2017 Annual Conference of Mine Ventilation Society of South Africa

27 – 28 July 2017

Shallow Depth Diurnal Variations of Rock to Air Heat Transfer in an Intake Incline

By
Pandey A. & Sastry B.S.
Indian Institute of Technology Kharagpur, India

Contents

Introduction

- The major heat sources for an intake shaft are the heat from wall rock and air auto-compression.
- With the exception of heat flow from the wall rock, the estimation of heat influx from various other sources is more or less an established procedure.
- For shallow intake shafts, the ambient climatic conditions play an important role in rock to air heat transfer.
- Absorption of heat from incoming air by the surrounding rock during day time and release of the same into the air during cooler night times is characterized by the effect of Thermal Flywheel (McPherson 1986)
- It is also possible that heat is retained by surrounding rock during warmer seasons of the year and released during the cooler seasons.

❑Site

- Jamadoba 5 no. incline of TATA Steel Limited
- Coal Mine (Jharia Coal Fields, India)
- On five different days (between November’16 to March’17) , 24-hour studies were conducted with readings noted at time intervals of 2 hours to obtain records of
  a) hygrometric survey at the surface (shaft collar)
  b) hygrometric survey at a measurement station in intake incline, and
  c) quantity survey.
- The underground measurement station (UMS) was situated at an inclined length of 187 m from shaft collar in 1 in 3 gradient incline.
- The airway dimensions are 5.9m in width and 2.9m in height.
- The measurement segment has no bends or splits or junctions.

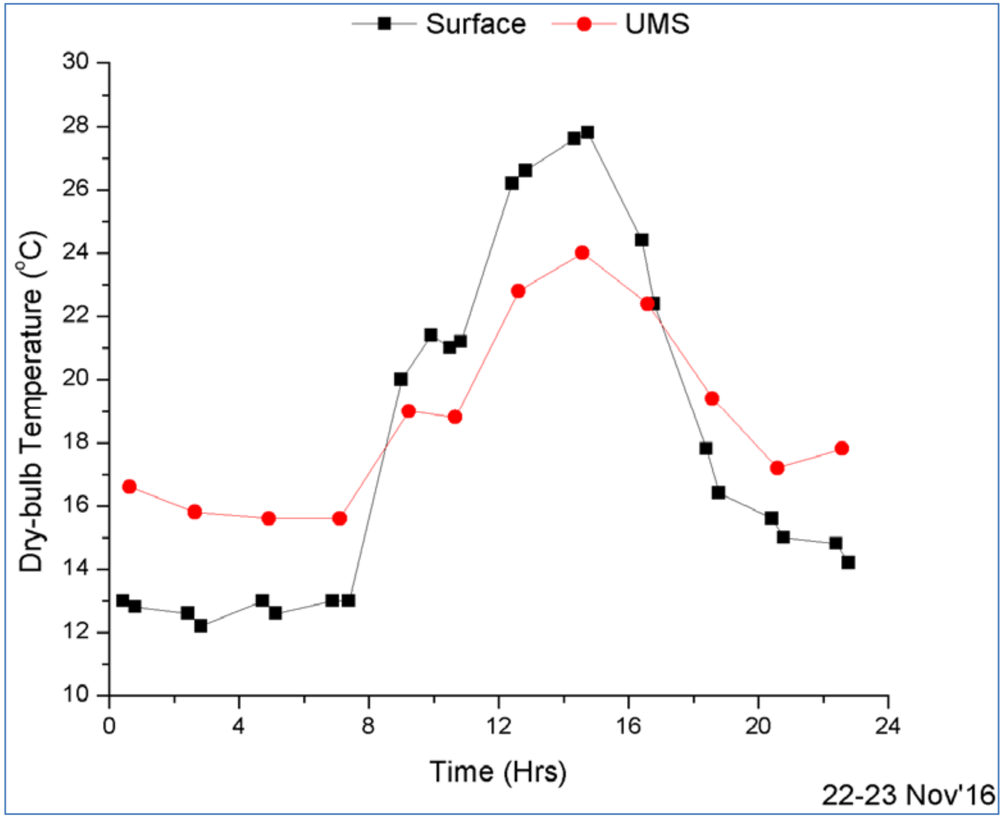
❑Apparatus

- Lambrecht Assmann psychrometer
  - Least count 0.2 °C

- Aneroid Barometer
  - measuring range of 930 to 1070 hPa / 700 to 800 mmHg
  - minimum graduations of 1 hPa / 1mmHg

- One-minute vane anemometer
  - least count of 1.0 m/min
  - maximum velocity of 1200 m/min

Diurnal Variation in Dry-bulb Temperature



Remarks:

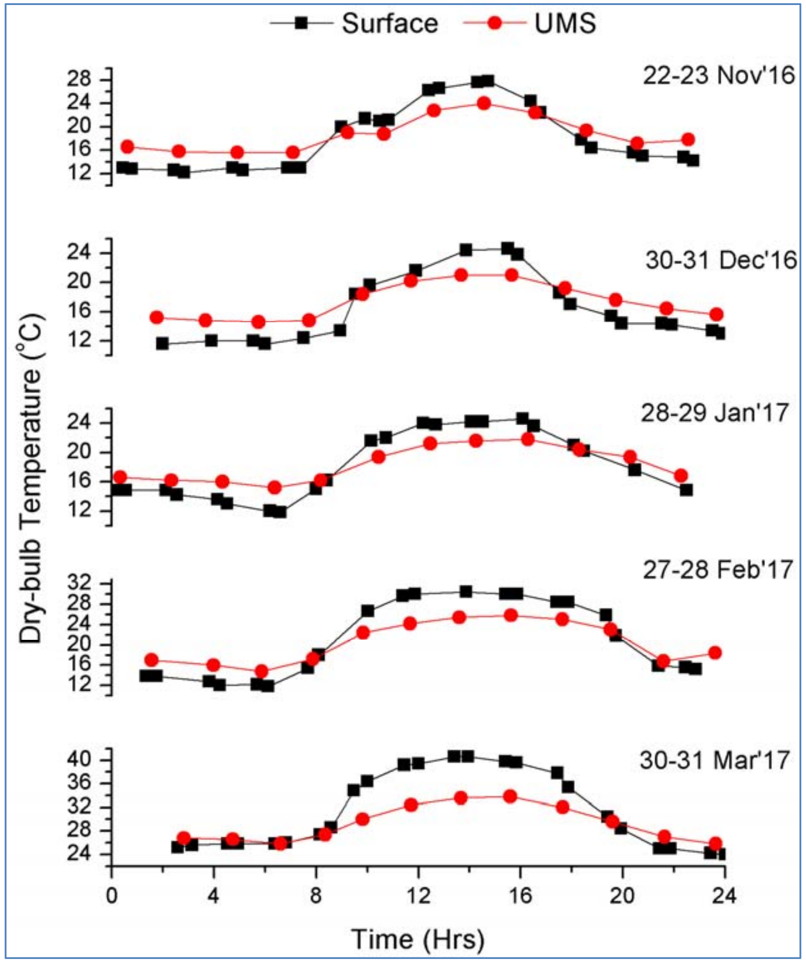
- From 00:00 Hrs to 09:30 Hrs –

  Td $_{UMS}$ > Td $_{Surface}$
- From 09:30 Hrs to 16:30 Hrs –

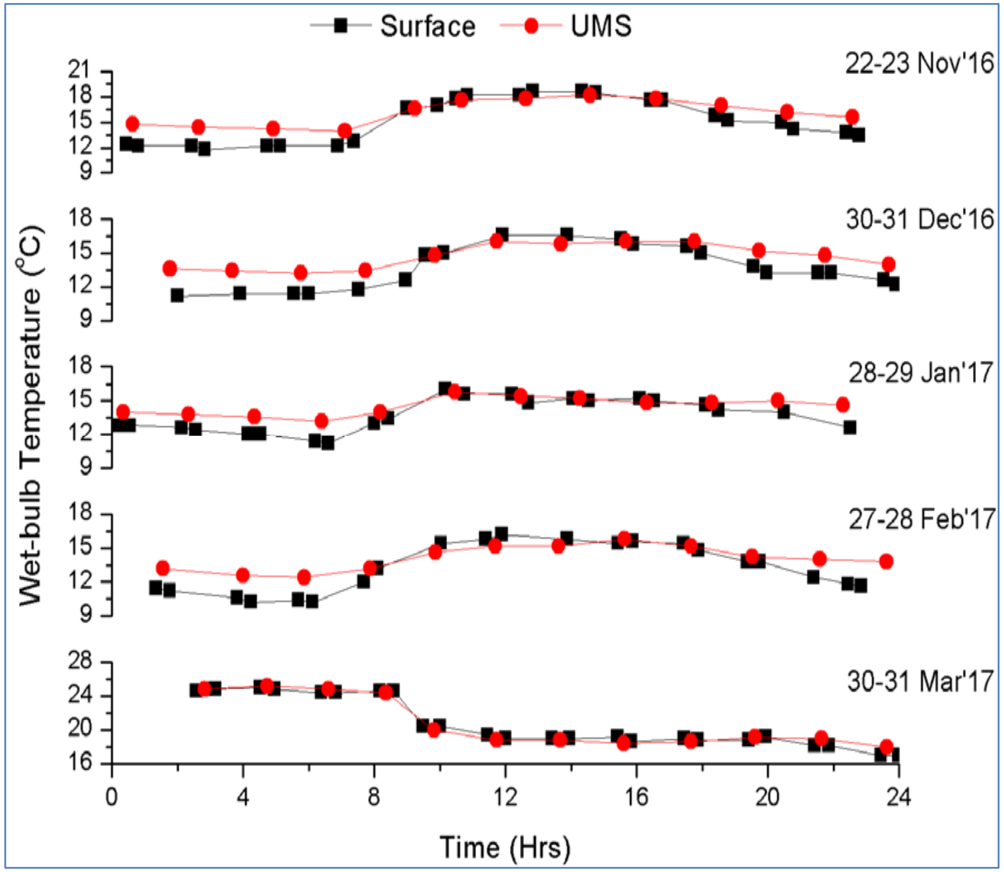
  Td $_{UMS}$ < Td $_{Surface}$
- From 16:30 Hrs to 24:00 Hrs –

  Td $_{UMS}$ > Td $_{Surface}$
- Damping of temperature peak at hotter day time and rise in temperature at cooler night time.

Diurnal Variation in Dry-bulb Temperature



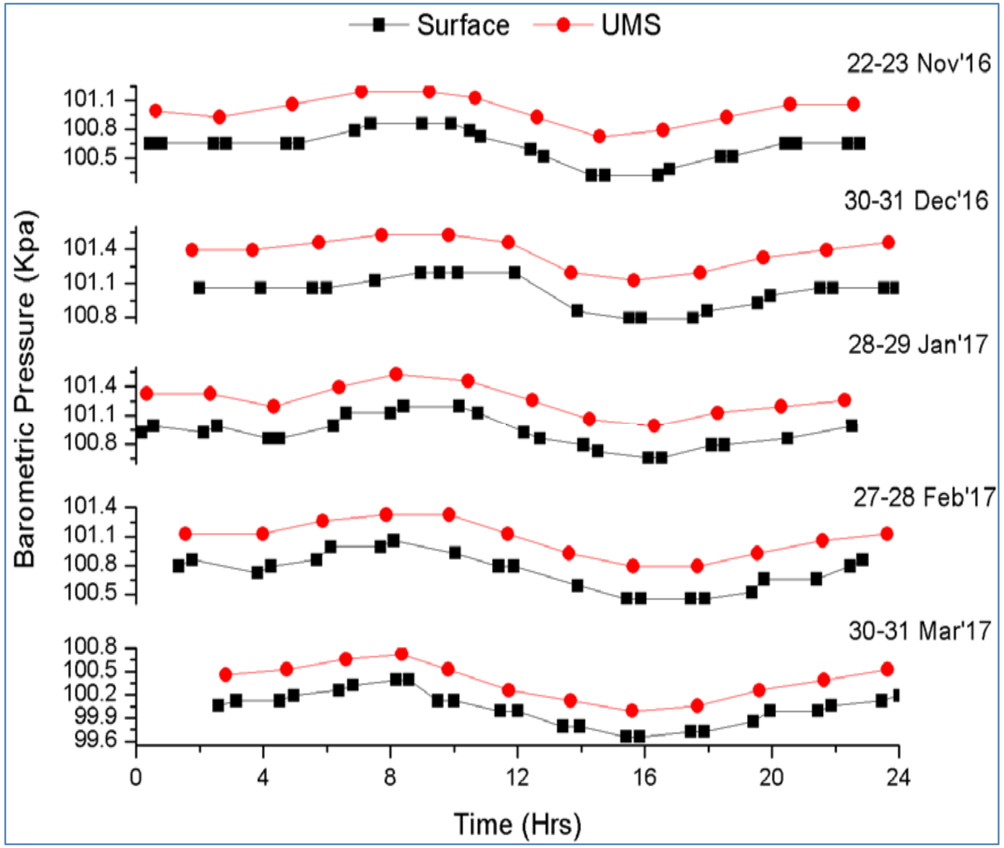
Diurnal Variation in Wet-bulb Temperature



Remarks:

- At night time the difference in Tw of air between surface and UMS is significant in cooler seasons.
- At hotter day times this difference reduces.
- On 30-31 Mar'17, this difference is negligible due to overcast weather condition at night time and dry & warm weather condition at day time.

Diurnal Variation in Barometric Pressure



Remarks:

- Barometric Pressure (P) shows semi-circadian (12 h) cycle.
- P is greater in cooler season of the year.
- Max. & Min. P at UMS found around 08.30 Hrs & 16:00 Hrs respectively.
- Difference between max. P at U/G & surface = 0.3 kPa.

Maximum, Minimum and Average Td & Tw

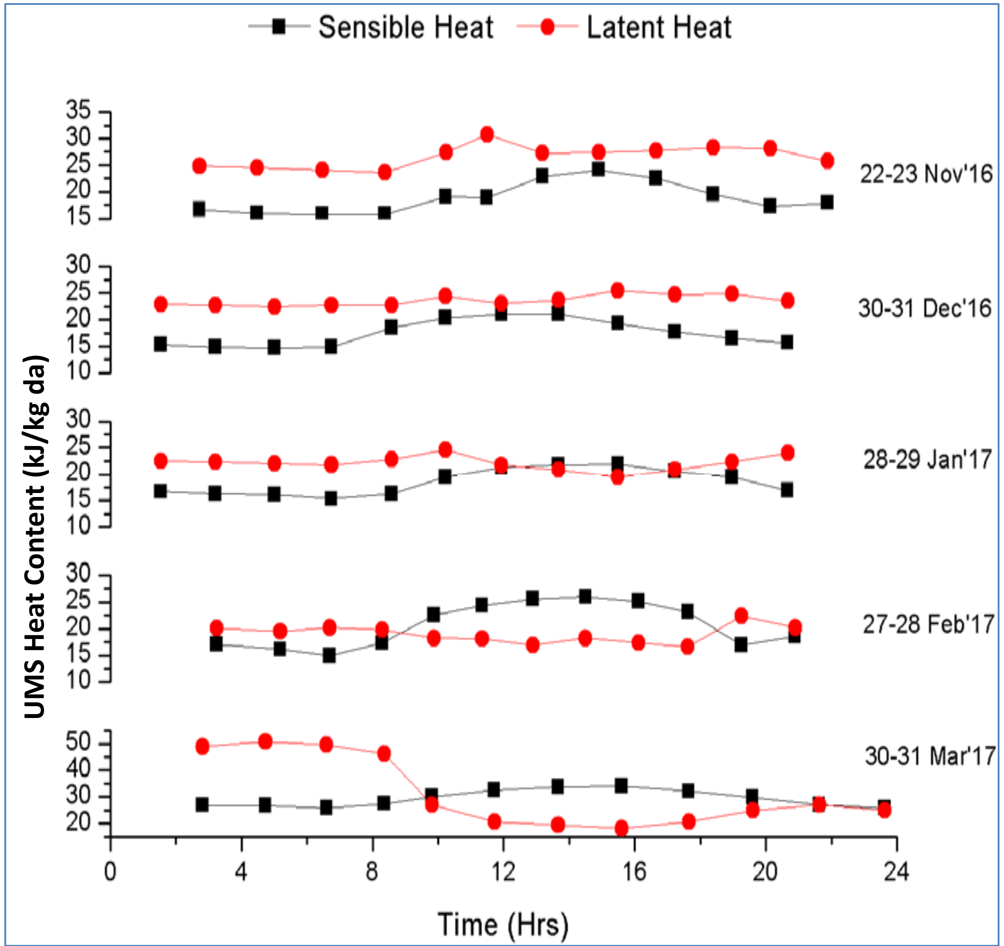
Maximum, minimum and average dry-bulb temperature (in ^{0}C) at different survey dates

Survey Dates	Maximum		Minimum		Average	
	Surf.	UMS	Surf.	UMS	Surf.	UMS
22-23 Nov'16	27.8	24	12.2	15.6	18.11	18.75
30-31 Dec'16	24.6	21	11.6	14.6	16.3	17.4
28-29 Jan'17	24.6	21.8	11.8	15.2	18.3	18.4
27-28 Feb'17	30.4	25.8	11.8	14.8	20.8	20.5
30-31 Mar'17	40.6	33.8	24	25.8	31.3	29.2

Maximum, minimum and average wet-bulb temperature (in ^{0}C) at different survey dates

Survey Dates	Maximum		Minimum		Average	
	Surf.	UMS	Surf.	UMS	Surf.	UMS
22-23 Nov'16	18.6	18.2	11.8	14	15.2	16.2
30-31 Dec'16	16.6	16	11.2	13.2	13.7	14.7
28-29 Jan'17	16	15.8	11.2	13.2	13.7	14.5
27-28 Feb'17	16.2	15.8	10.2	12.4	13.2	14.1
30-31 Mar'17	25	25.2	17	18	20.8	20.8

Diurnal Variation in Heat at Shaft Bottom



Remarks:

- Latent heat is the major contributor to the UMS heat at cooler part of the day.
- During the cooler season of the study period (22-23 Nov’16 to 28-29 Jan’17) latent heat is higher than sensible heat at UMS, all through the day .
- There is gradually increased contribution of sensible heat as the seasons become warmer and sensible heat is higher than latent heat in most part of the day time.

Strata Heat

$$q = \{(H_1 - H_2).m^{\cdot}\} - A.C$$

Where, q = strata heat (-ve for rock to air) kW

H1 = Enthalpy of air at surface (Shaft Collar) kJ/kg

H2 = Enthalpy of air at U/G measurement station (UMS) kJ/kg

A.C = Heat added to airway due to Auto-compression

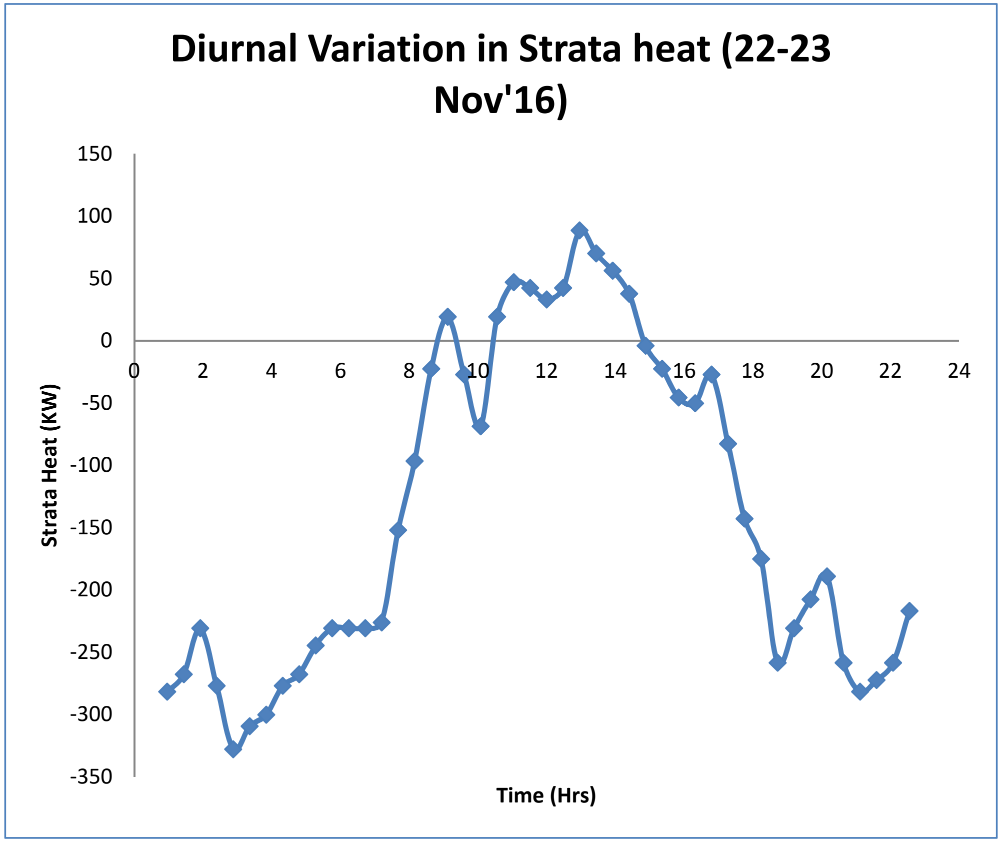
$= \{m^{\bullet}. (Z1-Z2). 9.81\}/1000$

Where, $m^{\bullet}$ = mass flow rate of air (kg/s)

= quantity of air (m^3/s) X density of air (kg/m^3)

Z2, Z1 = RL of UMS & Shaft collar (m)

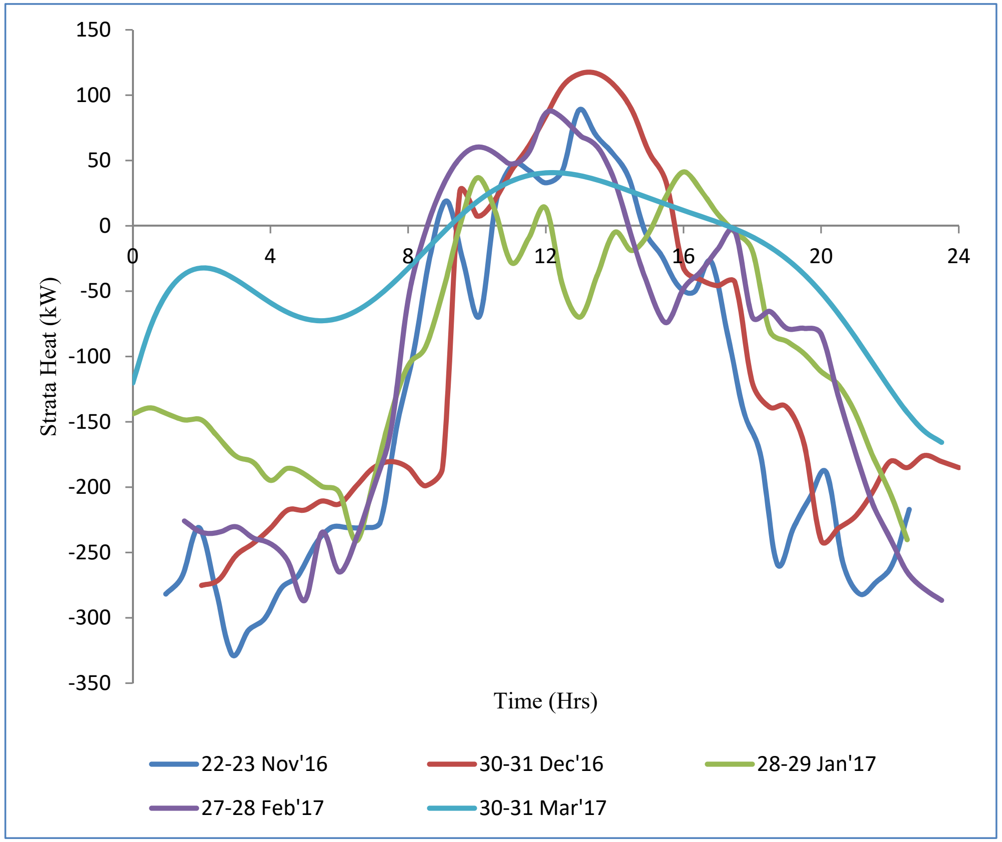
Diurnal Variation in Strata Heat



Remarks:

- Positive strata heat in the time period 10:00 Hrs to 16:00 Hrs suggests heat flow is from air to rock.
- Remaining part of the day strata emits heat into ventilating air.
- Illustrative of thermal flywheel behavior.

Diurnal Variation in Strata Heat



Discussion

- The variation in surface dry bulb temperatures dampens out as surface air travels through the 187 m incline, and gives rise to decreased difference in daily maximum and minimum temperatures at the UMS.
- The large ranges in the psychrometric properties of surface and UMS air suggest that it is not sufficient to use average values of the psychrometric properties of intake air for predicting air properties at UMS.
- Assumption proposed by Amano *et al.* (1982): "the inlet air temperature has a constant value equal to the average annual air temperature" may produce errors in predicting underground air properties at shallow depth.
- Peavy's (1961) assumption of "sinusoidal variation in entering air temperatures" for predicting extreme temperature values (maximum & minimum) at output, may be acceptable but the parameters of the temperature distribution are seen to depend very much on seasons.

Discussion

- The latent heat is the major contributor to the UMS total heat, especially for the night time and for cooler season of the year.
- The strata heat of the intake airway section, both in quantity and direction, changes according to time of the day and day of the year.
- The heat flows in the direction of rock to air during night time, but the direction of heat flow is reversed in the hotter daytime, illustrating thermal flywheel behavior.

Conclusion

- Most of the rock to air heat flow simulation models assume that the air temperatures in the airway are either constant or display small changes (Vost 1976) while the VRT boundary is assumed to be function of the age of the roadway.
- These models cannot predict rock to air heat transfer for the shallow mine entries where the inlet air properties are highly variable and the rock to air heat transfer is clearly influenced by the thermal flywheel effect.
- A transient model is, therefore, necessary to capture the diurnal and seasonal effect and the resultant thermal flywheel phenomena on heat flow between strata and ventilating air for shallow mine entries.
- It is also necessary to test these models by measured data from underground in order to validate its reliability and accuracy.

Future Work

- Quantify the dampening effect of the surrounding rock on the wet and dry bulb temperatures of the incoming air in a dedicated and shallow inlet airway.
- Develop a new climate simulation model to take into account the cyclic behavior of inlet climate properties presented by a 24 hour cycle and create a corresponding output climate trend for the UMS.