INCD INSEMEX PETROSANI

UNIVERSITY OF PETROSANI

LABOUR INSPECTION

INTERNATIONAL SYMPOSIUM

OCCUPATIONAL HEALTH AND SAFETY

SESAM 2017

-8TH EDITION-

MINISTRY OF RESEARCH & INNOVATION

ACADEMY OF ROMANIAN SCIENTISTS

PROCEEDINGS OF THE SYMPOSIUM

VOL II

BUCHAREST, ROMANIA

SIMPOZION INTERNAŢIONAL INTERNATIONAL SYMPOSIUM

SECURITATE ŞI SĂNĂTATE ÎN MUNCĂ

OCCUPATIONAL HEALTH AND SAFETY

SESAM 2017

Ediţia a VIII-a
8th Edition

LUCRĂRILE SIMPOZIONULUI
PROCEEDINGS OF THE SYMPOSIUM

Vol. 2

NATIONAL INSTITUTE FOR RESEARCH AND DEVELOPMENT IN MINE SAFETY AND PROTECTION TO EXPLOSION - INSEMEX

Trade Registry No. J20/1504/1992, VAT number: RO 2664676, Petroşani, G-ral Vasile Milea Street, no.32-34, Hunedoara county Postal Code 332047, Phone: 0254 / 541.621 / 541.622, FAX 0254 / 546.277, IBAN code RO 28 RNCB 0165020175140015

E-mail: insemex@insemex.ro; http://www.insemex.ro

ROMANIA

BUCHAREST, ROMANIA
2017

ORGANIZERS

INCD INSEMEX PETROŞANI
UNIVERSITY OF PETROŞANI
LABOUR INSPECTION

Printed:

ISSN 1843 - 6226

DATABASES, AN IMPORTANT TOOL FOR MANAGING CHEMICAL RISKS 235
Maria HAIDUCU, Raluca Aurora ȘTEPA, Elena Ruxandra CHIURTU, Ellen SCHMITZ-FELTEN

RESEARCH ON DEVELOPING NEW TESTING METHODS FOR RESPIRATORY PROTECTION EQUIPMENT 242
Cosmin ILIE, George Artur GĂMAN, Daniel PUPĂZAN, Alin IRIMIA, Andrei GIREADĂ

PERSPECTIVES OF THE DEVELOPMENT OF SUSTAINABLE TOURISM IN THE GEOGRAPHICAL AREA OF HUNEDOARA COUNTY 249
Mirela ILOIU, Diana Cornelia CSIMINGA, Sorin Iuliu MANGU, Sorin Radu ILOIU

USE OF DRONES IN SUPPORT OF RESCUE INTERVENTIONS 259
Alin IRIMIA, George Artur GĂMAN, Daniel PUPĂZAN, Cosmin ILIE, Andrei GIREADĂ, Lorand TOTH

NEW PERSPECTIVES OF THE RELATIONSHIP BETWEEN OCCUPATIONAL SAFETY AND HEALTH AND ERGONOMY 268
Sabina IRIMIE, Aurel MANOLESCU, Constantin LUPU

GREEN INFORMATION TECHNOLOGIES (GIT) WITHIN MODERN ENTERPRISES – AN EXPLORATORY STUDY 278
Claudia ISAC, Codruța DURA, Imola DRIGĂ

IMPROVING THE TECHNICAL AND QUALITATIVE LEVEL FOR PYROTECHNIC ARTICLES TESTING IN VARIABLE CONDITIONS OF MICRO CLIMATE 288
Ilie Ciprian JITEA, Gabriel Dragoș VASILESCU, Attila KOVACS, Daniela Carmen RUS

RESEARCH ON THE MODERNIZATION OF THE TEST METHOD FOR NON-SPARKING MATERIALS INTENDED FOR USE IN EXPLOSIVE ATMOSPHERES 294
Adrian Marius JURCA, Emilian GHICIOI, Florin PĂUN, Dan GABOR, Leonard LUPU

EXPLOSION-PROOF FANS CATEGORY 1G AND M1 302
Gerard KAŁUŻA

INTEGRATED SIGNALING AND COMMUNICATION SYSTEM IN FORESEEABLE RISK EXPOSURE SITUATIONS SPECIFIC TO EXPLOSIVE MATERIALS IN INSEMEX TEST CAMP 315
Attila Kovacs, Gabriel Dragos VASILESCU, Sorina STĂNILĂ, Emilian GHICIOI, Daniela Carmen RUS, Ilie Ciprian JITEA

PSYCHOLOGICAL TRAINING PROGRAM FOR INTERVENTION AND RESCUE PERSONNEL IN TOXIC / FLAMMABLE / EXPLOSIVE ENVIRONMENTS 323
Izabella KOVACS, George Artur GĂMAN, Daniel PUPĂZAN, Cosmin ILIE, Andrei GIREADĂ

STUDY ON EXPOSURE OF WORKERS TO INHALABLE WOOD DUST 333
Marius KOVACS, Angelica CĂLĂMAR, Lorand TOTH, Sorin SIMION

THE IMPACT OF THE PISTON EFFECT ON THE TECHNOLOGICAL CHARACTERISTICS OF VENTILATION IN THE SUBWAY TUNNELS 342
Omar LANCHAVA, Nicolae ILIAȘ, Giorgi NOZADZE, Sorin Mihai RADU, Roland MORARU, Zaza KHOKERASHVILI, Nino ARUDASHVILI

OCCUPATIONAL STRESS IN GAS TRANSPORT INDUSTRY 352
Raluca Maria IORDACHE, Viorica PETREANU, Doru Costin DARABONT

THE IMPACT OF THE PISTON EFFECT ON THE TECHNOLOGICAL CHARACTERISTICS OF VENTILATION IN THE SUBWAY TUNNELS

Omar Lanchava [1*,2], Nicolae Ilias [3], Giorgi Nozadze [1], Sorin Radu [3], Roland Moraru [3], Zaza Khokerashvili [2], Nino Arudashvili [2]

[1] Gr.Tsulukidze Mining Institute, 0186, No7, Mindeli Street, Tbilisi, Georgia

[2] Georgian Technical University, 0177, No77, Kostava Street, Tbilisi, Georgia

[3] University of Petrosani, No20, Universitaria, Petrosani, Romania

Abstract

Among the technological characteristics of the ventilation caused by the piston effect of the trains' motion, are the following flows: air flow ahead of the train, backflow through annular space between perimeters of train and tunnel, direct air flow after the train. By means of these flows possible to determine the air flow rate and konsumption that originate through piston effect. The work contains the results of computer modeling of the piston effect in the subway tunnels. Tables and graphs of the changes of the above-mentioned variables are presented depending on the length of the train and tunnel, on the area of their cross sections, on the equivalent radius of the tunnel, on the filling factor the tunnel with the train and in according to other important indicators. The obtained results have been compared with known analogous data from literature sources. There is good agreement between the main results presented here and with known general patterns. It is shown that due to the specificity of the subway, the piston effect caused by the train movement is non-stationary and the speed of the generated air flow does not stabilize for the entire period of train traffic between neighboring stations.

Keywords: piston effect, computer modeling, air flow ahead of the train, backflow, through annular space, direct air flow after the train, consumption of ventilating air.

1. Introduction

* **Omar Lanchava**: E-mail: o.lanchava@yahoo.com , iliasnic@yahoo.com

The air resistance of the train on the open track and in the tunnel, as well as the straight and reverse air flows in the tunnels, always caused a great interest from the point of view of the optimal design of the ventilation systems of rail tunnels and metro. In particular, these problems include works [1, 2, 3] which do not lose their significance along with other new studies in which modern computer methods for studying fluids are widely used.

In recent years many papers have been published on the piston effect, the piston effect in subways has become a topic of interest for researchers and engineers. This can be seen at least with a cursory revision of the bibliography of work [4]. Researchers and engineers are interested in different aspects of the manifestation of the piston effect in underground mine workings, railway tunnels and in tunnels of the metro. This refers to both the reduction of air resistance in order to save electricity on traction of rolling stock, and to various manifestations of the piston effect in order to develop optimal ventilation systems taking this factor into account.

In the paper [5], full-scale experiments on evacuation during fires were scheduled, and various means for alerting people were tested. Computer modeling of various scenes of fire under the ground was also performed. Exclusive data, particularly valuable in evacuation analyses of underground transportation systems, was retrieved and has filled a great gap of knowledge in the field of tunnel evacuation. In essence, the participants moved with an average speed of 0.9 meters per second in the smoke filled environment (average visibility of 1.5-3.5 meters). Among the new results of this work, it should be noted that a way-finding installation at the emergency exit, which consisted of a loudspeaker, was found to perform particularly well in terms of attracting people to the exit doors.

2. Modeling, discusion and results

The modern level of computer technology development allows for the dynamics of ventilation flows in the subway tunnels with a high accuracy to describe through numerical simulation of fluids. The paper discusses the nature of distribution of ventilation flows caused by the piston effect in metro tunnels which significantly affect the ventilation parameters of subway. The problem was posed for conditions of the tunnels of Tbilisi Metro, the base models were made by the following data: length of tunnel - 1200 m; Area of the tunnel cross section - 16 m^2, length of train - 80 m; Train speed - 10.0; 12.0; 15.0 m/s; Acceleration of the train - 1.0-1.2 m/s^2; The cross section of the train cross section - 4.00; 5.00; 6.25 m^2. Modeling and calculations were performed in the PyroSim 2016 software environment.

In the framework of the grant work, it was planned to study the dynamics of ventilation flows caused by the piston effect in the tunnels of the metro, which affects on the determination of ventilation parameters underground spaces. The purpose of the research was to demonstrate on the basis of numerical experiments that the characteristics of the air parameters in the tunnel depends with different kinetic parameters of the moving train.

In numerical tasks, for determining aerodynamic parameters of underground processes, in one of the tunnels between the stations was given a counter-current air with a mean speed of 6.0; 8.0; 10.0 and 12.0 m/s.

On the fig. 1 show a diagram of a moving train with speed V_0. At section 0-1 of the tunnel is formed air flow ahead of the train with speed C. By means of piston effect of moving train at the section 2-0 of the tunnel originates air flow after the train with similar speed C. In the annular space between perometers of train and tunnel takes place backflow with the speed W. The value of velocity Wdepends on the difference in dynamic pressures between first and last vagons of the train. The magnitude of the marked speed is also affected by the ejection of air due to the motion of the train, as well as the friction between the return flow of air and air in the space between the wagons. The air cushion between the wagons intensively circulates and aerodynamically interacts with the main return flow.

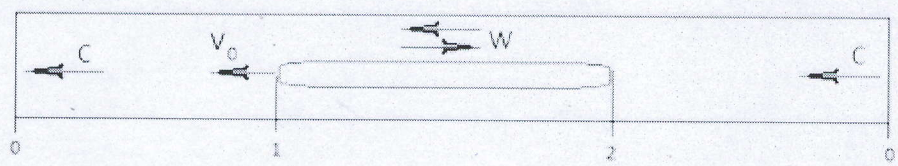


Fig. 1. The scheme fo absolute speeds in case of train movement in the tunnel:

V_0 - the speed of the train movement; C - the speed of air flow caused by the piston effect at the front and rear of the train; W- backflow through the annular space

Depending on the specific values of the above factors, the vector of velocity W may be directed towards the train movement as well as its opposite direction.

On the fig. 2 shows one of the results of modeling, from which it can be seen that the train movement starts with the collision to the air flowing stream, which is characterized by the dynamic pressure of 86.4 Pa. Between first and last wagons of the train takes place pressure fluctuation that does not stabilize even after 250 seconds and a pronounced nonstationary process is observed here. For the initial moment ($\tau = 0$ s) of the time, the different of the pressure is 6.4 Pa, which is steadily rising, and after τ =250 secund is approximately 41 Pa.

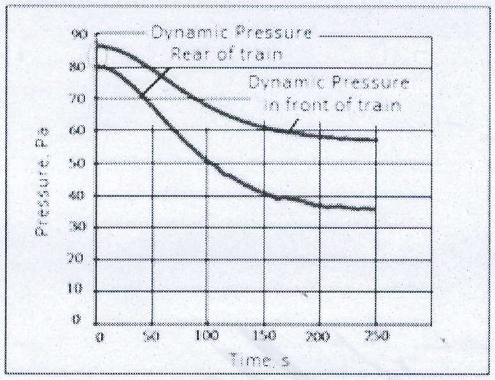


Fig. 2. The changing of dynamic pressure between first and last vagons of the train according to results of computer modeling

Thus, for the conditions of Tbilisi Metro, in the space between perimeters of the train and the tunnel, takes place pressure different and the resulting ventilation flow with the speed W is in the opposite direction of the train movement, as on the firs wagon is more pressure than on the last wagon. The other mentioned reasons in the originate of backflow through annular space, are insignificant. In adition, in according to the numerical value of the tunnel filling coefficient α that were used by modeling the air movement for subway conditions are mainly in the opposite of the traffic direction.

The tunnel filling coefficient can be calculated using the formula

$$\alpha = \frac{F}{f} \qquad (1)$$

Where, F - area of the wagons cross section, m^2; f - cross section of the tunnel, m^2.

The variation of the tunnel filling coefficient for the conditions of Tbilisi metro is in the range $\alpha = 0.25 - 0.50$, and the computer modeling was carried out for value $\alpha = 0.25$.

Consider the relative motion of air, provided that the train will not be in motion and only air flow will move, according to which computer modeling was conducted. The speeds scheme, which were modeled, is shown in fig. 3.

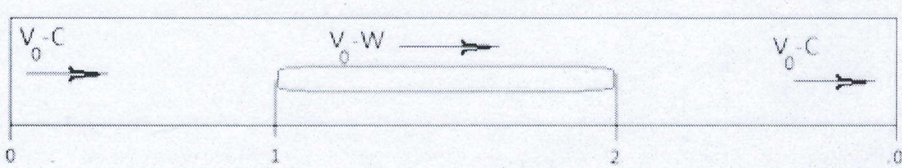


Fig. 3. The scheme of relative speeds in case of stopped train:

V_0-C- the speed of the oncoming flow ahead of the train (the simmilar value has the flow speed in rear part of the train); V_0-C - the relative speed of backflow through annular space

The velocities noted satisfy by formula

$$V_T = V_0 - C \qquad (2)$$

Where V_T - the speed of the oncoming flow ahead of the train, m/s; V_0 - train movement speed, m/s (km/h); C - the speed of air flow caused by the piston effect at the front and rear of the train, m/s.

In the case of a stopped train, the air velocity in the annular space can be determined from formula

$$V_G = V_0 - W \qquad (3)$$

Where V_G - stream speed in the annular space, m/s. The remaining values have already been determined.

Based on the continuity equation we can write

$$V_T f = V_G (f - F) \qquad (4)$$

From which by means of simple transformations and with consideration formula (1) is obtained

$$V_G = \frac{V_T}{(1-\alpha)} \qquad (5)$$

Relationship between the speed of the oncoming flow V_T and the speed of the train V_0 was examined for rail tunnels by G.N. Abramovich [1]. The railway tunnels with length differ from the subway tunnels, by which the process shown on the fig. 2 is stabilized in them. The most important studies of Abramovich have also differed from the results presented here by observing the real train on aerodynamic pipe with appropriate geometric and dynamic scales. Relationship between these velocities is given in [1] as follows

$$\frac{V_T}{V_0} = \frac{1}{1 + \dfrac{1}{(1-\alpha)\sqrt{\xi_T \dfrac{f}{F_e} \dfrac{1-\alpha}{1+0.004n\dfrac{S_w}{F_e}}}}} \qquad (6)$$

The following indications are in the formula (6) : ξ_T - The tunnel full resistance coefficient in according for: the length of the tunnel (l, m), the length of the train (L, m) and the equivalent radius of the tunnel (R, m); F_e - equivalent area of the wagon, m^2; n - number of wagons in the composition; S_w - the surface area of the wagon excluding the bottom area, m^2.

The tunnel resistance complete coefficient is calculated using a formula

$$\xi_T = 1.5 + 0.007\frac{l - L}{R} \qquad (7)$$

All of the input symbols in formula (7) have already been interpreted.

The equivalent area of the wagon is calculated by taking into account the value of the frontal resistance coefficient with the following formula

$$F_e = c_w F \qquad (8).$$

Where c_w - the frontal resistance coefficient of the wagon.

The air consumption originated by means of piston effect can be determined by a formula

$$Q = Cf \qquad (9)$$

Where Q - air consumption, m^3/s.

The terms of our model are consistent with the following values: the area of the train midway cross section - F = 4 m^2; the area of cross section of the tunnel - f = 16 m^2; perimeter of the tunnel - P = 16 m; the equivalent radius of the tunnel - $R = f/P$ = 1 m; length of the tunnel - l = 1200 m; length of the train - L = 80 m; the tunnel full resistance coefficient - $\xi_T = 9.34$; the frontal resistance coefficient of the wagon - c_w = 0.95; equivalent area of the wagon - F_e = 3.8 m^2; number of wagons in the composition of the train - n = 4; the surface area of the wagon excluding the bottom area - S_w = 72 m^2.

The speed of the oncoming flow V_T is a preset value according to the simulation conditions. By the formula (6) determines relationship between with the oncoming flow and the speed of the train, which is the unchanged size for the given specific values of the tunnels and train. In our conditions, in case of a 4-car train $V_T/V_0 = 0.781$, and in case of 5-car trains - $V_T/V_0 = 0.776$, from which the speed of train is determined. The following formula (2) determines the speed of air flow ahead of the train C originated with the piston effect, by formula (9) - air expenditure initiated by the piston effect Q, and with the formula (5) - stream speed in the annular space V_G. Thus, there is possible theoretically determine all the technological indicators that are interesting for ventilation, with presented material at the case of train movement in the tunnel. Calculating of numerical values, when the train consists of 4 wagons, is included in Table 1.

Table 1. Air flow indicators that were originated with a 4-car train piston effect

V_T, m/s	V_0, m/s (km/h)	V_G, m/s	C, m/s	Q, m^3/s
6.0	7.68 (27.6)	8.0	1.68	26.9
8.0	10.24 (36.8)	10.7	2.24	35.8
10.0	12.80 (46.1)	13.3	2.80	44.8
12.0	15.36 (55.3)	16.0	3.36	53.8

For the given initial and boundary conditions were performed numerical modeling on the left entrance when the speeds of the oncoming flow ahead of the train equils V_T = 6.0, 8.0, 10.0, 12.0 m/s.

The train's first carriage was located in the subway tunnel at different distance of the portal. As a shows on the fig. 4 that this distance is 200, 300 and 400 m. Ventilation flow rate, as follows from fig. 4, was measured at different points of the tunnel. A more detailed scheme of the experiment with the train and detectors of speed is given on the fig. 5.

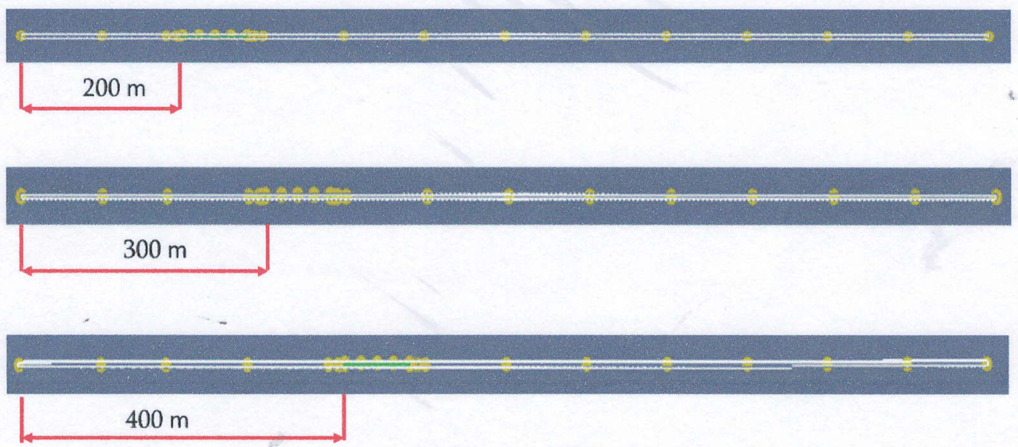


Fig. 4. The layout of the train and detectors of speed during numerical modeling: the points show the speed detectors

As shown from the figures numerical modeling have been performed in the tunnel for the 5 different zones selected in advance according to the location of the train. In the above zones the nature of the changing velocity flow was determined. In each zone the speed detectors were distant from each other in different distance. For example, in the first and fifth zone detectors have been placed at every 100 meters (see Figure 5: Zones 1 and 5). In the second and fourth zones, at ahead and rear of the train on the length 20 m of the tunnel, the detectors were separated from each other by 5 m (see Figure 5: Zones 2 and 4). The speed detectors in annular space were deployed at each 20 m (see Figure 5: Zone 3).

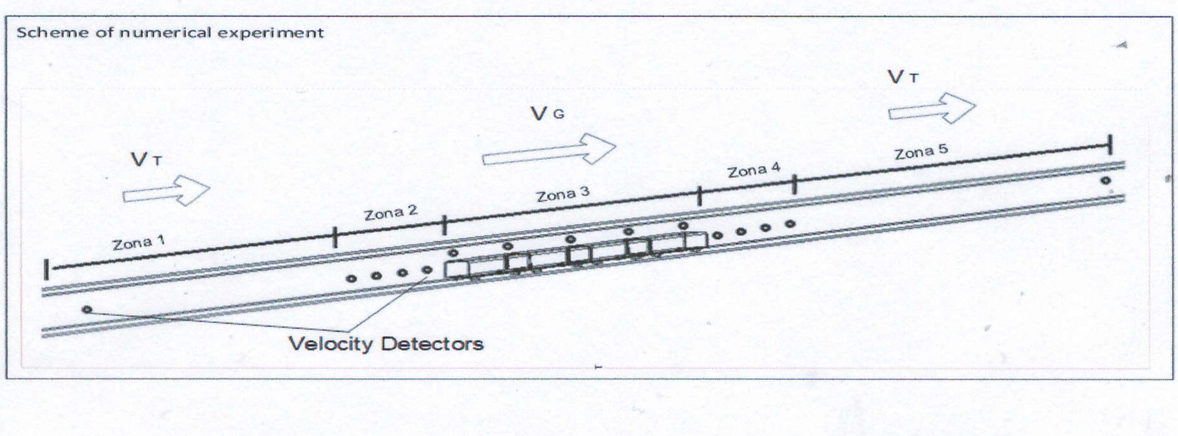
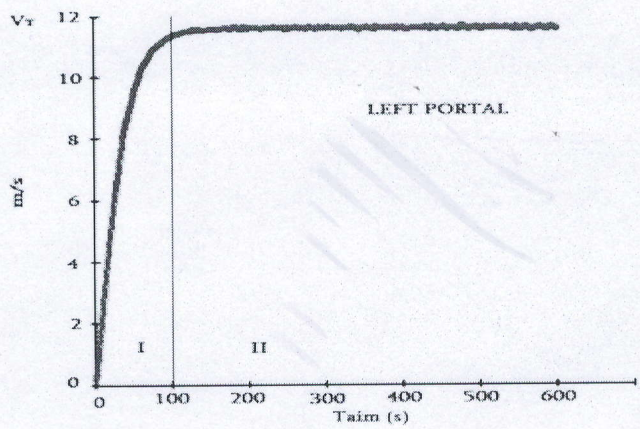


Fig. 5. Detailed scheme of numerical experiments by zones

It is also noteworthy that the Reynolds number for the metro and other transport tunnels is great and so we have a strongly developed turbulent movement in the subway tunnels, even with the relatively low speed of air movement.



Dynamics of the speed of oncoming flow ahead of the train for the left portal when its maximum value is 12 m/s

$$Re = \frac{\rho V L}{\mu} \gg 3000 \quad (10)$$

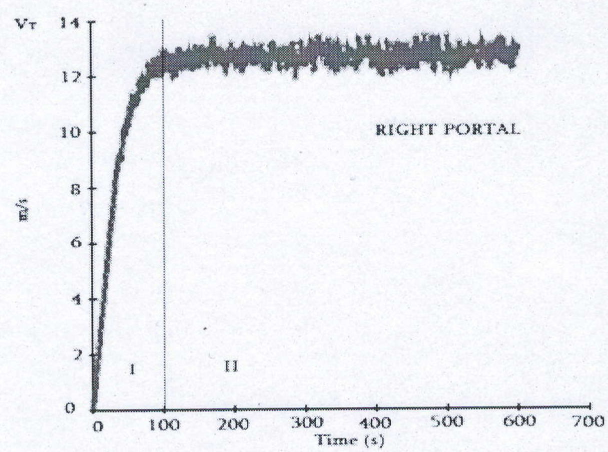


Fig. 6. Dynamics of the speed of oncoming flow ahead of the train for the right portal when its maximum value is 12 m/s

Changing the boundary value of the of the speed of oncoming flow ahead of the train in numerical experimentation have been carried out according to the development of dynamic pressure and its variation. The results obtained can be analyzed by one of the numerical experiments. Consider the dynamical change rate of the flow speeds in tunnel portals, as well as in the annular space between the perimeters of tunnel and the train (Figures 6, 7 and 8).

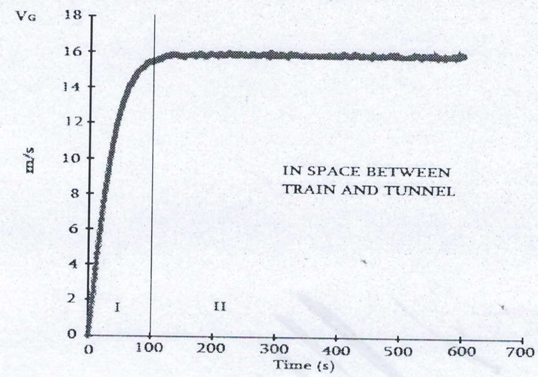


Fig. 7. Dynamics of the stream speed in the annular space when speed of oncoming flow ahead of the train is 12 m/s

From the presented data from the figures 6, 7 and 8 it is evident that the dynamics of flow flow can be divided into two phases: I - non-stationary and II - stationary. The duration of the non-stationary phase on these drawings is 100 seconds. This time is sufficient for the Tbilisi Metro's conditions in case of the average speed of train to cover the length of the tunnel between neighboring stations. The duration of the non-stationary phase changes in the range of 100-200 seconds according to the completed numerical models and it is possible to note that the field of speeds in the tunnels of Tbilisi metro is always non-stationary. On the drawings 6, 7 and 8 are presented results when the speed stabilization occurs on the edge of 100 seconds and then virtually unchanged for over 700 seconds, is more characteristic for the long of railway tunnels.

It is noteworthy that the results obtained from presented numerical experiments of the oncoming flow ahead of the train and stream speed in the annular space are in good agreementag with theoretically calculated values (see table 2).

Table 2. Comparison the results of numerical experiments and theory

N	The speed of oncoming flow (theory) V_T, m/s	The speed in the annular space (theory) V_G, m/s	The speed of oncoming flow (experiment) V_{T_EX}, m/s	The speed in the annular space (experiment) V_{G-EX}, m/s
1	6.0	8.0	5.45	7.50
2	8.0	10.7	8.00	10.80
3	10.0	13.3	10.00	13.50
4	12.0	16.0	12.00	16.00

As noted, by means of the speed of oncoming flow and by speed in the annular space can be calculated air speed of direct flow and air consumption generated by piston effect that are one of the main technological characteristics of the underground ventilation. Using the results of these researches should be taken into consideration that the piston effect caused by the train movement will work with the tunnel ventilation system in sequence mode. Due to this, the flow of the piston effect will be assisted the ventilation system or vice versa - will interfere with effective ventilation.

3. Conclusions

- In according to the specificity of Tbilisi Metro, which is due to the distance between the two neighboring stations, the piston effect process caused by the movement of the train is non-stationary and the speed of the generated air flow does not stabilize for the entire period of train traffic.
- Results presented in this work, obtained by numerical experiments, is in good agreement correspond to the theory given for the railway tunnels in appropriate literature.
- Based on the results obtained by the studies, the technological parameters of metro ventilation based on the piston effect of the moving train can be identified.

Acknowledgements

This work was supported by Shota Rustaveli National Science Foundation (SRNSF) [Grant number 216968, Project title "Prevention methods development against aerosol terrorism for ventilation of Tbilisi subway"].

References

G.N. Abramovich, (1939), *K raschetu vozdushnogo soprotivlenia poezda na otkritoi trasse I v tonnele*, Moscow, 1939, 32 p., (CAGI im. N.E. Jukovskogo. Trudi, vip. 400). (Г.Н. Абрамович. К расчету воздушного сопротивления поезда на открытой трассе и в тоннеле. Москва, 1939, 32 с., Труды ЦАГИ им. Н.Е. Жуковского, вып. 400).

G.N. Abramovich., (1969), *Prikladnaia gasovaia dinamika*, Moscow, Nauka, 1969, 824 p. (Г.Н. Абрамович. Прикладная газовая динамика. Москва, Наука, 824 с., 1969).

V.I. Tsodikov., (1975), *Ventiliacia I teplosnabjenie metro*, Moscow, Nedra, 1975, 568 p. (В.Я. Цодиков. Вентиляция и теплоснабжение метрополитенов. Москва, Недра, 1975.).

S. Pan, L. Fan, J.Liu, J. Xie, Y.Sun, N. Cui, L. Zhang, B. Zheng, (2013), *A Review of the Piston Effect in Subway Stations*, Hindawi Publishing Corporation, Advances in Mechanical Engineering, Volume 2013, Article ID 950205, 7 pages. http://dx.doi.org/10.1155/2013/950205.

H. Ingason, M. Kumm, D. Nilsson, A. Lönnermark, A. Claesson, Y.Z. Li, K. Fridolf, R. Åkerstedt, H. Nyman, T. Dittmer, R. Forsén, B. Janzon, G. Meyer, A. Bryntse, T. Carlberg, L. Newlove-Eriksson, and A. Palm, (2012), *The METRO Project*, Report, Mälardalen University, 2012