		50		Trockentemperatur (°C)
22	80	**90**	85	**90**																			22
23	75	**90**	80	**90**	80	**90**	85	**90**							Einsatzdauer 90 Min.								23
24	70	**90**	70	**90**	75	**90**	80	**90**	85	**90**													24
25	65	**90**	65	**90**	70	**90**	70	**90**	75	**90**	80	**90**	85	**90**									25
26	60	**90**	60	**90**	65	**90**	65	**90**	70	**90**	75	**90**	80	**90**	85	**90**							26
27	55	**90**	55	**90**	60	**90**	60	**90**	65	**90**	70	**90**	70	**90**	75	**90**	80	**90**	85	**90**			27
28	50	**80**	50	**85**	55	**90**	55	**90**	60	**90**	65	**90**	65	**90**	70	**90**	75	**90**	80	**90**	85	**90**	28
29	45	**75**	50	**75**	50	**80**	55	**85**	55	**90**	60	**90**	60	**90**	65	**90**	70	**90**	75	**90**	80	**90**	29
30	45	**65**	45	**70**	45	**75**	50	**80**	50	**85**	55	**90**	55	**90**	60	**90**	65	**90**	70	**90**	75	**90**	30
31	40	**60**	40	**65**	45	**70**	45	**70**	50	**75**	50	**80**	55	**85**	55	**90**	60	**90**	65	**90**	70	**90**	31
32	35	**55**	40	**60**	40	**60**	40	**65**	45	**70**	45	**75**	50	**80**	50	**85**	55	**90**	60	**90**	65	**90**	32
33	35	**50**	35	**55**	40	**55**	40	**60**	40	**65**	45	**70**	45	**75**	50	**80**	55	**85**	55	**90**	60	**90**	33
34	35	**45**	35	**50**	35	**50**	35	**55**	40	**60**	40	**65**	45	**65**	45	**70**	50	**75**	50	**85**	55	**90**	34
35	30	**45**	30	**45**	35	**50**	35	**50**	35	**55**	40	**60**	40	**60**	45	**65**	45	**70**	50	**75**	50	**85**	35
36	30	**40**	30	**40**	30	**45**	35	**45**	35	**50**	35	**55**	40	**55**	40	**60**	40	**65**	45	**70**	50	**75**	36
37	25	**35**	30	**40**	30	**40**	30	**45**	30	**45**	35	**50**	35	**55**	40	**55**	40	**60**	40	**65**	45	**70**	37
38	25	**35**	25	**35**	30	**40**	30	**40**	30	**45**	30	**45**	35	**50**	35	**50**	35	**55**	40	**60**	40	**65**	38
39	25	**30**	25	**35**	25	**35**	25	**40**	30	**40**	30	**40**	30	**45**	35	**50**	35	**50**	35	**55**	40	**60**	39
40	25	**30**	25	**30**	25	**35**	25	**35**	25	**35**	30	**40**	30	**40**	30	**45**	35	**50**	35	**50**	40	**55**	40
41	20	**30**	25	**30**	25	**30**	25	**35**	25	**35**	25	**35**	30	**40**	30	**40**	30	**45**	35	**50**	35	**50**	41
42	20	**25**	20	**30**	20	**30**	25	**30**	25	**30**	25	**35**	25	**35**	30	**40**	30	**40**	30	**45**	35	**50**	42
43	20	**25**	20	**25**	20	**25**	20	**30**	25	**30**	25	**30**	25	**35**	25	**35**	30	**40**	30	**40**	30	**45**	43
44	20	**25**	20	**25**	20	**25**	20	**25**	20	**30**	25	**30**	25	**30**	25	**35**	25	**35**	30	**40**	30	**45**	44
45	20	**20**	20	**25**	20	**25**	20	**25**	20	**25**	20	**30**	25	**30**	25	**30**	25	**35**	25	**35**	30	**40**	45
46	15	**20**	15	**20**	20	**20**	20	**25**	20	**25**	20	**25**	20	**30**	25	**30**	25	**30**	25	**35**	25	**35**	46
47	15	**20**	15	**20**	15	**20**	20	**20**	20	**25**	20	**25**	20	**25**	20	**30**	25	**30**	25	**30**	25	**35**	47
48					15	**20**	15	**20**	20	**20**	20	**25**	20	**25**	20	**25**	20	**30**	25	**30**	25	**35**	48
49							15	**20**	15	**20**	20	**20**	20	**25**	20	**25**	20	**25**	20	**30**	25	**30**	49
50									15	**20**	15	**20**	20	**20**	20	**25**	20	**25**	20	**25**	20	**30**	50
51											15	**20**	15	**20**	20	**20**	20	**25**	20	**25**	20	**25**	51
52			Einsatz nur in Abstimmung mit der Einsatzleitung										15	**20**	15	**20**	20	**20**	20	**25**	20	**25**	52
53															15	**20**	15	**20**	20	**25**	20	**25**	53
54																	15	**20**	15	**20**	20	**25**	54
55																			15	**20**	20	**20**	55

Messung mit dem elektronischen Psychrometer

German Work-time Standards for Rescue Teams Wearing Flame Protective Clothing, With and Without Cooling Vests (90-minute limit)

Einsatztabelle für leichte Bekleidung ohne und mit Kühlweste Einsatzdauer in Minuten

Trockentemperatur (C)	relative Feuchte (%)																						Trockentemperatur (C)
	100		95		90		85		80		75		70		65		60		55		50		
30	95	*																					30
31	65	*	80	*	105	*									Einsatzdauer 120 Min.								31
32	55	**60**	60	*	70	*	90	*															32
33	50	**60**	50	**60**	55	**60**	60	*	80	*	110	*											33
34	45	**60**	45	**60**	50	**60**	55	**60**	60	*	70	*	100	*									34
35	40	**55**	40	**60**	45	**60**	50	**60**	50	**60**	55	**60**	65	*	90	*							35
36	35	**45**	35	**50**	40	**55**	45	**60**	45	**60**	50	**60**	55	**60**	65	*	90	*					36
37	30	**40**	35	**45**	35	**50**	40	**55**	40	**60**	45	**60**	50	**60**	55	**60**	60	*	90	*			37
38	30	**35**	30	**40**	30	**45**	35	**50**	40	**55**	40	**60**	45	**60**	50	**60**	55	**60**	60	*	90	*	38
39	25	**30**	25	**35**	30	**40**	30	**40**	35	**45**	35	**50**	40	**60**	45	**60**	50	**60**	55	**60**	65	*	39
40	25	**30**	25	**30**	25	**35**	30	**35**	30	**40**	35	**45**	35	**50**	40	**55**	45	**60**	50	**60**	55	**60**	40
41	20	**25**	20	**25**	25	**30**	25	**30**	30	**35**	30	**40**	35	**45**	35	**50**	40	**55**	45	**60**	50	**60**	41
42	20	**20**	20	**25**	20	**25**	25	**30**	25	**30**	25	**35**	30	**40**	35	**45**	35	**50**	40	**60**	45	**60**	42
43	15	**20**	20	**20**	20	**25**	20	**25**	25	**30**	25	**30**	25	**35**	30	**40**	35	**45**	35	**50**	40	**60**	43
44	15	**15**	15	**20**	20	**20**	20	**20**	20	**25**	20	**30**	25	**30**	25	**35**	30	**40**	35	**45**	35	**50**	44
45	15	**15**	15	**15**	15	**20**	15	**20**	20	**20**	20	**25**	20	**25**	25	**30**	25	**35**	30	**40**	35	**45**	45
46	15	**15**	15	**15**	15	**15**	15	**20**	15	**20**	20	**20**	20	**25**	20	**25**	25	**30**	25	**35**	30	**40**	46
47	10	**10**	10	**15**	15	**15**	15	**15**	15	**15**	15	**20**	20	**20**	20	**25**	20	**30**	25	**30**	30	**35**	47
48					10	**15**	15	**15**	15	**15**	15	**15**	15	**20**	20	**20**	20	**25**	25	**30**	25	**35**	48
49							10	**10**	15	**15**	15	**15**	15	**15**	15	**20**	20	**20**	20	**25**	25	**30**	49
50									10	**10**	15	**15**	15	**15**	15	**15**	15	**20**	20	**25**	20	**25**	50
51											10	**10**	15	**15**	15	**15**	15	**20**	15	**20**	20	**25**	51
52			Einsatz nur in Abstimmung mit der Einsatzleitung										10	**10**	15	**15**	15	**15**	15	**20**	20	**20**	52
53															10	**10**	15	**15**	15	**15**	15	**20**	53
54																	10	**15**	15	**15**	15	**15**	54
55																					15	**15**	55

Messung mit dem elektronischen Psychrometer

German Work-time Standards for Rescue Teams Wearing Light Clothing, With and Without Cooling Vests (120-minute limit)

Poland

The worst mine rescue disaster attributed to heat exposure occurred in Poland in 1998, claiming the lives of six mine rescuers overcome by heat during an exploration activity and a subsequent rescue attempts. The tragedy prompted authorities to research heat stress and prepare what may be the most comprehensive approach to controlling the hazard of heat exposure for mine rescuers.

Polish mine rescue authorities determine time limits on rescue operations in hot environments based on dry bulb temperature and relative humidity, but other factors – type of breathing apparatus, use of cooling vests, and work level, and clothing, can alter the time limits (see charts, Pgs. 36-38).

Prior to going underground to respond to an incident that may involve heat exposure, brigadesmen or mine rescuers must be examined by a physician and cleared for work. Additionally, the anticipated work level is assessed on a scale of light work to very hard work, and assigned an energy level value used to assist in determining operational time limits.

Brigadesmen wear natural fiber coveralls, unless the incident is uncertain in nature or requires the extra protection of chemical fiber clothing.

Each team working in a hot environment has two teams on standby at the fresh air base. If the fresh air base is distant from the work site, one standby team may be placed en route to the work site, or in the vicinity of the site provided conditions are not stressful.

When mine rescue teams are required to work in hot environment, authorities place a priority on improving environmental conditions, and on measures to reduce the exposure on subsequent operations.

Team captains have limited discretion during operations to depart from the time limits, if:

- It is necessary to save a life (lives)
- It is necessary to identify conditions of an increasing threat, and
- The work site is not greater than 20 metres from a fresh air source and visibility is good

Brigade captains are require to monitor regularly air temperature and relative humidity, as well as the pulse rate of team members. If the temperature at the work site increases by 3°C, the captain should inform the control group and consider removing the team from the area. If a team member reports a pulse rate exceeding 140 heartbeats per minute, the captain must rest the team. If the pulse rate does not decrease to a suitable resting rate, the captain should consider returning the team to the fresh air base.

Brigadesmen must report all potentials symptoms of heat exposure – lightheadedness, headaches, cramps, nausea, blurred vision or hearing, to the captain who must immediately withdraw the team and report to the control group.

The working team in a hot environment must always have contact with the fresh air base, and must make every effort to re-establish communications if contact is broken, including returning to the fresh air base. The control group must send a standby team to locate the working team, if contact is broken and not re-established.

Brigadesmen are limited to one mission in a 24-hour period, but may return early if:

- It is necessary to save a life (lives); and
- The physician at the mine site examines and clears the brigadesmen for operation

Table of Safe Working Time at Moderate Work in Natural Fiber Clothing												
Kind of apparatus	**W-70**	**W-70 +SAT + vest**	**BG-4 + vest**	**APS 3 N/4080**	**W-70**	**W-70 +SAT + vest**	**BG-4 + vest**	**APS 3 N/4080**	**W-70**	**W-70 +SAT + vest**	**BG-4 + vest**	**APS 3 N/4080**
Temp. [°C]	**95%**				**85%**				**70%**			
22	**The max. time spent in action for breathing apparatus is 120 min. and for self-contained breathing apparatus is 90 min.**											
23												
24												
25												
26												
27	120											
28	101		120		120							
29	84	120	106	90	117							
30	72	103	92	89	99		120					
31	63	88	80	79	85	120	112	90	120	120		
32	56	76	70	68	72	110	100	86	112	112	120	
33	50	66	62	57	64	98	87	75	98	105	105	90
34	45	57	55	53	57	88	71	66	85	92	90	89
35	40	50	48	44	51	76	62	59	75	82	78	79
36	36	44	43	40	46	66	55	52	66	72	70	71
37	32	38	37	35	41	58	49	47	58	64	62	62
38	29	34	33	32	37	51	44	42	51	58	53	57
39	26	30	31	29	34	45	40	38	46	52	50	53
40	24	27	28	27	31	39	36	34	41	47	43	49
41	22	24	25	23	28	35	32	31	36	42	40	43
42	20	21	23	21	25	31	29	28	33	38	38	40
43	18	19	21	19	23	28	27	25	29	35	33	38
44	17	17	19	17	21	26	24	23	26	32	30	35
45	15	15	17	15	20	23	23	21	24	28	26	31
46	14	14	16	14	18	21	21	19	22	26	24	28
47	13	13	15	13	17	19	18	17	20	23	21	25
48	12	12	13	12	15	17	17	16	18	21	19	24
49	11	11	12	11	14	16	16	15	16	20	17	22
50	10	10	11	10	13	15	15	14	15	18	16	20

Table of Safe Working Time at Hard Work in Natural Fiber Clothing												
Kind of apparatus	**W-70**	**W-70 +SAT + vest**	**BG-4 + vest**	**APS 3 N/4080**	**W-70**	**W-70 +SAT + vest**	**BG-4 + vest**	**APS 3 N/4080**	**W-70**	**W-70 +SAT + vest**	**BG-4 + vest**	**APS 3 N/4080**
Temp.[°C]	**95%**				**85%**				**70%**			
22	**The max. time spent in action for breathing apparatus is 120 min. and for self-contained breathing apparatus is 90 min.**											
23												
24												
25												
26	120											
27	107											
28	93	120	120	90	120							
29	82	111	105	87	105	120	120					
30	70	93	91	80	92	117	115		120			
31	59	79	79	75	81	103	104	90	106	120	120	
32	50	68	68	63	70	91	91	85	91	111	104	90
33	43	58	60	54	62	80	84	74	77	91	90	85
34	37	50	52	50	54	71	70	65	67	81	78	78
35	32	43	46	42	47	63	61	57	58	74	68	72
36	27	38	41	39	41	56	52	51	51	66	60	67
37	24	33	36	33	36	50	46	45	44	62	53	61
38	21	29	32	30	31	45	40	40	40	56	47	54
39	18	25	29	27	28	40	37	36	34	50	44	50
40	16	22	27	21	24	36	33	32	32	46	41	45
41	14	20	24	19	22	33	30	29	27	41	39	41
42	12	17	22	16	19	30	28	26	24	36	37	38
43	11	16	20	14	17	27	26	23	22	34	31	33
44	10	14	18	12	15	24	23	21	19	31	27	32
45	9	12	16	10	14	22	22	19	17	26	24	30
46	8	11	15	10	12	20	20	17	16	21	22	27
47	7	10	14	9	11	18	17	16	15	19	19	23
48	6	9	12	8	10	16	14	14	13	17	16	22
49	6	8	11	7	9	15	13	13	12	16	15	20
50	5	7	10	6	8	13	11	12	11	14	14	17

Table of Safe Working Time at Very Hard Work in Chemical Fiber Clothing												
Kind of apparatus	**W-70**	**W-70 +SAT + vest**	**BG-4 + vest**	**APS 3 N/4080**	**W-70**	**W-70 +SAT + vest**	**BG-4 + vest**	**APS 3 N/4080**	**W-70**	**W-70 +SAT + vest**	**BG-4 + vest**	**APS 3 N/4080**
Temp. [°C]	**95%**				**90%**				**85%**			
22	**The max. time spent in action for breathing apparatus is 120 min. and for self-contained breathing apparatus is 90 min.**											
23												
24												
25	120											
26	115											
27	105	120	120	90								
28	89	118	114	87	120	120	120	90			120	
29	73	105	96	77	103	114	110	89	120	120	118	
30	61	86	80	71	87	99	97	87	117	119	106	
31	51	72	68	68	73	86	86	81	101	107	97	90
32	43	60	58	59	62	75	76	76	87	91	88	89
33	37	51	52	50	53	66	68	61	75	82	80	81
34	31	43	47	41	45	58	61	55	65	76	75	73
35	27	36	43	34	39	51	55	49	57	68	67	67
36	23	31	38	28	34	45	49	42	50	60	59	63
37	20	27	34	25	29	41	45	38	43	58	51	58
38	17	23	31	22	26	36	38	35	39	52	42	51
39	15	20	28	18	22	32	33	30	33	49	40	49
40	13	17	26	16	20	29	29	28	31	45	39	42
41	11	15	23	14	17	26	25	25	26	40	36	39
42	10	13	21	12	15	24	22	22	23	35	33	37
43	9	11	19	11	14	21	20	20	21	33	30	31
44	8	10	17	10	12	19	18	17	18	30	26	28
45	7	9	15	9	11	18	16	15	16	24	19	25
46	6	8	14	8	10	16	15	12	15	20	18	21
47	5	7	13	7	9	15	14	11	14	18	16	20
48	5	6	10	6	8	13	12	10	12	15	13	19
49	4	5	9	5	7	12	10	10	11	13	11	17
50	4	5	8	5	6	10	9	8	9	11	10	16

Republic of South Africa

South African mine rescue authorities started to do research on heat stress in the 1990s, and developed the Emergency Heat Stress Index (EHSI) to determine the maximum time a mine rescuer or brigadesman can be exposed to a hot environment. The EHSI applies only to emergency (non-routine) work and embraces all mines, including those generally held to be 'cool' (i.e. wet bulb temperature of <27.5°C with the dry bulb temperature not exceeding 37.0°C).

Many South African mines have their own standards for emergency work in hot environments. These standards are mine-specific, in which case the EHSI is viewed as complementary and does not necessarily superseding existing in-house standards. However, in absence of any such standards, the EHSI is interpreted as a minimum standard.

The EHSI is the arithmetic mean of the dry and wet bulb temperatures. In calculating the EHSI, all fractions of a degree are rounded up. For example, if dry bulb temperature is 38.2°C and the wet bulb temperature 34.5°C, then the EHSI = (39 + 35)/2 or 37°C.

Maximum Tolerance Times (in minutes)		
EHSI	**Without Cooling (min.)**	**With Cooling (min.)**
<30	No Limit	N/A
30	230	N/A
31	180	210
32	140	170
33	110	140
34	85	115
35	60	90
36	40	70
37	25	55
38	**NO WORK, EVACUATE AREA**	30
39		30
40		25
41		24
42		23
43		21
44		20
45	**NO WORK, EVACUATE AREA**	

Under the EHSI the recommended action levels are:

EHSI greater than or equal to 28°C – emergency work to be undertaken only by heat-tolerant or heat acclimated task forces (brigadesmen); no time limits are proposed but work should proceed under supervision and with regular water breaks.

EHSI greater than or equal to 30°C – special precautions (adequate and sufficient drinking water, sufficient water breaks, emergency body cooling facilities, standby medical staff) and tolerance times (work rates, travelling times and distance) are to be observed.

EHSI greater than or equal to 45°C – maximum permissible upper limit, no work should be undertaken unless whole body cooling is feasible.

The EHSI provides two exposure limits, one with and one without cooling garments. Cooling garments can extend the exposure limits by as much as 30 minutes, and allow mine rescuers to do limited work under conditions they would otherwise not be allowed to work.

The EHSI does not establish a work/rest regimen, only a maximum exposure time limit during which brigadesmen are expected to work and rest as required. Teams are equipped with an EHSI chart and a whirling hygrometer to determine environmental conditions. As conditions deteriorate, captains are to recalculate the exposure limit, allowing for the exposure time already experienced, as well as time for the team to return to the fresh air base.

The EHSI is intended as a guideline for use by captains when strenuous conditions prevail. The decision to follow the guideline lies with the captain. "He will have to rely on his experience and sound knowledge of his team's abilities when making this decision," a mine rescue authorities document states.

Brigadesmen are required to take and pass an annual medical examination, meeting physical minimum standards, including for body mass index. They are also required to undergo and pass a Heat Tolerance Screening protocol before being authorized to conduct mine rescue activities.

Brigadesmen must also take periodic Heat Tolerance Tests (HTT) and Workload Tests (WL) during the year to determine their ongoing suitability. Specifically, they must take an HTT and WL following any surgery, any illness that lasts seven or more days, and any incident involving heat stress at work.

Prior to taking an HTT, brigadesmen are questioned as whether they:

- have taken alcohol within 24 hours
- feel unwell
- are taking any prescription medication
- are taking performance enhancing substances
- worked a shift in the previous 24 hours

During training and operations, South African mine rescue also require that:

- Fresh air bases have a maximum EHSI factor between 28 and 29.9°C
- Environmental conditions at fresh air bases must be such that teams can recuperate quickly after enduring harsh temperatures.

- The fresh air base be as close as possible to the incident to avoid unnecessary travelling time and effort to and from the operating site, and
- That isotonic mixes be added to the water to sustain the body's electrolyte balance

During training, rescue teams are taught that when involved in a heat exposure mission:

- Teams should hydrate with isotonic drinks prior to entry.
- The work should be done at a slow, even pace with a minimum of movement.
- Rest pauses should be frequent and taken in turn.
- The captain must observe his men carefully; be aware of the signs and symptoms of heat disorder. A sound awareness of each member's personality could be used to identify exhaustion or distress.
- The captain should not work too hard; setting an example by working hard is, in these conditions, stupid. He must watch his men, regulate the rest periods and plan time for the return trip.
- Pressures should be checked at least every 20 minutes and more frequently in lower pressure ranges.
- The captain must never split his team.
- Refer to the ESHI chart and use cooling garments when necessary

United Kingdom

Mine rescue authorities in the United Kingdom, Mine Rescue Services Ltd. (MRSL), have regulated mine rescue activities in hot and humid environments for more than 50 years, introducing their first permissible wearing (tolerance) times for breathing apparatus in 1955.

The current standard used for the Dräger BG4 (see chart below) cross-references dry and wet bulb temperatures to determine the mission time limit. These time limits were originally developed by the Institute of Occupational Medicine (IOM) in the 1980s for the Selected Elevated Flow Apparatus (SEFA) in use at that time.

After conferring in 2008 with the IOM researchers responsible for the SEFA time limits who reviewed their study, MRSL decided the SEFA time limits would be suitable for the BG4. The IOM advised the mine rescue organization that the exposure limits are based more on the wearer's "heat strain limits rather than specific apparatus imposed limit," and "Equally, no valid scientific evidence was put forward to suggest the BG4 apparatus would provide a significant increase in wearing time against earlier apparatus types."

Partly Saturated Atmospheres															
	Dry Bulb														
Wet Bulb	Temp.	24	26	28	30	32	34	36	38	40	42	44	46	48	50
	23	*	*	*	118	113	108	103	98	93	89	85	81	77	73
	24	119	114	108	103	99	94	90	85	81	78	74	71	67	64
	25		99	95	90	86	82	78	75	71	68	65	62	59	56
	26		87	83	79	75	72	68	65	62	59	56	54	51	49
	27			72	69	66	63	60	57	54	52	49	47	45	43
	28			63	60	57	55	52	50	47	45	43	41	39	37
	29				53	50	48	45	43	41	39	38	36	34	32
	30				46	44	42	40	38	36	34	33	32	30	30
	31					38	36	35	33	32	31	30	29	28	27
	32					33	32	31	30	29	28	27	26	26	25
	33						29	28	27	27	26	25	24	23	23
	34						27	26	25	24	23	23	22	22	22
	35							24	23	22	22	22	21	20	20
	36							22	22	21	20	20	19	19	19
	37								20	19	19	19	19	19	
	38								19	19	19	19			
* 120 minutes or more															

Appendix D – Additional Reading

Heat Stress Guidelines, The Ontario Ministry of Labour, May 2011.

Humidex Based Heat Response Plan, Occupational Health Clinics for Ontario Workers Inc., May 2011.

Management and Prevention of Heat Stress Guideline, Department of Industry and Resources, Government of Western Australia, Dec. 1997

Note on UK and German Breathing Apparatus Safe Wearing Time Guidelines Under Hot and Humid Conditions, Mines Rescue Service Limited, Edinburgh, UK, November, 2008

Thermal Stress Guideline, Department of Minerals and Energy, Republic of South Africa, 2002

Donoghue A.M., Sinclair M.J., Bates G.P., Heat Exhaustion in a Deep Underground Metalliferous Mine, Occupational Environmental Medicine 2000;57:

Graveling R.A., Miller B.G., Permissible Wearing Times for Rescue Personnel Using a New Self-contained Breathing Apparatus, Institute of Occupational Medicine, Edinburgh, UK, 1989

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Kampmann B. and Bresser G., Heat Stress and Flame Protective Clothing in Mine Rescue Brigadesmen: Inter- and Intraindividual Variation of Strain,

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McLellan Tom M. and Selkirk Glen A., The Management of Heat Stress for the Firefighter: A Review of Work Conducted on Behalf of the Toronto Fire Service, *Industrial Health 2006, 44, 414–426.*

Payne T. and Mitra R., A Review of Heat Issues in Underground Metalliferous Mines, 12th U.S./North American Mine Ventilation Symposium 2008

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Varley F., A Study of Heat Stress Exposures and Interventions for Mine Rescue Workers, Society of Mining, Metallurgy, and Exploration, 2004.

Wyndham C.H., Allan A. McD., Bredell G.A.G., and Andrew R., Assessing the Heat Stress and Establishing the Limits for Work in a Hot Mine, Brit. 7. industr. Med., 1967, 24, 255

Appendix E – Other Ontario Mine Rescue Resources

Publication:

- The Handbook of Training in Mine Rescue and Recovery Operations (2014 edition)

Courses:

- Heat Stress Modules for Mine Rescue Volunteers
- Supervisory/Management Mine Rescue Training