Archives of Mining Sciences 46, 3 (2001) 227–236

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TESTING AIR-FLOW VELOCITY DISTRIBUTIONS ACROSS A SECTION OF A DUCT AT A MINE-VENTILATION STATION

POLE PRĘDKOŚCI PRZEPŁYWU POWIETRZA W KANALE KOPALNIANEJ STACJI WENTYLACYJNEJ

This paper details the construction of air volume flow rate measurement apparatus in mine ventilation ducts using the profile of velocities integration method and describes measurements with the use of this equipment to take measurements the duct in a main, multi-fan ventilation station installed in one of the mines in the Polish copper field. The results of the in-situ measuring procedure were used to calculate the distribution of velocities of air-flow across the duct section for single fans and with various parallel configurations of fans.

Key words: mine ventilation, velocity profile, ventilation survey, fan station

W artykule przedstawiono budowę urządzenia do pomiaru strumienia objętości powietrza w kopalnianych kanałach wentylacyjnych metodą całkowania bryły prędkości oraz podano opis wykonania pomiaru z zastosowaniem tego urządzenia w kanale wielowentylatorowej stacji głównego przewietrzania jednej z kopalń zagłębia miedziowego. Wyniki przeprowadzonych pomiarów wykorzystano do wyznaczenia pola prędkości przepływu powietrza w kanale przy pracy pojedynczych wentylatorów i różnych wariantów pracy równoległej.

Słowa kluczowe: wentylacja kopalń, profil prędkości, pomiary wentylacyjne, stacja wentylatorowa

1. Introduction

Deep mine ventilation has a significant impact on the overall energy balance of a mine. The energy used for ventilation purposes also includes energy lost at the main ventilation station. The energy expenditure associated with the air-flow in the

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ventilation duct accounts for some of the dissipated energy. The more disturbed and the more irregular the profile of this flow is, the higher the losses. Knowledge of the profile of the air flow in the ventilation duct enables means to be developed to reduce the irregularity of distribution pattern of the air flow velocities in the duct's section, thus lowering overall flow losses. Significant irregularities of the velocity section can be expected in ducts where substantial changes in the direction of the air-flow occur. This is often a problem in multi-fan ducts at the main ventilation station. Therefore, a programme of tests of the velocity profile was launched in the common duct of a triple-fan main ventilation station in one of the mines in the copper field.

2. Measurement method of the air velocity profile in the ventilation duct

Air flow velocity profiles in the section plane of the ventilation duct were identified on the basis of the results of measurement of local velocities at various points in this plane. The location of measurement points was determined in accordance with recommendations specified in PN-81/M-42366 Standard *"Measurement of the volume flow rate by means of the distribution of velocities integration method"* and PN-ISO 5221:1994 *"Methods of the air stream measurement in a duct"* for Log-Chebyshev method. A grid of 25 measurements points was used (five points horizontally and five points vertically). For these points, the following relative distances between measurement points from the measurement section's symmetry axis of the duct of width L and height H are valid:

Relative distances x_i/L and y_i/H between measurement points from the axis of the measurement section		
0	±0.212	±0.426

Local velocities at the selected points were measured by an indirect method, i.e. by means of measurement of the difference of pressures on Recknagel-Krell shields (Roszczynialski et al. 1992). It was assumed that the velocity vectors were approximately parallel to the duct's axis. Because the presence of a human operator with a measuring probe in the ventilation duct was totally impractical, simultaneous measurement at all measurement points was made possible by placing 25 measurement shields in five columns situated between the roof and the floor of the duct, with five measuring probes on each column. From the measuring shields 25 pairs of signal cables were connected to two measuring sets located outside the duct. Each measuring set included a differential pressure switch and two differential pressure converters. The switch allowed pressure signals from two measuring shields be directed to two differential pressure converters. Equipped with a lineariser with characteristic correction, these two converters were calibrated directly in units of velocity. Each of the four converters was calibrated, together with the Recknagel-Krell shields, in the aerodynamic tunnel of the Strata Mechanics Research Institute of the Polish Academy of Science. The location of columns with measuring probes in the section of the ventilation duct and the diagram of connections of probes with measuring sets is illustrated in Fig. 1 and a more detailed description of the whole measuring apparatus is outlined in

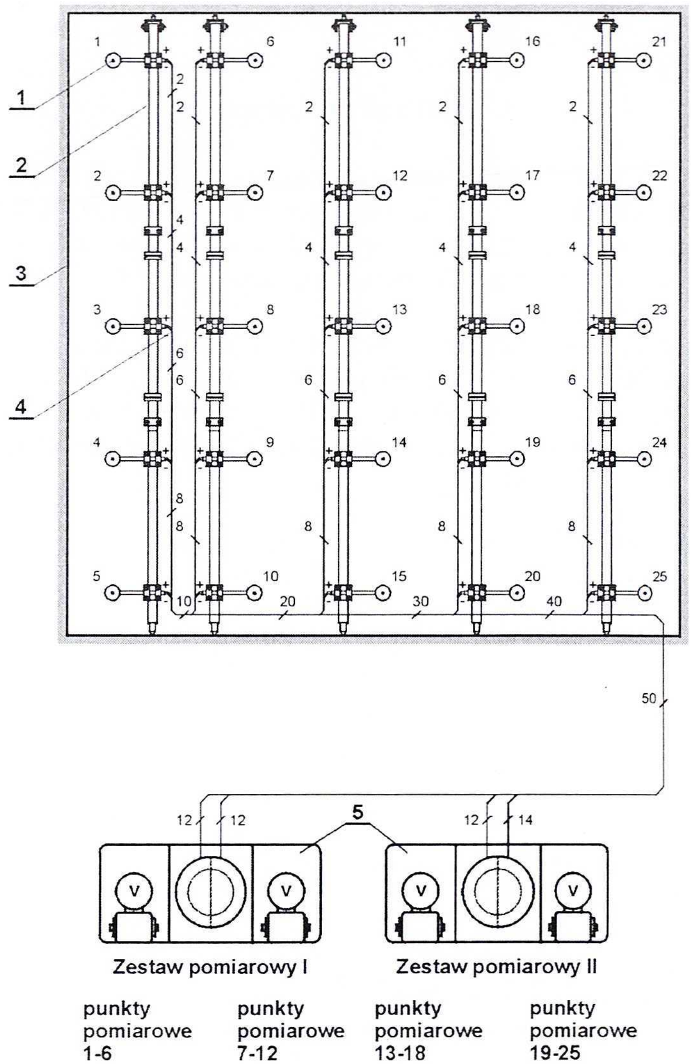

Fig. 1. Volume flow of air measuring apparatus
1 — Recknagel-Krell shield, 2 — column, 3 — ventilation duct,4 — flexible hoses, 5 — measuring set

Rys. 1. Urządzenie do pomiaru strumienia objętości powietrza
1 — tarcza Recknagel-Krella, 2 — kolumna, 3 — kanał wentylacyjny, 4 — węże giętkie, 5 — zestaw pomiarowy

the article (Dziurzyński, Krach 2000). The measurement of local velocities at the measurement points of the section surface of the ventilation duct consisted of readings of four velocities, then placing the switches in the next positions and taking readings of velocities for the next four measurement points. This procedure was repeated until values of local velocities for all measurement points of the duct's section surface were obtained.

3. Results of measurements

The testing procedure, aimed to determine profiles of velocity of the flowing air, was conducted in the common duct of the triple-fan main ventilation station. In this duct appropriate places were selected for the installation of the above-mentioned measuring columns (Fig. 2), while whilst the measuring instruments themselves were placed outside the common fan duct.

The testing programme included a cycle of measurements for the operation of each fan in isolation (W1, W2, W3) and for parallel connections (W1 + W2, W1 + W3, W2 + W3). The cycle of measurements of the volume flow was performed for all possible positions of the stator for individual fans. The testing was carried out for four

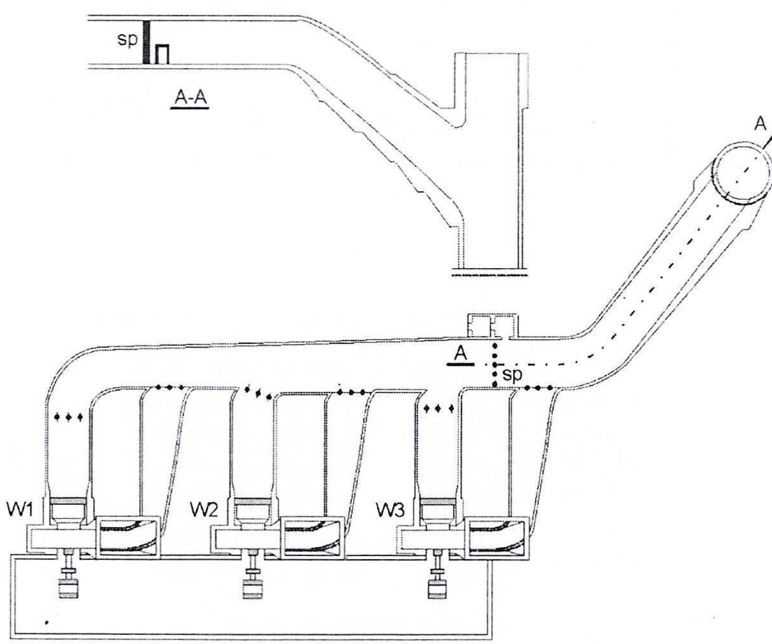

Fig. 2. Location of the measuring section in the duct of the triple-fan ventilation station
W1,W2, W3 — fans, sp — measuring station

Rys. 2. Położenie przekroju pomiarowego w kanale trójwentylatorowej stacji wentylacyjnej
W1,W2, W3 — wentylatory, sp — stacja pomiarowa

positions of the stator, thus obtaining a wide range of variations in the volume of the flowing air stream.

The distribution of velocities of the air-flow in the fan duct section was measured for the following opening positions of the regulator's flaps: 20, 40, 60 and 90 degrees. In the course of the measurement procedure a total 24 measurement cycles were carried out. Because of the abundance of data thus gathered the results of measurements of the air velocity are presented in several tables together with the graphic presentation of these results for fan W1 fan working in isolation and for fans W1 and W2 connected in parallel.

TABLE 1

Results of measurements — W2 fan working the stator opened at 90 degrees

TABLICA 1

Zestawienie wyników pomiarów — pracuje wentylator nr W2 — otwarcie kierownicy 90 stopni

	A	B	C	D	E	Total	Q[m^3/min]
1	13.80	14.10	13.50	13.60	23.40	78.40	
2	14.50	14.00	12.90	8.90	8.80	59.10	
3	12.30	13.30	11.90	10.60	9.40	57.50	
4	13.90	12.70	12.40	11.30	10.10	60.40	
5	13.60	10.70	11.40	10.70	9.7	46.40	
	68.10	64.80	62.10	55.10	51.70	12.07	19 557

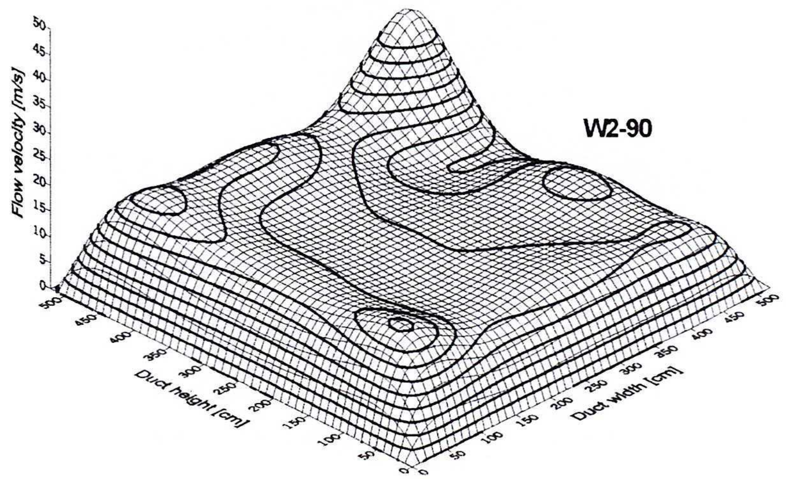

Fig. 3. Distribution of velocity for single fan W2 — the flaps opened at 90 degrees

Rys. 3. Rozkład prędkości dla pojedynczej pracy wentylatora nr W2 — otwarcie kierownicy 90 stopni

Tables 1 and 2 show results of measurements for fan W2 working in isolation as a component of the triple-fan installation at the main ventilation station of the mine ventilation system.

TABLE 2

Results of measurements — W2 fan working the stator opened at 20 degrees

TABLICA 2

Zestawienie wyników pomiarów — pracuje wentylator nr W2 — otwarcie kierownicy 20 stopni

	A	B	C	D	E	Total	Q[m³/min]
1	5.8	5.8	5.9	5.2	17.9	40.60	
2	5.5	5.4	5.0	3.8	2.9	22.60	
3	5.2	4.8	5.12	4.7	3.7	23.52	
4	5.5	5.13	4.85	5.1	5.25	25.83	
5	4.9	4.6	5.1	4.8	4.6	24.00	
	26.9	25.73	25.97	23.6	34.35	5.46	8 848

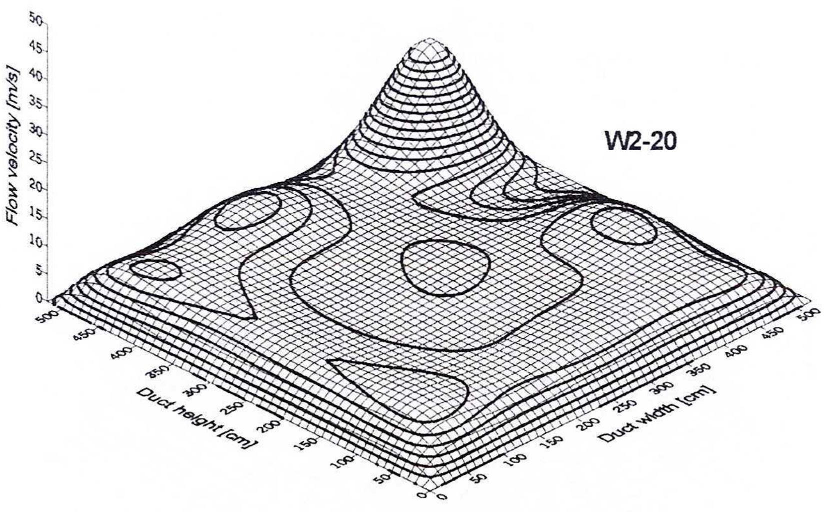

Fig. 4. Distribution of velocity for single fan W2 — the flaps opened at 20 degrees

Rys. 4. Rozkład prędkości dla pojedynczej pracy wentylatora nr W2 — otwarcie kierownicy 20 stopni

In Tables 3 and 4 results of measurement for fans W1 and W2 fans working in parallel are presented. The results obtained are as follows.

TABLE 3

Results of measurements — W1 and W2 fans working — the stator opened at 90 degrees

TABLICA 3

Zestawienie wyników pomiarów — pracuje wentylator nr W1 i nr W2 — otwarcie kierownicy 90 stopni

	A	B	C	D	E	Total	Q[m^3/min]
1	23.5	24.7	24.6	20.9	49.8	143.5	
2	24.6	25.1	21.3	18.1	14.2	103.3	
3	22.3	20.9	20.7	18.9	17.9	100.7	
4	23.3	21.1	21.17	20.85	19.9	106.32	
5	21.7	20.9	20.4	19.2	18.8	101.0	
	115.4	112.7	108.17	97.95	120.6	22.19	35 952

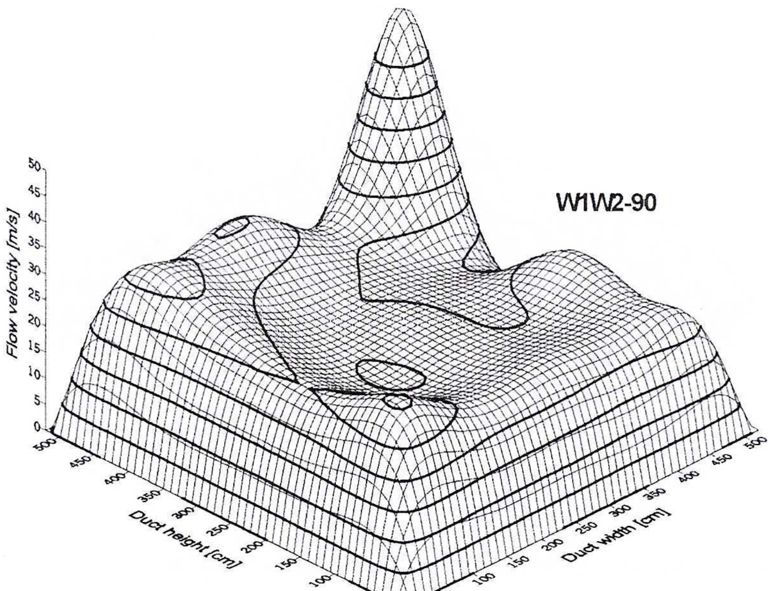

Fig. 5. Distribution of velocity for fans W1 and W2 in parallel — the flaps opened at 90 degrees

Rys. 5. Rozkład prędkości dla równoległej pracy wentylatora nr W1i nr W2 — otwarcie kierownicy 90 stopni

The results of the air velocity distribution in the mine ventilation station presented above are characterised by significant irregularities. In all cases tested the maximum

TABLE 4

Results of measurements — W1 and W2 fans working the stator opened at 20 degrees

TABLICA 4

Zestawienie wyników pomiarów — pracuje wentylator nr W1 i nr W2 — otwarcie kierownicy 20 stopni

	A	B	C	D	E	Total	$Q[m^3/min]$
1	11.7	11.6	11.5	9.3	20.1	64.20	
2	11.9	10.9	10.8	8.5	5.9	48.00	
3	10.2	9.8	9.9	8.6	7.9	46.40	
4	10.1	8.3	8.4	7.85	7.3	41.95	
5	11.6	9.5	9.1	9.7	8.0	47.90	
	55.5	50.1	49.7	43.95	49.2	9.94	16 100

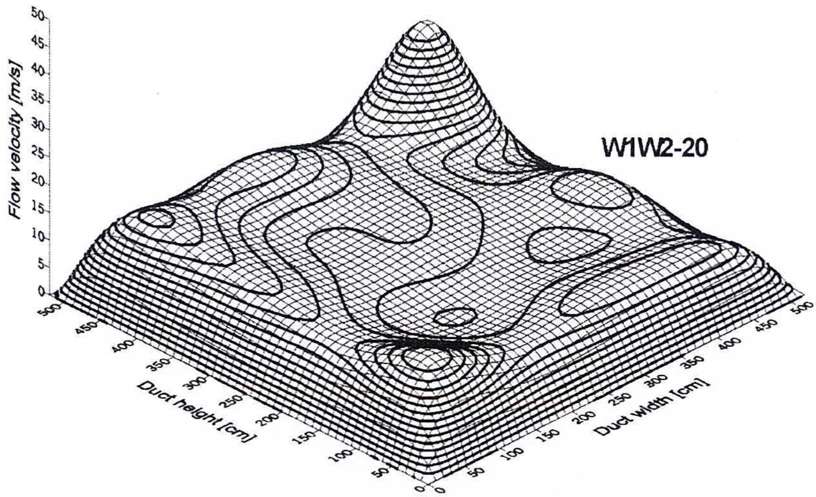

Fig. 6. Distribution of velocity for fans W1 and W2 in parallel — the flaps opened at 20 degrees

Rys. 6. Rozkład prędkości dla równoległej pracy wentylatora nr W1i nr W2 — otwarcie kierownicy 20 stopni

velocity occurs in the top corner of the measured section. Table 5 presents values of the maximum air velocity, the average air velocity in the duct section and the *peaking factors*, calculated as a proportion of the difference between the maximum velocity and the average velocity to the average velocity $(k = (V_{max} - V_{ave})/V_{ave})$ for single and parallel operation of fans at different opening angles of stators.

TABLE 5

Maximum velocities, average velocities and peaking factors for individual fans and various opening angles of stators

TABLICA 5

Zestawienie prędkości maksymalnych, prędkości średnich i współczynników nierówności dla poszczególnych wentylatorów i różnych kątów otwarcia aparatów kierowniczych

	W1			W2			W3		
	V_{max}	V_{ave}	k	V_{max}	V_{ave}	k	V_{max}	V_{ave}	k
20°	17.5	5.91	1.96	17.9	5.54	2.23	17.1	5.52	2.1
40°	19.6	9.48	1.07	19.5	9.14	1.13	24.4	9.54	1.56
60°	22.1	11.37	0.94	21.1	11.17	0.89	28.6	11.85	1.41
90°	21.3	12.25	0.74	23.4	12.07	0.94	32.2	12.91	1.49
	W1 + W2			W1 + W3			W2 + W3		
	V_{max}	V_{ave}	k	V_{max}	V_{ave}	k	V_{max}	V_{ave}	k
20°	20.1	8.23	1.44	26.2	10.62	1.47	27.2	11.1	1.45
40°	34.5	16.83	1.05	38.5	16.71	1.30	39.7	17.36	1.29
60°	43.5	20.99	1.07	49.3	20.49	1.41	47.3	21.15	1.24
90°	49.8	22.21	1.24	51.5	23.11	1.23	51.3	22.64	1.27

3. Conclusions

The analysis of peaking factors presented in Table 5 indicates that maximum and minimum values of the peaking factor occur when fans W1 and W2 work in isolation, whereas when working in parallel the difference between these values is significantly lower. The lowest peaking factor occurs when fan W1 operates on its own. This which is the most remote fan from the measured section and takes place with the full opening of its regulator. The presence of such high irregularities and the location of the maximum velocity in the right top corner of the duct (as viewed from the pit shaft side) is difficult to explain without additional measurements in other sections of the duct. It may be assumed that the cause of this phenomenon is the shape of the duct, which forces changes in the air-flow direction both horizontally and vertically. If further testing confirms that the cause of this velocity distribution is the duct's geometry, a reduction of the peaking factor may be made by placing appropriate stators in places where the change of the air-flow direction in the duct takes place.

This testing was performed as a part of research project no T12A 020 15 named "Working stability of multi-fan stations" financed by the Committee of Scientific Research.

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REVIEW BY: PROF. DR HAB. INŻ. WACŁAW TRUTWIN, KRAKÓW

Received: 28 Febuary 2001