

JOURNAL HOMEPAGE jsm.gig.eu

The online version of the Journal of Sustainable Mining is the primary, reference version of the journal

Cygankiewicz J., Knechtel J. (2014). Isotherm maps of virgin rock temperature in collieries of Katowicki Holding Węglowy. *Journal of Sustainable Mining*, *13*(4), 1–4. doi: 10.7424/jsm140401

ORIGINAL PAPER

Received: 5 September 2014

Revised: 17 October 2014

Published online: 12 November 2014

ISOTHERM MAPS OF VIRGIN ROCK TEMPERATURE IN COLLIERIES OF KATOWICKI HOLDING WĘGLOWY

Janusz Cygankiewicz¹, Józef Knechtel^{1*}

Department of Mining Aerology, Central Mining Institute (Katowice, Poland) * Corresponding author: jknechtel@gig.eu, tel. + 48 32 259 21 94, fax: +48 32 259 21 82

ABSTRACT

Purpose	Assessing the level of heat hazard in rock mass. Measurements of virgin rock temperature were made in 89 active workings of collieries located in the area of Katowicki Holding Węglowy.
Methods	Experimental method – in situ measurements, the results of the measurements are developed with the least square method. Using maps of the coal seams in the collieries, coordinates (x, y, z) of measurement points were determined, and then, by utilizing a surface map, the geodetic height of the physical surface over the measurement points was determined. The next stage was to analyse geological cross-sections; the thickness of stratigraphic layers i.e. overburden, carboniferous rocks and the total thickness of the coal seams located above the measurement points was determined. Coefficients characterising heat transport in the aforementioned types of rock were calculated using the least square method. By re-analysing geological cross-sections we determined the thickness of the previously mentioned stratigraphic layers for the locations, where rock temperature was to be determined. Virgin rock temperature was calculated for five levels in approximately 200 locations of Katowicki Holding Węglowy.
Results	Using these locations, isotherm maps of virgin rock temperatures in the collieries of Katowicki Holding Węglowy for the following levels were prepared: -450 m, -550 m, -650 m, -750 m and -850 m.
Practical implications	Preparing climate forecasts for the collieries of Katowicki Holding Węglowy.
Originality/ value	Developing a method to determine rock temperature in a point which cannot be reached, when values of the temperature in other points are known.

Keywords

workplace safety, heat hazard, geothermics, heat transfer, rock temperature, isotherm maps

1. INTRODUCTION

One of the main sources of heat influencing the temperature of mine air is the heat of the rock mass surrounding a mine working (McPherson, 1993). The flow of the heat is directly proportional to the difference between virgin rock temperature and the temperature of the air in the mine. It is commonly believed that virgin rock temperature at a specified mining depth is an initial criterion in assessing climatic hazards. If appropriate steps to prevent climatic hazards are to be taken, knowing the virgin rock temperature in the rock mass surrounding a mine working at various distances from the sidewalls of a mine working is essential (Nottrot & Sadèe, 1966). That is why the geothermal conditions of areas about to be mined for useful minerals are checked (Chomakov, Jankov, Shushulov, & Nachkov, 1981) and measurements of rock temperature are made (Danko et al., 1987). It is not always possible to measure virgin rock temperature directly, especially in designed workings. That is why every colliery where mining activities reach deeper than 700 m is advised to have up-to-date isotherm maps of virgin rock temperatures. Most collieries have isotherm maps of virgin rock temperatures for the levels (or seams) which are mined. Nowadays there are an increasing number of problems (ventilation, fire, mining and technical), which affect neighbouring collieries. That is why we decided to prepare isotherm maps for a wider area including several collieries. The paper refers to virgin rock temperature in the collieries of Katowicki Holding Węglowy.

2. MEASUREMENTS OF VIRGIN ROCK TEMPERATURE

Making isotherm maps of virgin rock temperature, first and foremost, requires the measurement of temperature. In the Polish hard coal mining industry, two methods of measuring virgin rock temperature are used. In the first, virgin rock temperature is measured in newly cut longwalls, faces of mine workings (driven in coal, in coal and rock, and in rock). The method, described in the paper (Knechtel, Markefka, & Zgryza, 1980) and in standard PN-G-04038 (1998), is widely used in the Polish hard coal mining industry. In the second method, virgin rock temperature is measured in exploration wells drilled from the surface. The method, described in the paper (Majorowicz, 1975), was used in reference to Lublin Coal Basin (LZW). It is less accurate than the first method and its use in pre-existing collieries is not recommended.

Table 1. Measurements of virgin rock temperature in the collieries of Katowicki Holding Węglowy

	Geodetic height of		Thickness o the	Tomporatura							
No.	the measurement point	the physical surface	overburden	carboniferous rocks	coal seam	of the rock					
	Z	Z 0	Δz_n	Δz_k	Δz _w	tpg					
	m	m	m	m	m	°C					
1	2	3	4	5	6	7					
Kazimierz Juliusz colliery											
1	-401.0	268.0	15.0	654.0	58.80	26.2					
	-128.0	251.0	46.0	333.0	12.75	19.5					
<u>3 – 110.0 202.0 3.0 3/3.0 5.84 18.0</u>											
1	125.0	area of tr		a-modrzejow co	40 FO	20.0					
	-435.0	240.0	5.0	73/ 0	40.50	31.5					
- 2	0	230.0	8.0	693.0	44.00	30.5					
	_473.0	220.0	4.0	657.0	40.30	29.0					
5	-88.0	237.0	31.0	294.0	11 70	17.3					
6	-102.5	215.0	32.5	285.0	19.20	17.7					
7	-69.0	212.5	31.0	250.5	12.10	16.6					
8	-241.8	238.0	20.0	459.8	14.58	22.5					
Wujek – Ruch Śląsk colliery											
1	-433.1	282.5	5.0	710.6	29.95	29.0					
2	-450.3	271.0	52.5	668.5	42.55	29.6					
3	-328.3	274.0	20.0	582.5	27.36	28.6					
4	-429.9	266.0	67.5	628.4	37.21	30.2					
5	-352.1	276.0	5.0	623.1	43.20	28.2					
6	-363.0	305.0	5.0	663.0	35.13	29.6					
	-476.0	281.0	5.0	752.0	25.75	30.0					
8	-382.0	304.0	20.0	566.0	37.24	29.8					
<u>9</u>	-4/7.5	272.0	15.0	734.5	42.34	31.0					
10	-490.1	200.0	5.0	701.1	20.20	31.0					
12	<u>-656 2</u>	290.0	5.0	946 7	75.17	38.6					
13	-652.8	288.0	5.0	935.8	48.95	37.8					
14	-397.3	332.0	10.0	719.3	37.48	28.2					
15	-491.2	306.5	12.5	785.2	40.28	30.2					
16	-596.0	282.0	30.0	848.0	36.40	33.0					
		V	Vujek – Ruch V	Vujek colliery							
1	-322.8	307.0	30.0	599.8	28.05	28.7					
2	-311.6	291.8	10.0	593.4	50.00	28.2					
3	-381.0	315.0	11.0	685.0	42.75	27.0					
4	-382.8	315.0	11.0	686.8	42.75	28.4					
		area of th	ne former Kato	wice-Kleofas col	liery						
	-47.7	260.0	68.0	239.7	9.30	16.1					
	-98.9	267.5	23.0	343.4	10.55	18.1					
	-314.0	287.0	29.0	572.0	20.50	24.1					
4	-131.0	200.0	47.0	344.0	24.09	20.0					
5	-130.4	LIU.J Murchi	11.U Staszic – Ruch	Boże Dary colli	00.10 erv	21.0					
1	85.0	320.0	6.0	229 0	7 81	13.3					
2	64.2	330.0	5.0	260.8	8.23	14.3					
3	68.0	327.0	5.0	254.0	7.86	14.0					
		Murck	i-Staszic – Rud	ch Staszic collier	v						
1	-325.2	277.5	23.0	579.7	46.70	30.2					
2	-326.4	277.8	23.0	581.2	46.70	30.8					
3	-346.1	278.4	18.0	606.5	38.20	31.5					
4	-431.2	305.0	14.0	722.2	24.60	33.0					
5	-382.2	290.2	4.2	668.2	29.10	31.0					
6	-376.0	294.5	7.5	663.0	22.80	31.5					
	-154.2	277.0	27.0	404.2	26.60	24.5					
8	-240.6	330.9	12.0	559.5	14.60	26.5					
<u> </u>	-200.5	203.1	19.0	532.0	24.10	20.0					
11	-210.2	200.1	19.0	644.3	24.10	20.0					
12	-249.9	300.2	8,8	541.3	33.00	28.5					

13	-411.0	295.0	29.0	677.0	34.50	31.2					
14	-420.0	295.0	11.0	704.0	33.20	30.6					
15	-366.0	290.0	5.0	651.0	31.10	33.6					
16	-355.0	287.0	5.0	637.0	27.60	32.8					
17	-339.0	276.0	8.0	607.0	47.10	29.4					
18	-502.0	285.0	20.0	767.0	34.10	32.6					
19	-325.0	284.0	22.0	587.0	41.10	29.2					
20	-364.0	290.0	5.0	649.0	36.40	28.6					
21	-297.0	287.0	7.0	577.0	38.20	27.8					
22	-476.0	304.0	4.0	776.0	47.70	35.6					
23	-168.0	291.0	5.0	454.0	16.30	23.2					
24	-174.0	286.0	5.0	455.0	16.90	24.0					
25	-190.0	300.0	10.0	480.0	21.70	23.6					
Mysłowice-Wesoła Ruch Mysłowice colliery											
1	-289.1	282.5	0.0	571.6	44.50	26.5					
2	-330.0	309.0	4.0	635.0	38.00	28.2					
3	-247.0	272.5	0.0	519.5	36.40	26.0					
4	-208.6	270.0	0.0	478.6	23.10	25.0					
5	-88.0	268.0	30.0	326.0	11.70	17.3					
6	-215.0	243.5	30.0	428.5	12.10	16.6					
7	-225.7	288.7	15.0	499.4	27.00	25.4					
8	-263.7	278.7	30.0	512.4	31.00	25.6					
9	-215.0	270.0	6.0	479.0	19.50	22.5					
10	-320.5	289.0	4.0	605.5	46.05	28.4					
			Wieczoreł	colliery							
1	6.0	270.0	27.0	237.0	14.60	17.5					
2	-12.0	285.0	0.0	297.0	14.79	17.0					
3	-225.7	288.7	12.0	502.4	34.80	25.4					
4	-263.7	278.7	30.0	512.4	30.77	25.6					
5	-294.5	273.5	14.0	554.0	45.60	26.2					
	Mysłowice-Wesoła Ruch Wesoła colliery										
1	-193.4	277.0	30.0	440.4	17.50	20.1					
2	-166.2	294.0	0.0	460.2	11.75	19.4					
3	-196.0	325.0	5.0	516.0	18.75	19.6					
4	-390.0	301.0	20.0	671.0	23.50	30.9					
5	-547.0	269.0	10.0	806.0	39.93	34.0					
6	-380.0	311.0	20.0	671.0	19.80	31.0					
7	-391.0	280.0	10.0	661.0	22.60	28.0					
8	-386.0	299.5	2.5	683.0	18.95	28.0					
9	-339.0	271.0	25.0	585.0	15.55	28.0					
10	216.0	200 E	7.5	507.0	10.05	20.0					

3. RULES OF PREPARING ISOTHERM MAPS OF VIRGIN ROCK TEMPERATURE

To prepare an isotherm map of virgin rock temperature it is advisable to have a range of measurement points scattered, if possible, across the mapped area. Within the framework of the paper there were 89 measurement points at our disposal. The results of the measurements made by the personnel of the GIG Department of Mining Aerology were collected in Table 1. Columns of the table contain: the geodetic height of a measurement point, the geodetic height of physical surface above a measurement point, the thickness of stratigraphic layers (overburden, carboniferous rocks) and the total thickness of coal seams above a measurement point, as well as the measured virgin rock temperature. Measurements of the virgin rock temperature were made at different depths. If they are to be used for making isotherm maps of a particular level, it is necessary to determine the coefficients characterising vertical heat transport within the rocks, based on the results of the measurements and analyses of the geological cross--sections of a given mining area (Chmura & Chudek, 2001). The coefficients are the ratios of heat flow density and thermal conductivity coefficient (q/λ_q) of a given type of rock (Knechtel et al., 1980). Based on many years of mining experience it can be assumed that above a measurement point there are three types of stratigraphic layers, i.e.: overburden, carboniferous rocks (without coal) and coal. Transforming Chmura's equation (Chmura, 1976) referring to virgin rock temperature at a particular level, the following equation can be written:

$$t_{pg} = t_0 + a_n(\Delta z_n - 30) + a_k(\Delta z_k - \Delta z_w) + a_w \Delta z_w$$

where:

 t_{pg} – virgin rock temperature at a particular level, °C;

 t_0 – the average annual ambient temperature (Pawiński, Roszkowski, & Strzemiński, 1979; Recknagel, Sprenger, Hönmann, & Schramek, 1994), °C;

 a_n , a_k , a_w – heat transfer coefficients for, respectively: overburden, carboniferous rocks and coal, K/m;

 Δz_n , Δz_k , Δz_w – the thickness of stratigraphic layers above a measurement point respectively: overburden, carboniferous rocks and coal, m.

Coefficients a_n , a_k , and a_w are determined using the least square method (Bronsztejn & Siemiendajew, 1970). In the map of a given level a few dozen points were chosen, more or less evenly distributed over the whole investigated area, and for these points virgin rock temperature was calculated using the aforementioned equation, whereby the thickness of particular stratigraphic layers refers to the points which were used to forecast virgin rock temperature and not measurement points. The results of the calculations are marked in the map of the investigated level. Due to the fact that each colliery can have its own mining levels (different to the levels of neighbouring collieries), in the paper we present isotherm maps of virgin rock temperature for horizons (levels) measured from the sea level of: -450 m (Fig. 1), -550 m (Fig. 2), -650 m (Fig. 3), -750 m (Fig. 4) and -850 m (Fig. 5).

To draw isotherm maps of virgin rock temperature SURFER 8 (specialist software) was used, wherein statistical methods are applied for interpolation and extrapolation. The margin of error in determining virgin rock temperature does not exceed 0.2° C.



Fig. 1. Isotherm map of virgin rock temperature, Katowicki Holding Węglowy, level –450 m



Fig. 2. Isotherm map of virgin rock temperature, Katowicki Holding Węglowy, level –550 m



Fig. 3. Isotherm map of virgin rock temperature, Katowicki Holding Węglowy, level –650 m



Fig. 4. Isotherm map of virgin rock temperature, Katowicki Holding Węglowy, level –750 m



Fig. 5. Isotherm map of virgin rock temperature, Katowicki Holding Węglowy, level –850 m

4. CONCLUSIONS

Isotherm maps of virgin rock temperature in the collieries of Katowicki Holding Węglowy for five levels (horizons): -450 m, -550 m, -650 m, -750 m and -850 m were made. Analysis of the previously mentioned maps shows that the highest values of virgin rock temperature are to be expected in the central part of Katowicki Holding Węglowy (collieries: Wujek and Murcki-Staszic – Ruch Staszic). For a level of -450 m the temperature reaches 37°C, and for a level of -850 m the temperature reaches 52°C. The lowest rock temperatures occur in the north-western part of Katowicki Holding Węglowy (Kazimierz Juliusz colliery), where virgin rock temperature at a level of -450 m is 26°C, and at a level of -850 m it reaches 40°C. The average geothermic step for the collieries of Katowicki Holding Węglowy is 28.7 m/K and it is lower than the average geothermic step for the whole Upper Silesian Coal Basin (GZW), which is approximately 32 m/K (Knechtel & Gapiński, 2005).

Acknowledgments

In the paper the Authors used the results of measurements of virgin rock temperature commissioned, as they were needed, by the collieries included in Katowicki Holding Węglowy.

References

- Bronsztejn, I.N., & Siemiendajew, K.A. (1970). Matematyka – poradnik encyklopedyczny, Część VI: Opracowanie danych doświadczalnych [Guidebook to Mathematics, Part VI: Developing experimental data]. Warszawa: PWN.
- Chmura, K. (1976). Analiza ziemskiego strumienia ciepła na przykładzie kopalni Borynia [Analysis of earth's heat flow, Borynia colliery case study]. *Przegląd Górniczy*, 32(12), 480–489.
- Chmura, K., & Chudek, M. (2001). *Geotermomechanika górnicza* [Geothermal mechanics in mining]. Mikołów: Suplement – Księgarnia Nakładowa.
- Chomakov, P., Jankov, S., Shushulov, G., & Nachkov, I. (1981). Geothermal conditions of Polymetallic Erma-Reka Deposit. In International Bureau of Mining Thermophysics, Transactions of the First session of Working Group No 1 (pp. 179–188). Katowice, 9–13 June 1980.
- Danko, G., et al. (1987). Development of an improved method to measure in situ thermal rock properties in a single drill hole. In *Proc. 3rd US Mine Ventilation Symposium* (pp. 33–52). Littleton, CO: SME.

- Knechtel, J., Markefka, P., Zgryza, S. (1980). Mapy pierwotnej temperatury skał Górnośląskiego Okręgu Przemysłowego dla horyzontów –450, –550, –650 i –750 m [Maps of virgin rock temperature for the Upper Silesian Industrial Regions for horizons –450, –550, –650 and –750 m]. Prace Naukowe Głównego Instytutu Górnictwa, Komunikat (719).
- Knechtel, J., Gapiński, D. (2005). Zaktualizowane mapy izolinii temperatury pierwotnej skał kopalń Górnośląskiego Zagłębia Węglowego (GZW) [Updated isotherm maps of virgin rock temperature of Upper Silesian Coal Basin collieries (GZW)]. Katowice: Główny Instytut Górnictwa.
- Majorowicz, J. (1975). Warunki geotermiczne Lubelskiego Zagłębia Węglowego w rejonie Łęcznej [Geothermal conditions in Lublin Coal Basin, Łęczna area]. *Przegląd Geologiczny*, 75(12), 614– 620.
- Nottrot, R., & Sadèe, C. (1966). Abkühlung homogenen isotropen Gesteins um eine zylindrische Strecke durch Wetter von konstanter Temperatur. *Glückauf Forschungshefte* 27(4), 193–200.
- McPherson, M.J. (1993). Subsurface Ventilation and Environmental Engineering, Part Four: Heat and Humidity. London – Glasgow – New York – Melbourne – Madras: Chapman & Hall.
- Pawiński, J., Roszkowski, J., & Strzemiński, J. (1979). Przewietrzanie kopalń [Ventilation of collieries]. Katowice: Wydawnictwo Śląsk.
- PN-G-04038. (1998). Zabezpieczenie kopalń przed zagrożeniem temperaturowym. Skały. Pomiar temperatury pierwotnej [Polish Standard: PN-G-04038 (1998). Securing collieries against heat hazard. Rocks. Measurements of virgin rock temperature].
- Recknagel, H., Sprenger, E., Hönmann, W., & Schramek, E. (1994). Poradnik – ogrzewanie i klimatyzacja [Handbook – heating and air-conditioning]. Gdańsk: EWFE.