Cold Weather Considerations for Mine Health & Safety Management Practices

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How Cold is Cold?

DECIDING ON A TEMPERATURE

- How does your workplace define “cold work environment”?
- Available standards define cold as ***conditions that cause uncomfortable sensations of cool or cold***
- When conducting light physical work ISO 15743 defines ***+10˚C or below*** as ***unfavorable conditions for human function***
- Anglo American: +10˚C or below

ISO (International Organization of Standards) ISO 15743.2008. “Ergonomics of the Thermal Environment – Cold Workplaces – Risk Assessment and Management” Geneva

How Cold is Cold?

There are two basic human thresholds to cold stress:

- **Thermal Comfort** – the conditions at which the thermal environment leads to thermal dissatisfaction, discomfort and loss of productivity; typically expressed in terms of continuum of thermal sensation

(ANSI/ASHRAE Standard 55-2017 – *Thermal Environmental Conditions for Human Occupancy)*

- **Cold Stress** – the conditions at which the thermal environment is associated with the onset of the first observable health effects:
  - Hypothermia – core body temperature falls below 35ºC
  - Frostbite – human tissue temperature falls below 0°C

(ACGIH – *2019 TLVs® and BEIs® Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents & Biological Exposure Indices)*

Hypothermia

- ACGIH TLV for hypothermia is based on the prevention of the core body temperature falling below 36°C, through a risk management process to use in cold weather environments
- Cold stress risk factors include:
  - Environmental – air temp, wind, rain, solar load, duration, immersion, altitude
  - Anthropogenic – metabolic rate, clothing/shelter, time of day, acclimatization
  - Predisposition – nutrition, body fat, fatigue, health, fitness, experience
- Advancing symptomatology – cold, shivering, apathy, social withdrawal, sleepiness, slurred speech, changes in behaviour or appearance
- Almost all fatal occupational exposures to cold have resulted from accidental exposures involving failure to escape from low air temperature, or immersion in low temperature water

Frostbite

- Frostbite is the freezing of the skin and underlying tissues resulting from exposure of the extremities to subzero temperatures
- Can develop over an extended period of cold exposure or acutely through direct contact with supercooled liquids or highly conductive cold surfaces
- Frostbite risk factors include temperature, wetness, wind chill, constrictive clothing, sex, level of acclimatization, hypoxia (oxygen deficiency) and pre-existing conditions such as Raynaud's disease (restricted blood flow)
- Limited research indicates that race can be a pre-disposing risk factor

Frostbite

- The onset of frostbite through continued exposure to a cold environment is progressive:
    - When skin temp reaches 15°C, vasoconstriction occurs, restricting blood flow to the skin
    - Neuropraxia (blockage of peripheral nerve conduction) occurs at 10°C, resulting in a loss of sensation and motor control
    - Below 0°C, blood flow becomes negligible and skin temperature drops rapidly
    - Extended cold exposure at this point can result in symptoms ranging from temporary skin damage (first degree) to damage to underlying connective tissue and bone, necrosis, mummification and autoamputation (fourth degree)

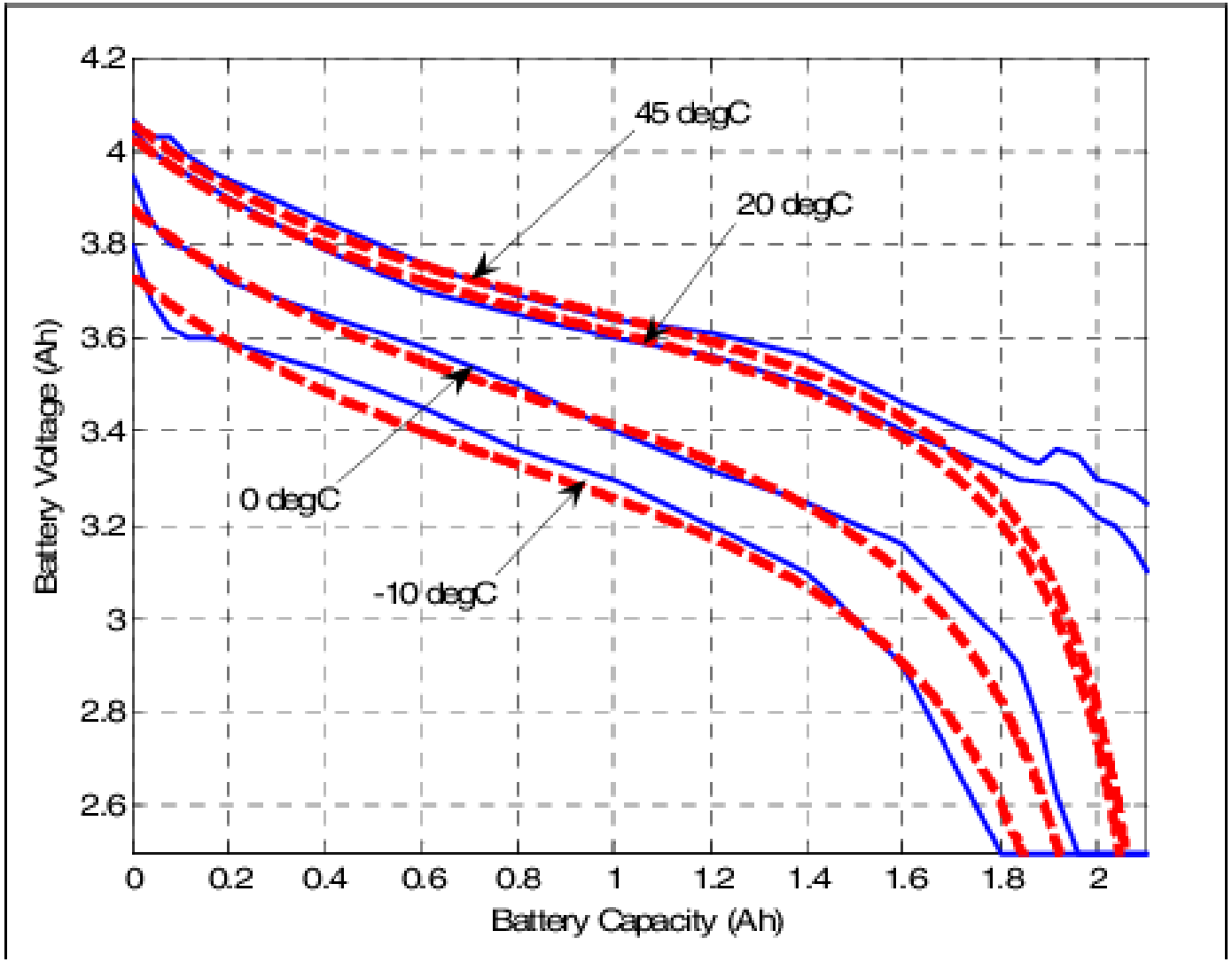
Industrial Hygiene Assessment Capabilities

Table of Minimum Operating Temperatures for Select IH Assessment Equipment

Instrument	Minimum Operating Temperature
Gas/Vapour Detection	
Honeywell BW Ultra	-20ºC
Honeywell ToxiPro H_2S	-18ºC
ISC Ventis MX4	-20ºC
ppbRAE 3000 PID	-20ºC
Noise	
Quest Edge eg5 Noise Dosimeter	-10ºC
Quest SoundPro Sound Level Meter	-10ºC
Vibration	
Nexgen Series 2A WBV	0ºC
Larson Davis HVM200	-10ºC
Aerosol Monitors	
TSI Dusttrak II - 8532	0ºC
TSI SidePak AM520	0ºC
Thermoscientific DataRAM PDR-1000AN	+10ºC

Temperature Effects on Instrumentation – Battery Performance

Graph of Panasonic CGR18650HG 3.6V Battery Performance



Bhide, Sachin & Shim, Taehyun. (2009). Development of improved Li-ion battery model incorporating thermal and rate factor effects. 544 - 550. 10.1109/VPPC.2009.5289800.

Cold Exposure – Ergonomic Considerations

SYMPTOMS, ILLNESSES & DISEASES

Symptoms	Illnesses & Diseases
Musculoskeletal Pain, stiffness, swelling, restriction of movements, paresthesia, muscle weakness	**Musculoskeletal** Carpal tunnel syndrome, lower back pain, tension neck syndrome, tenosynovitis
Respiratory Shortness of breath, wheezing, cough, mucous excretion	**Respiratory** Asthma, COPD, rhinorrhea
Cardiovascular Chest pain, arrythmias, shortness of breath	**Cardiovascular** Coronary disease, heart attack
Peripheral circulatory Colour changes in digits, pain, numbness, tingling	**Peripheral circulatory** Raynaud's syndrome, hand-arm vibration
Dermatological (Skin) Itching, eruption of skin, pale skin, erythema	**Dermatological (Skin)** Cold urticaria, atopic dermatitis

Adapted from: Mäkinen, T. M., & Hassi, J. (2009). Health problems in cold work. *Industrial health*, *47*(3), 207-220.

Muscular, Skin and Respiratory Effects

SEAFOOD INDUSTRY WORKERS - NORWAY

Study Population	Workers from 17 seafood industry plants (n = 1,767)
Methods	Questionnaire; Temperature measurements (ambient air, foot and finger)
Exposure Temperature	+2˚C to +18˚C
Health Symptoms	Muscular (neck/shoulders, wrists/hands, back, legs) Skin (itching, dry skin, chapped skin, chronic sores) Respiratory (chest tightness, cough, irritated/runny nose, frequent wheezing)
Results	Feeling cold at work increases the risk of muscular, skin, and respiratory symptoms
Discussion Points	No clear association between low ambient air temperature and prevalence of workers feeling cold (possible due to activity levels, clothing and cold adaptation) • **Individual factors play a key role in how cold exposure affects workers**

Bang, B. E., Aasmoe, L., Aardal, L., Andorsen, G. S., Bjørnbakk, A. K., Egeness, C., ... & Kramvik, E. (2005). Feeling cold at work increases the risk of symptoms from muscles, skin, and airways in seafood industry workers. *American journal of industrial medicine*, *47*(1), 65-71

Lower Back Pain

MINERS - RUSSIA

Study Population	Workers from 4 mines (2 underground, 2 open-pit) (n = 3,530)
Methods	Questionnaire
Exposure Temperature	Underground mines – stable at +5˚C to +8˚C Open-pit mines – down to -40˚C
Health Outcome	Lower back pain in the last 12 months
Results	Workers who were exposed to +10˚C or less on a weekly basis were approximately 1.5 times more likely to report lower back pain
Discussion Points	50% of the miners reported lower back pain Other factors were also associated with lower back pain: working with wet clothes, heavy lifting and having a previous job as a driver • **Lower back pain is a prominent issue in the mining industry and working in cold conditions has been identified as a contributing factor**

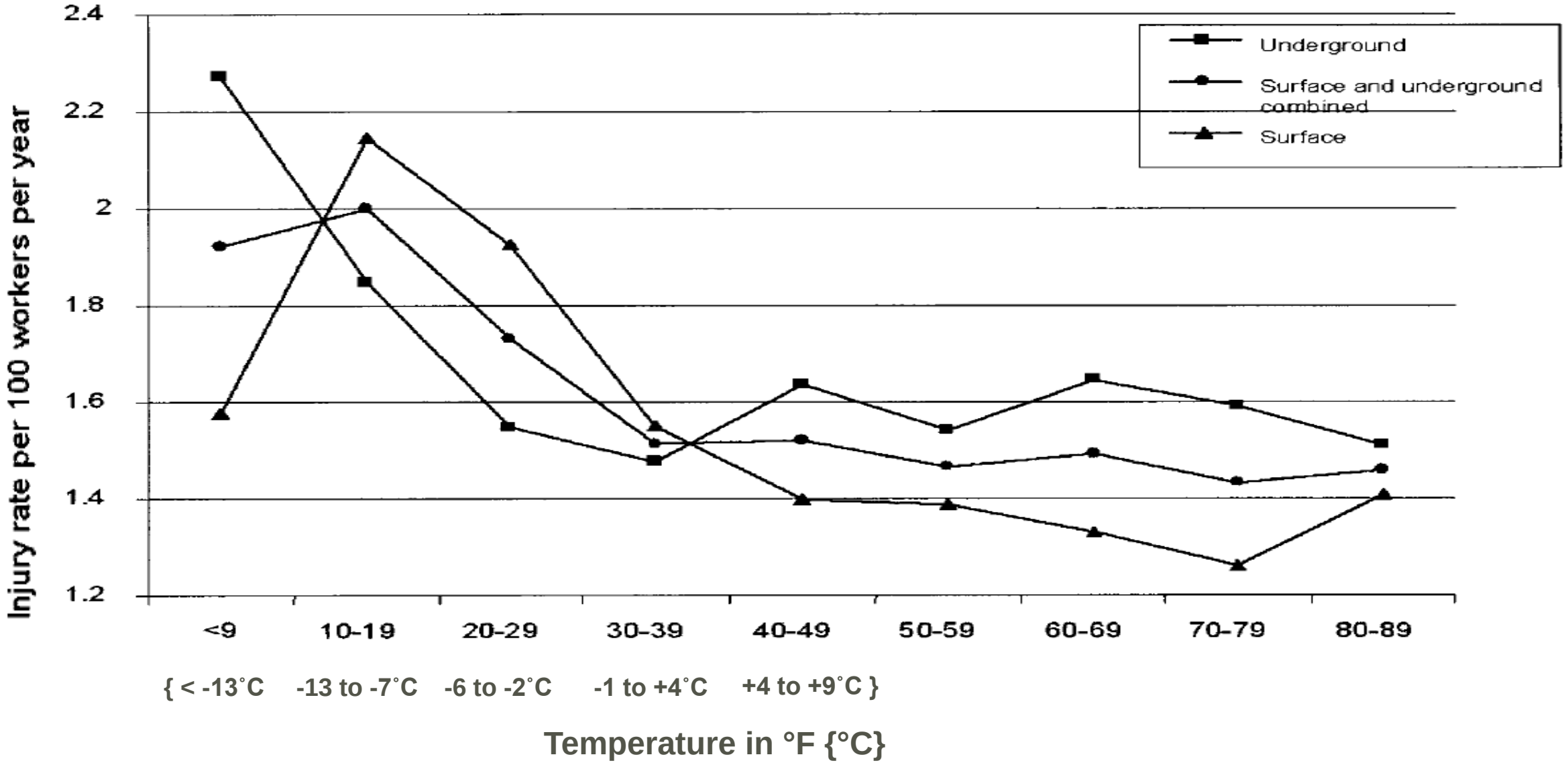
Skandfer, M., Talykova, L., Brenn, T., Nilsson, T., & Vaktskjold, A. (2014). Low back pain among mineworkers in relation to driving, cold environment and ergonomics. *Ergonomics*, *57*(10), 1541-1548

Cold Exposure & Cold-Associated Injuries

COAL MINERS - USA

Study Population	Coal miners (surface and underground operations) in 6 different States
Methods	Injury reporting to MSHA over a 6-year period; Average daily temperature
Exposure Temperature	Average daily temperatures were down to -16˚C to +32˚C
Health Outcome	72,716 injuries reported to MSHA
Results	49 cold injuries, incidence increased with colder temperatures 10,933 slips, trips and falls, incidence increased with colder temperatures
Discussion Points	Under-reporting of cold exposure injuries, such as frostbite and hypothermia Distinction needed between cold exposure injuries and cold-associated injuries • **There is a relationship between colder temperatures (below freezing) and higher rates of slips, trips and falls.** • **More detailed active surveillance will help determine risk and prevention strategies for cold injuries.**

Hassi, J., Gardner, L., Hendricks, S., & Bell, J. (2000). Occupational injuries in the mining industry and their association with statewide cold ambient temperatures in the USA. *American journal of industrial medicine*, *38*(1), 49-58.



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Cold Exposure

EFFECTS

Thermal sensations, Comfort	Performance	Health	Cold-associated injuries
Cold sensations ↑	Physical ↓	Disease ↑	Slips and falls ↑
Discomfort ↑	Cognitive ↓	Mortality ↑	
Pain ↑	Psychomotor ↓	Cold injuries ↑	

Adapted from: Mäkinen, T. M., & Hassi, J. (2009). Health problems in cold work. *Industrial health*, *47*(3), 207-220.

Cold Exposure

CONTRIBUTING FACTORS

Climatic Exposure	Physical Activity	Clothing	Individual
Temperature	Level (heat prod.)	Insulation	Age
Humidity	Type of activity	Air permeability	Gender
Wind		Water resistance	Health
Cold objects		Weight	Medication
Cold liquid		Ergonomics	Fitness
			Adaptation

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In Summary …

- Cold weather is a contributing factor for a broad range of mine risk management practices beyond physiological response
- The cold environment is a risk factor in the occurrence of ergonomic related injuries as well as dermatological and respiratory effects
- In addition to cold exposure incidents, there is also increased risk in the occurrence of cold-associated injuries (slips, trips, falls, frostbite)
- Evidence of significant under-reporting of cold related injuries

Holmer, I. (2009). Evaluation of cold workplaces: an overview of standards for assessment of cold stress. *Industrial Health*, *47*(3), 228-234.

Cold Weather OH&S Management Practices

- Control programs for thermal stress and ergonomics should incorporate risk management strategies that address changing environmental conditions.
- Management programs for thermal stress rely heavily on symptom awareness and training of workers and supervisory staff.
- Ergonomic programs should include accommodations for acclimatization and reduced material handling limitations.
- IH assessment programs should include seasonal adjustments for cold weather equipment limitations.
- Cold weather impacts other IH hazards controls, such as limitations in dust suppression options, and increased failure rate of critical engineering controls.

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