MODELING OF THE COMPLEX VENTILATION NETWORK RELATED TO LIVEZENI MINE

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Abstract: *In order to ensure the microclimate conditions for the exploitation of useful mineral substances underground, it is necessary to ensure the control of gas emissions from the field and from the exploited space. For this it is necessary to ensure a balanced air flow at the level of each active mining work in order to dilute the gases. Specialized programs are used to ensure the optimal distribution of air flows at the level of each mining work. The paper presents the modelling and solving of the ventilation network related to Livezeni Mine with the help of the 3D CANVENT program.*

Keywords: *modeling, ventilation, network, CANVENT program, air flow*

1. Introduction

Mine ventilation is an extremely sensitive and complex domain that includes several disciplines used to accomplish and preserve safe conditions in underground [1, 2, 3]. In this sense, solving the ventilation networks with the help of the calculation technique allows the practitioners to visualize in real time the changes occurred in the network and, what is even more important, they can anticipate the possible disturbances in the ventilation system.

2. Presentation of the problem

In order to extract the upper coals underground, it is necessary to carry out a complex of mining works for opening, preparation and exploitation, which require their location both horizontally and vertically. The shape and dimensions of the mining works are different and have free surfaces for the migration of gases from the deposit or from the massif [4, 5].

The gases present in the active mining works can be explosive, toxic or suffocating in nature. Additionally, on the alignment of mining works and workplaces, the relative humidity is high and can reach the value of RH = 100%. At the same time, the thermal gradient manifests itself permanently and leads to an increase in the ambient temperature with depth.

To combat gas accumulations, excessive humidity and heat, the general ventilation system is used, which involves the presence of one or more main ventilation stations located on the surface and which are equipped with two main fans, one of which is active and one is Reserve.

In order to ensure the necessary flows on each active mining work, specialized programs are used, with the help of which the modeling, solving and optimization of the ventilation networks can be performed.

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3. Mine ventilation network

The ventilation network of Livezeni mine includes three fresh air inlet shafts: Schip shaft, auxiliary shaft, auxiliary shaft no. 3 and two ventilation shafts: east ventilation shaft and ventilation shaft no. 2. It also includes underground mining located on four horizons (horizon 100; horizon 300; horizon 350; and horizon 475). The ventilation network is divided vertically by horizons and horizontally by operating blocks. The whole ventilation network includes 201 junctions (knots) and 267 branches [6, 7, 8, 9].

The connections between the horizons are made by means of shafts, inclined planes or risings. The horizontal connection is made through directional, transverse or diagonal galleries.

The intersection of two works in the ventilation network or the change of direction of a work, defines a node. Mining between two successive nodes, defines a branch.

The ventilation network related to Livezeni mine includes 201 junctions (nodes) and 267 branches [6, 7, 8, 9].

4. Ventilation network modeling

Internationally, several specialized programs are used to model a ventilation network such as: VentSim, VentGraph, VentPri, Canvent, etc. The specialized 3D Canvent program was used to model the ventilation network for Livezeni mine. This program is based on the use of the Hardy Cross successive approximation method [10, 11, 12, 13].

The solution of the aeration network related to Livezeni mine required certain steps, namely:

- Identification of nodes on topographic drawings;
- Identifying the coordinates for each node;
- Entering the values specific to the coordinates in the program database (fig. 1);

#:	name:	x :	y:	z:
121	Gal. leg. P.A. 2 oriz. 4'	88524	34062	481.5
122	Ab.fr. Pan. 5A	88483	33700	389.89
123	Ab.fr. Pan. 5A	88681	33675	409.20
124	Ab.fr. Pan. 5A	88806	33654	416.89
125	Ab.fr. Pan. 5A	88872	33630	420
126	Ab.fr. Pan. 5A	88893	33679	439.79
127	Ab.fr. Pan. 5A	88871	33690	439.70
128	Ab.fr. Pan. 5A	88657	33723	430.70
129	Ab.fr. Pan. 5A	88478	33755	410.89
130	Plan aeraj\Valache	88472	33762	414.60
131	Plan aeraj\Valache	88540	34050	480
132	Gal. leg. P.A. 2 oriz. 4'	88547	34082	481
133	Gal. leg. P.A. 2 oriz. 4'	88601	34126	475
134	Statie trafo oriz. 475	88592	34140	475
135	Statie trafo oriz. 475	88618	34160	475
136	Gal. leg. P.A. 2 oriz. 4'	88638	34157	475
137	Gal. leg. P.A. 2 oriz. 4'	88649	34166	475

Fig. 1. Nodes - input data

- Carrying out the measurement campaign which includes:
 - measurements regarding the aerodynamic parameters of the mining works;
 - measurements regarding the geometric parameters of the mining works;
 - measurements regarding the physical parameters of the air.
- Calculation of the aerodynamic resistances specific to each branch;
- Entering the values of the parameters specific to the ventilation network, in the database of the specialized program CANVENT (fig. 2);

#	from:	to:	name:	fan:	fan pressure [Pa]	type of resistance:	shape factor	door res.:	resistance	sym:	con:	line style:
48	32	33	Bitea leg. gal. mag.	none	0	PQ Given LU Hw PA L 32 U 1.534 0 0 1 0 0.491 0 9 2 0						
49	33	34	Gal. mag. carbune o	none	0	PQ Given LU Hw PA L 394 U 0.006 0 0 1 0 0.024 0 9 2 0						
50	34	37	Gal. mag. carbune o	none	0	PQ Given LU Hw PA L 64 U 0.006 0 0 1 0 0.004 0 9 2 0						
51	34	35	Bitea leg. gal. mag.	none	0	PQ Given LU Hw PA L 30 U 0.925 0 0 1 0 0.278 0 9 2 0						
52	35	36	Gal. mag. steril oriz.	none	0	PQ Given LU Hw PA L 50 U 0.006 0 0 1 0 0.003 0 9 2 0						
53	36	38	Gal. mag. steril oriz.	none	0	PQ Given LU Hw PA L 22 U 0.031 0 0 1 0 0.007 0 9 2 0						
54	37	39	Gal. mag. carbune o	none	0	PQ Given LU Hw PA L 37 U 0.008 0 0 1 0 0.003 0 9 2 0						
55	37	36	Bitea leg. gal. mag.	none	0	PQ Given LU Hw PA L 24 U 1.691 0 0 1 0 0.406 0 9 2 0						
56	38	41	Gal. mag. steril oriz.	none	0	PQ Given LU Hw PA L 264 U 0.009 0 0 1 0 0.024 0 9 2 0						
57	39	40	Gal. mag. carbune o	none	0	PQ Given LU Hw PA L 230 U 0.005 0 0 1 0 0.012 0 9 2 0						

Fig. 2. Branches - input data

g) Data entry for fans (fig. 3.);

3D-CANVENT-2K						
File: E. M. LIVEZENI 2010 - 1 - baza bun - Fan Input						
Fan name: V1 E-VAD 2.1 - 15q			Stalling Volume [m³/s]: 15.00			
Quan. [m³/s]	Pressure [Pa]	Effici. [%]	Quan. [m³/s]	Pressure [Pa]	Effici. [%]	
15.63	1680.00	17.50	23.33	1320.00		
16.66	1650.00	18.00	25.00	1205.00		
17.50	1610.00	18.50	26.66	1150.00		
18.33	1580.00	19.00	28.00	1080.00		
19.16	1540.00	19.50	27.50	1020.00		
19.63	1500.00	20.00	28.33	950.00		
20.63	1450.00	20.50				
21.66	1400.00	21.00				
22.50	1370.00					
Fan name: V1 E-VAD 2.1 - 20q			Stalling Volume [m³/s]: 15.00			
Quan. [m³/s]	Pressure [Pa]	Effici. [%]	Quan. [m³/s]	Pressure [Pa]	Effici. [%]	
20.00	1680.00	21.00	33.16	1300.00		
21.66	1600.00	21.50	35.00	1200.00		
23.33	1740.00	22.50				
25.00	1680.00	23.00				
26.66	1610.00	24.50				
28.33	1530.00	25.00				
30.00	1470.00	25.00				
31.50	1400.00	25.50				
31.66	1396.00	26.00				
Fan name: V2 E-VAD 2.1 - 15q			Stalling Volume [m³/s]: 15.00			
Quan. [m³/s]	Pressure [Pa]	Effici. [%]	Quan. [m³/s]	Pressure [Pa]	Effici. [%]	
15.63	1750.00	17.00	23.33	1460.00		
16.66	1715.00	17.00	24.16	1405.00		
17.50	1680.00	17.50	25.00	1370.00		
18.33	1650.00	18.00	25.63	1320.00		
19.66	1610.00	19.00	26.66	1270.00		
20.00	1600.00	20.00	27.50	1200.00		
20.63	1570.00	20.50	28.33	1130.00		
21.66	1540.00	21.00	29.16	1060.00		
22.50	1500.00	22.00				
Fan name: V2 E-VAD 2.1 - 20q			Stalling Volume [m³/s]: 15.00			
Quan. [m³/s]	Pressure [Pa]	Effici. [%]	Quan. [m³/s]	Pressure [Pa]	Effici. [%]	
16.66	2090.00	19.00	31.66	1710.00		
18.33	2070.00	21.00	33.33	1640.00		
20.00	2040.00	22.50	35.00	1560.00		
21.66	2010.00	24.00				
23.33	1970.00	25.00				
25.00	1940.00	26.00				
26.66	1880.00	27.00				
28.33	1830.00	28.00				
30.00	1770.00	29.00				
Fan name: V1PA2-VOD2.1-20q			Stalling Volume [m³/s]: 15.00			
Quan. [m³/s]	Pressure [Pa]	Effici. [%]	Quan. [m³/s]	Pressure [Pa]	Effici. [%]	
21.66	2040.00	16.00	35.00	1670.00		
23.33	2040.00	17.00	35.66	1600.00		
25.00	2010.00	17.50	36.16	1565.00		
26.66	1980.00	18.00	36.66	1550.00		
28.33	1950.00	20.00	38.33	1550.00		
30.00	1920.00	21.00	38.33	1550.00		
31.66	1880.00	22.50				
33.33	1800.00	23.50				
34.66	1700.00	24.00				

Fig. 3. Fans - input data

- h) Representation of the ventilation network, which can be done in a flat system or in a spatial system;
- i) Balancing the ventilation network;
- j) Solving the ventilation network. This stage provides the values of the air flows on each branch (fig. 4; fig. 5; fig. 6; fig. 7).

Fig. 4. Livezeni mine ventilation network solved with 3D CANVENT in 3D projection -x-y-z

Fig. 5. Livezeni mine ventilation network solved with 3D CANVENT in 2D projection -x-0-y

Fig. 6. Livezeni mine ventilation network solved with 3D CANVENT in 2D projection -x-0-z

Fig. 7. Livezeni mine ventilation network solved with 3D CANVENT in 2D projection -y-0-z

k) Obtaining the final data. At this stage, access to program data is provided on both electronic and paper support.

The technique presented above allows solving any ventilation networks, regardless of their degree of complexity.

5. Ventilation network solving

After entering all the data regarding nodes, branches and fans, the ventilation network of the mine was solved. The results obtained after solving the ventilation network are presented in fig. 8 for nodes, fig. 9 for branches and fig. 10 for fans.

3D-CANVENT-2K
File: E. M. LIVEZENI 2010 - 1 - baza bun - Junction Results

Junc.#:	Description:	Energy(NM/KG):	Junc.#:	Description:	Energy(NM/KG):
78	Plan transport benzi oriz. 300	-83.92	179	Statie trafo oriz. 300	-73.72
79	Siloz 9 A oriz. 300	-89.83	180	Statie trafo oriz. 300	-74.15
80	Plan transport benzi	-93.48	181	Gal. maq. Isroni oriz. 300	-74.48
81	Plan transport benzi	-312.98	182	Plan transport benzi 300-100	-86.97
82	Plan aeral pan. 4N	-595.32	183	Plan aeral str. 13	-765.44
83	Plan aeral Stanca	-671.90	184	Sutor Hauser	-766.79
84	Plan transport benzi siloz 15	-344.95	185	Sutor Hauser	-779.00
85	Put aux 3	-0.00	186	Plan aeral str. 15	-799.25
86	Put aux 3	-2.59	187	Gal. maq. Isroni oriz. 300	-800.98
87	Circuit Put aux 3 oriz. 475	-2.99	188	Gal. maq. Isroni oriz. 300	-802.96
88	Circuit Put aux 3 oriz. 475	-3.39	189	Put aeral Est	-815.94
89	Circuit Put aux 3 oriz. 475	-3.79	190	Put aeral Est	0.00
90	Circuit Put aux 3 oriz. 475	-3.65	191	Put aeral Est	-1004.02
91	Circuit Put aux 3 oriz. 475	-4.07	192	Canal Put aeral Est	0.00
92	Circuit Put aux 3 oriz. 475	-4.35	193	Put aeral 2	-0.00
93	Put aux. 3	-3.90	194	Put aeral 2	-2039.79
94	Circuit Put aux 3 oriz. 350	-5.02	195	Canal Put aeral 2	-0.00
95	Circuit Put aux 3 oriz. 350	-6.15	196	Put skip	-2.45
96	Circuit Put aux 3 oriz. 350	-6.95	197	Siloz put skip	-10.73
97	Circuit Put aux 3 oriz. 350	-7.61	198	Siloz put aux.	-8.73
98	Gal. transv. oriz. 350	-13.40	199	Put aux.	-7.08
99	gal. diag. oriz. 350	-338.45	200	Gal. maq. steril oriz. 300	-74.75
100	gal. diag. oriz. 350	-359.78	201	Acces siloz nr.8	-78.59
101	Statie trafo oriz. 350	-380.07			

Fig. 8. Output data nodes

3D-CANVENT-2K
File: E. M. LIVEZENI 2010 - baza - Branch Results

Branch From:	To:	Description:	Sym- bol	Resistance (Ns ² /M ⁶):	Quantity (m ³ /s):	Pressure Drop (PA):	Air Power (KW):	Annual Cost (\$):
52	53	Gal. maq. carbune oriz. 300		0.0119	11.63	1.61	0.02	82
52	53	Siloz nr. 2	D	71.0050	0.22	3.59	0.00	4
53	55	Plan trans. pan. 4 N		12.0158	0.45	2.41	0.00	7
54	55	Gal. maq. carbune oriz. 300		1.4238	1.04	1.53	0.00	7
54	55	reteq. leq. plan trans. pan. 4 N		0.0148	17.22	4.40	0.08	332
55	57	Plan trans. pan. 4 N		0.0328	17.67	10.24	0.18	792
56	54	3reteq. leq. gal. maq. oriz. 300		0.0075	6.63	0.33	0.00	10
56	200	Gal. maq. steril oriz. 300		0.0814	5.66	2.62	0.01	65
57	64	Plan trans. pan. 4 N		31.3100	14.42	329.34	1.07	4678
57	58	Pla. leq. Gal. baza pan. 4 N		0.0880	14.42	18.30	0.28	1158
58	59	Gal. baza pan. 4 N		0.4750	14.42	98.80	1.42	6241
59	60	Ab. fr. Pan. 4 N		0.0825	14.42	141.95	2.05	8967
60	61	Gal. cap pan. 4 N		0.2106	14.42	43.80	0.63	2767
61	62	Gal. cap pan. 4 N		0.0140	14.42	2.92	0.04	194
62	63	Gal. cap pan. 4 N		0.1111	14.42	23.11	0.33	1480
63	64	Plan leq. Gal. cap pan. 4 N		0.0043	10.81	0.50	0.01	24
63	65	Gal. leq. Gal. cap pan. 4 N		0.0621	3.61	0.81	0.00	13
64	66	Plan trans. pan. 4 N		0.0036	14.05	0.71	0.01	44
65	66	3al. leq. Plan trans. pan. 4 N		0.0311	0.41	0.41	0.00	6
66	67	Gal. leq. plan aeral		0.0171	17.67	5.33	0.08	412
67	77	Plan aeral pan. 4 N		0.1806	17.67	56.35	1.00	4360
68	70	Gal. maq. carbune oriz. 300		4.5088	0.29	0.39	0.00	0
68	69	3reteq. leq. gal. maq. oriz. 300		3.9239	0.74	2.18	0.00	7
69	72	Gal. maq. steril oriz. 300		0.1300	5.49	3.92	0.02	94
70	71	Siloz nr. 8	D	71.0000	0.29	6.09	0.00	8
71	74	Plan trans. benzi		0.9811	1.23	1.47	0.00	8
72	73	Gal. maq. steril oriz. 300		0.1992	3.33	2.21	0.01	32
72	75	Gal. leq. plan trans. benzi		0.7960	2.16	3.73	0.01	35
73	75	Gal. maq. steril oriz. 300		0.8003	3.40	9.27	0.03	138
74	73	Siloz nr. 8 bis	D	61.0000	0.38	0.38	0.00	0
74	78	Plan trans. benzi		1.4333	1.15	1.89	0.00	10
75	76	Plan leq. bretea oriz. 300		0.7511	3.40	8.70	0.03	130
76	77	Bretea leq. plan aeral	DD	25.0000	3.89	378.44	1.47	6449
77	82	Plan aeral pan. 4 N		0.2421	21.56	112.47	2.42	10619
78	79	Plan trans. benzi	D	0.5135	3.31	5.94	0.02	62
79	149	Siloz nr. 9	D	39.0000	0.26	9.26	0.00	20
79	80	Plan trans. benzi		0.4737	2.83	3.78	0.01	47
80	81	Plan trans. benzi	DD	27.0000	2.83	215.58	0.61	2668
81	83	Gal. leq. Plan aeral Stanca	DD	633.0000	0.75	356.32	0.27	1171
81	84	Plan benzi oriz. 300		7.2664	2.08	31.29	0.06	284
82	83	Gal. leq. Plan aeral Stanca		0.1598	2.51	74.16	1.50	7002
83	115	Plan aeral Stanca		0.0738	22.31	36.72	0.82	3587
84	103	Plan trans. benzi		10.0577	1.23	15.33	0.02	83
84	107	Siloz nr. 15 oriz. 300		49.0000	0.84	34.65	0.03	128
85	86	Put aux. nr. 3		0.0200	11.32	2.56	0.03	127
86	83	Circuit P.A. 3 oriz. 475		0.0172	8.66	1.29	0.01	49
86	87	Circuit P.A. 3 oriz. 475		1.1619	0.58	0.58	0.00	1
87	88	Circuit P.A. 3 oriz. 475		0.2404	2.07	1.03	0.00	9
88	89	Circuit P.A. 3 oriz. 475		1.1619	0.58	0.39	0.00	1
89	91	Circuit P.A. 3 oriz. 475		1.1620	0.58	0.39	0.00	1
89	89	Circuit P.A. 3 oriz. 475		0.3846	0.84	0.27	0.00	1
90	92	Circuit P.A. 3 oriz. 475		2.1311	0.26	0.14	0.00	0
91	92	Circuit P.A. 3 oriz. 475		0.2098	1.81	0.89	0.00	5
92	119	Circuit P.A. 3 oriz. 475	DD	0.3845	0.84	0.27	0.00	1
93	94	Gal. transv. oriz. 475		210.0000	2.65	1479.68	3.93	17207
93	94	Circuit P.A. 3 oriz. 350		1.6255	0.83	1.11	0.00	4
94	95	Circuit P.A. 3 oriz. 350		0.0597	7.94	3.87	0.03	126
94	95	Circuit P.A. 3 oriz. 350		1.6255	0.83	1.11	0.00	4
95	96	Circuit P.A. 3 oriz. 350		1.1532	0.83	0.79	0.00	3
96	97	Circuit P.A. 3 oriz. 350		0.9600	0.83	0.66	0.00	2
97	98	Gal. leq. P.A. 3 oriz. 350	DD	0.0782	8.66	5.72	0.05	217
98	99	Gal. transv. oriz. 350		4.2770	8.66	321.02	2.78	12182
99	100	Circuit P.A. 3 oriz. 350		0.2806	9.90	21.05	0.16	790
100	103	Circuit P.A. 3 oriz. 350		0.0183	7.43	0.90	0.01	29
100	101	Statie trafo oriz. 350		0.1960	1.24	0.30	0.00	2
101	102	Statie trafo oriz. 350		0.1961	1.24	0.30	0.00	2
102	103	Statie trafo oriz. 350		0.1960	1.24	0.30	0.00	2
103	104	Circuit P.A. 3 oriz. 350		0.0924	9.90	9.05	0.09	392
104	105	Circuit P.A. 3 oriz. 350		0.0394	6.03	1.43	0.01	38
104	106	Statie trafo oriz. 350		0.0930	3.87	1.39	0.01	24
105	122	Plan trans. panou SA		0.1638	6.17	6.24	0.04	169
106	105	Plan leq. siloz nr. 15		1.7793	0.14	0.04	0.00	0
106	107	Plan leq. siloz nr. 15		0.6371	3.73	8.85	0.03	145
107	108	Gal. leq. siloz nr. 15		1.6488	4.57	34.42	0.16	689
108	109	Gal. leq. Pan. 6		0.3864	4.57	7.65	0.03	153

Fig. 9. Output data Branches

3D-CANVENT-2K
File: E. M. LIVEZENI 2010 baza - Fan Results

Fan Name:	Branch From:	To:	Pressure (Pa):	Quantity (m ³ /s):	Air Power (KW):	Cost (\$):
V 1 E- VAD 2.1 - 20q	191	192	1408.37	31.38	44.11	193198
V2PA2- VOD2.1-25q	194	195	2123.90	42.35	89.98	394009

Fig. 10. Output data fans

Analyzing the ventilation network of Livezeni mine, as well as of the data presented in fig. no. 9, mainly resulted in the following aspects:

- Under the action of the main ventilation Station East, ventilation shafts and Ventilation Station no. 2, a fresh air flow of 53.89 m³/s or 3233.4 m³/min is introduced underground, distributed as follows:
 - oriz. 300: 42.47 m³/s (2548.2 m³/min).
 - oriz. 350: 8.74 m³/s (524.4 m³/min).
 - oriz. 475: 2.68 m³/s (160.8 m³/min).
 TOTAL ENTRY: 53.89 m³/s (3233.4 m³/min).
- Under the action of the depression created by the main ventilation stations, a polluted air flow at mine level is 53.88 m³/s or 3232.8 m³/min and is evacuated from the underground, distributed as follows:
 - Main ventilation station East Ventilation Shaft: 17.80 m³/s (1068 m³/min).
 - Main ventilation station Ventilation Shaft No. 2: 36.08 m³/s (2164.8 m³/min).
- The air flow achieved at the level of the main fans was of 70.89 m³/s or 4253.4 m³/min, distributed as follows:
 - Main ventilation station East Ventilation Shaft: 28.08 m³/s (1684.8 m³/min).
 - Main ventilation station Ventilation Shaft No. 2: 42.81 m³/s (2568.6 m³/min).
- The flow of short-circuited air with the surface at the level of the main ventilation Station East Ventilation Shaft was 10.28 m³/s (616.8 m³/min), and at the level of the main ventilation station Ventilation Shaft No. 2 was 6.72 m³/s (403.2 m³/min).

In fig. 11 and 12 (fan no. 1, Main Ventilation Station Shaft Est), fig. 13 and 14 (fan no. 2, Main Ventilation Station Shaft Est), fig. 15; 16 and 17 (fan no. 1, Main Ventilation Station Shaft no. 2) and fig. 18; 19 and 20 (fan no. 2, Main Ventilation Station Shaft no. 2) are presented the characteristic curves related to the four fans and the resistance curve of the ventilation network at which they operate as a result of solving the mine aeration network Livezeni, by using the 3D-Canvent program.

Fig. 11. Shaft East, V1, VAD 2.1, $\alpha = 15^\circ$

Fig. 13. Shaft East, V2, VAD 2.1, $\alpha = 15^\circ$

Fig. 12. Shaft East, V1, VAD 2.1, $\alpha = 20^\circ$

Fig. 14. Shaft East, V2, VAD 2.1, $\alpha = 20^\circ$

Fig. 15. Shaft nr. 2, V1, VOD 2.1, $\alpha = 20^\circ$

Fig. 18. Shaft nr. 2, V2, VOD 2.1, $\alpha = 20^\circ$

Fig. 16. Shaft nr. 2, V1, VOD 2.1, $\alpha = 25^\circ$

Fig. 19. Shaft nr. 2, V2, VOD 2.1, $\alpha = 25^\circ$

Fig. 17. Shaft nr. 2, V1, VOD 2.1, $\alpha = 30^\circ$

Fig. 20. Shaft nr. 2, V2, VOD 2.1, $\alpha = 30^\circ$

The last column of fig. no.9 presents the annual cost of air circulation on each branch of the ventilation network (at an average price of 0.287 lei/kWh), highlighting the following:

- The annual cost of air circulation on the East Ventilation Shaft is 28,065 lei;
- The annual cost of air circulation on the Ventilation Shaft No. 2 is 39,550 lei;
- The annual cost of air circulation at the level of the two East ventilation shafts and ventilation shafts no. 2 is 67,615 lei;
- The annual cost of air circulation on the ventilation plans 15 layer Respectively Stanca is of 1,997 lei respectively 145,332 lei;
- In the case of the ventilation channel of the East Ventilation Shaft, it is of 29,653 lei and on the air short circuit a value of 86,498 lei was registered;
- In the case of the ventilation channel of the Ventilation Shaft No. 2 a value of 45,852 lei was registered and on the air short circuit a value of 114,936 lei was registered.

At the level of the main ventilation station Ventilation Station Shaft Est, the annual cost of air circulation was 265,948 lei, and at the level of the Ventilation Station Ventilation Shaft nr. 2, the annual cost of air circulation was 777,751 lei.

5. Conclusions

For the modeling and solving of the ventilation network of Livezeni mine, which has a high degree of complexity, the method of the iterative technique and that of the successive approximations was used, which is the basis of the program for solving the 3D-CANVENT ventilation networks.

When drawing up the single-wire ventilation scheme related to the mine, the topographic plans for each horizon were used, on the basis of which the nodes and the branches of the networks were established, resulting in a number of 201 nodes and 267 branches.

The 3D - CANVENT program simulates the ventilation systems in operation by taking into account parameters such as: air flows and their distribution in the network, frictional pressure losses, fan performance, energy required for air circulation and the costs involved mining work in the ventilation process.

The elements necessary for running the program, which constitute input data, result from the ventilation monitoring activity, respectively flow and depressiometric measurements performed in underground.

Based on the processing of the results obtained from the measurements performed, the ventilation network of Livezeni mine was modeled and solved. The modeling took into account the distribution in size and direction of flow of air currents.

For the economic characterization of the ventilation process of Livezeni mine, an average energy price of 0.287 lei / kWh was taken into account in the initial phase.

Under the action of the depression created by the main ventilation installations, a polluted air flow at mine level of 53.88 m³/s or 3232.8 m³/min is evacuated from the underground;

The annual cost of air circulation in the initial phase at the level of the main ventilation station ventilation shaft Est the annual cost of air circulation was 265,948 lei, and at the level of the main ventilation station ventilation shaft nr. 2, the annual cost of air circulation was 777,751 lei.

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