USABILITY OF THERMAL CAMERAS IN MONITORING PEOPLE IN A SMOKED ENVIRONMENT

Ladislav JÁNOŠÍK[1], Šárka BERNATÍKOVÁ[2]

Research article

Abstract: The article presents results from the use of a thermal camera in experimental monitoring people in a smoked environment during exercise tests under heavy conditions in gas-tight chemical protective clothing. Experiments were carried out on the ground of former barracks, at present the training ground of Fire and Rescue Service of the Vysočina Region in Jihlava. The article describes the place and the procedure of the experiment, gas-tight chemical protective clothing and a range of usage of the thermal camera. Measured values of temperature field are stated and discussed. In the conclusion, recommendations for measurements using the thermal camera in further experiments, aimed at acquiring more accurate knowledge of external manifestations of strain on firefighters when using gas-tight clothing, are presented.

Keywords: Experiment, temperature field, temperature, gas-tight clothing, thermal camera.

Introduction

According to the data published by the Directorate General of Fire and Rescue Service of the Czech Republic (Ministry of the Interior, 2013), in 2008 - 2012 in the Czech Republic altogether more than 5 570 interventions associated with releases of dangerous chemicals occurred annually on an average; the minimum being 5 106 interventions in the year 2012 and the maximum being 6 242 interventions in the year 2008. Of this, 4 570 interventions on an average were associated with releases of oil products. Differences between the stated averages furnish us with the number of interventions with potential to introduce gas-tight chemical protective clothing as the highest level of firefighter's protection. Firefighters wearing clothing of this type are exposed to increased physical strain represented by growing temperature and moisture in a gas-tight layer under the clothing, and last but not least, by decreased ability to orientate themselves due to a reduced field of vision. All this can make the rescue of persons, mainly inside the building, as well as the successful intervention in the case of release of a dangerous substance more difficult.

For rapid and safe coping with extraordinary events in general, not only in enclosed space, firefighters are to be systematically prepared (Polakovič et al., 2009). A suitable way is practical training in conditions that simulate as best as possible real conditions of interventions (Murphy et al., 2005). Testing buildings for training in coping with releases of dangerous substances are there in the School and Training Facility of the Fire and Rescue Service of the Czech Republic, namely in the Brno and Frýdek-Místek Centres. These serve especially training in stopping the release of a dangerous substance, largely in the case of open technologies. In co-operation with members of Fire and Rescue Service of the Vysočina Region, the National Institute for Nuclear, Chemical and Biological Protection interconnected successfully, in the framework of security research of the Ministry of the Interior, a research project with training (Slabotinský et al., 2011).

Materials and methods

Experiments are to answer the questions concerning the behaviour of organisms being exposed to physical strains while wearing various types of chemical protective clothing. In the course of testing in July 2013, two types of firefighting and two types of military chemical protective clothing were used. Photos of them are there in Fig. 1. In the text below, the clothing is described briefly in the order as shown in Fig.1 from left to right.

[1] VŠB - Technical University of Ostrava, Faculty of Safety Engineering, Ostrava, Czech Republic, ladislav.janosik@vsb.cz
[2] VŠB - Technical University of Ostrava, Faculty of Safety Engineering, Ostrava, Czech Republic, sarka.bernatikova@vsb.cz

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Protective Clothing

OPCH-90 PO. One-piece, gas-tight, type 1a clothing providing high-level protection against environments dangerous to life that contain chemicals of unknown composition in liquid and gas phases, including aerosols. It is designed for use in combination with a breathing apparatus and a face mask, worn under the clothing. The manufacturer of the clothing is ECOPROTECT, Ltd., Zlín.

SOO CO. Gas-tight, type 1b clothing designed for the protection of user's body against the effects of poison war gases and biological substances and against radioactive surface contamination. It is a coverall; the base material being polyamide textile with a coat of special rubber (butyl rubber with a fire retardant) on both sides. The opening in the front of the hood is fitted with a rubber rim to seal a face mask CM 4.

FOP-96. Gas-tight, type 1b chemical protective clothing, used by the Army of the Czech Republic, consists of a jacket, trousers, rubber gloves, boots, suspenders. It is designed for body surface protection against vapours, aerosols and drops of chemical warfare agents, radioactive fallout and biologically active particles. The manufacturer of the clothing is B.O.I.S. - FILTRY, Ltd., Brno.

RST Demron. One-piece clothing obtained type 2 certificate according to NFPA 1994/2007. It provides protection against CBRN agents, toxic industrial chemicals, Alpha particles, X-radiation, gamma radiation, high-energy beta radiation and thermal stress. The manufacturer is the company Radiation Shield Technologies from the USA.

Fig. 1 Chemical protective clothing

Thermal Camera

For monitoring the temperature field and measuring the spatial temperature, i.e. quantities used for the description of natural and technical processes (Švec et al., 2008), an IR thermal camera ThermoPro TP8 from the manufacturer WuhanGuideInfrared Technology Co., Ltd., China was used. Its basic parameters are as follows:

detector	FPA 384 x 288 pixels
spectral band	8 - 14 μm
temperature sensitivity	0.08 °C at 30 °C
temperature range:	filter No. 1 -20 °C to +250 °C ±1 °C filter No. 2 +100 °C to +800 °C ±2 °C
emissivity correction	user-defined variably adjustable degree of emission from 00.01 to 1.00 (0.01 increments)
working conditions	temperature: -20 °C to +60 °C, moisture: 10 % to 95 % (without condensation)
image record	to the file of JPEG format, an IR image and a visible image are recorded; if set, voice and text comments as well.

The temperature range of filter No. 2 was used in monitoring the temperature field in flashover containers (Bernatíková et al., 2012). For measuring the data on temperature in selected places of measured protective clothing in the course of testing in Jihlava, filter No. 1 with a temperature range from 0 to 250 °C was used.

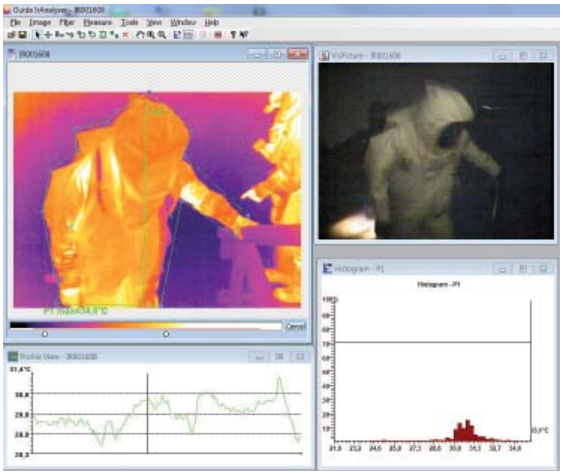

Fig. 2 Application of polygon in the analysis of temperature field

For the evaluation of measurement, the thermal camera offers several functions, of which are, in addition to the determination of temperature at a point, most frequently used the functions of automatic search for places having maximum and minimum temperatures, setting of up to 8 combinations of measurements in a form of areas (quadrangular, oval, polygonal ones), construction of a vertical or horizontal line of temperature profile, creation of a temperature histogram and isotherms in the image. Of the above-mentioned functions, the creation of a vertical line of temperature profile and the creation of a temperature histogram in the application of polygon are given as an example in Fig. 2. The application of polygon is used in case

that a certain area is to be analysed and separated from surrounding objects and/or subjects in the course of evaluation. In the observed delimited field, the maximum, minimum and calculated average temperatures are evaluated automatically.

Experimental monitoring took place from the 9th to the 11th July 2013. Testing was divided into the morning and afternoon parts and on the 10th July 2013 the night part (after 10 p.m.) to achieve reduced visibility.

Description of the Training Ground of Fire and Rescue Service of the Vysočina Region in Jihlava

The training ground is situated on the unused premises of former barracks. Training was executed in a building having the character of flat building with 3 floors and 1 basement storey; the ground area being 42 x 16 m. Fig. 3 shows a photo with a route of training. In the longitudinal axis of the building, a passage is there on each floor and along both sides of it, rooms are located. In the middle of the building, sanitary facilities are there (toilet, showers, bathroom). This building is connected with a former catering block which is connected with the main building by means of a passage with a ramp where the difference in level of the ends of the ramp is 1.2 m. The starting point of the route was a former dining hall. Here, a monitoring base of the whole experiment was situated.

Fig. 3 Training ground

Description of the Route of the Experiment

The total length of the route was about 770 m, the height difference between the second floor and the basement storey was about 10 m and the total ascent of the route was about 56 m. In a simplified fashion, the route can be described in the following steps.

1) Starting point of the route - dining hall.
2) Going up along the passage and subsequently the inclined plane (1.2 m difference in height) to the passage on the ground floor.
3) Going down to the basement storey (3.2 m depth), examination of rooms, going up to the ground floor, walk along the passage, again going down the other staircase to the basement storey and examination of rooms.
4) Going up to the first floor (6.2 m difference in height) and examination of all rooms on the floor.
5) Going up to the second floor (3 m difference in height) and examination of rooms on the floor, finding of two dummies, namely dummy No. 1 of 47 kg mass, dummy No. 2 of 61 kg mass.
6) Loading the dummy No. 1 on a stretcher, taking it down from the second floor to the basement storey, going up back to the ground floor, walk to the dining hall and putting the dummy away.
7) Return for the dummy No. 2 to the second floor, loading the dummy on the stretcher, taking it down to the basement storey, going up back to the ground floor, walk to the dining hall, putting the dummy away and ending the route.

Altogether, 10 experiments were carried out and the route was covered by reconnaissance teams of different numbers of members.

Probands

Probands were professional firefighters aged 27 to 45 from brigades of Fire and Rescue Service of the Vysočina Region. They were healthy and physically fit men who were familiar with action performed in chemical protective clothing of the types 1a, and 1b with a self-contained breathing apparatus. Testing was carried out on them when wearing OPCH-90 PO, SOO CO and FOP-95 clothing. RST Demron clothing was used by a volunteer outside testing. This test with a sequence number 6 took place in the afternoon on the 10th July 2013. The numbers of probands in test groups in specific days during experiments are presented in Tab. 1. In order to obtain an idea about time consumed by conducting the whole experiment, informative data on start of individual tests are given here. Test duration is given in a graph in Fig. 4.

Tab. 1 Distribution of probands

Date	9. 7. 2013			10. 7. 2013					11. 7. 2013	
Test No.	1	2	3	4	5	6	7	8	9	10
Start	10:49	12:07	15:49	10:48	14:41	16:09	22:03	23:02	10:03	13:41
Number of probands	4	2	4	4	4	3	4	2	4	4

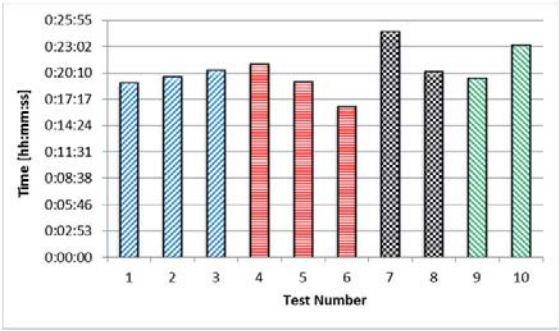

Fig. 4 Test duration

Results

Climatic conditions inside the building during the experiment were measured at the staircase on the first floor. Air temperature was about 24 °C, air humidity was about 55 %.

In the following figures, Figs. 5 to 12, results from the evaluation of the temperature field only from 8 selected experiments are presented owing to the prescribed extent of the article. These results were selected with regard to monitoring the same type of chemical protective clothing, namely OPCH-90 PO clothing.

Graphs show maximum temperatures on the surface of the chemical protective clothing during the experiment. Evaluation of the maximum temperature was done after completing the experiments using software IrAnalyser ver. AUS 2009-05-15_1 from the manufacturer of the thermal camera. This was carried out for each image separately. Mostly it was necessary to confront the automatically searched value with its position in the image to find out whether it belongs to the evaluated tester or the other participants in the experiment. For correction, the selected fields of a common polygon shape (see Fig. 2) were used. From the obtained temperatures, graphs were constructed in MS Excel. Furthermore, through the maximum values, a linear connected line of trend was put.

Values of minimum temperatures were taken as automatic result of measurement using the thermal camera. They represent the point of contact between the clothing and the breathing apparatus. In some cases, when these values could not be filtered owing to the low resolution of the thermal camera, they represent the temperature of surrounding building constructions. They represent the temperature of the surrounding building constructions or the point of contact between the clothing and the breathing apparatus. They do not have any influence on the evaluation of response of the organism of the proband.

Values of ambient temperatures are automatic data that characterise the temperature of the thermal camera in the given environment.

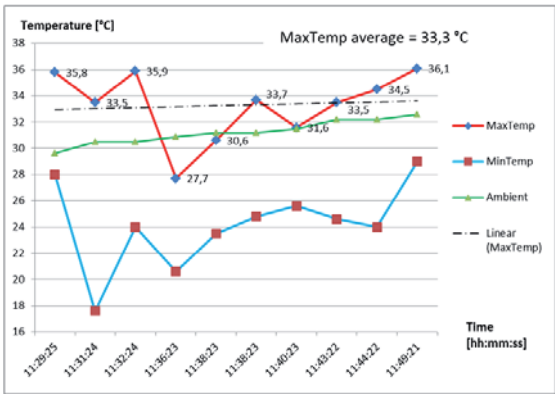

Fig. 5 Results of test No. 1 (9 July 2013 - morning)

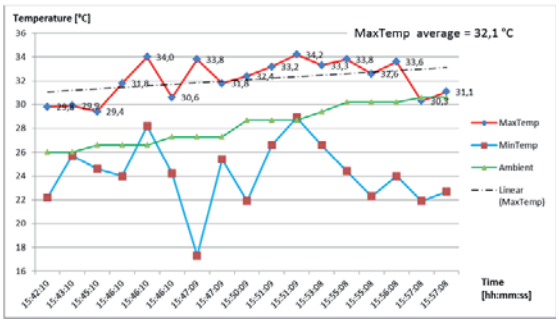

Fig. 6 Results of test No. 3 (9 July 2013 - afternoon)

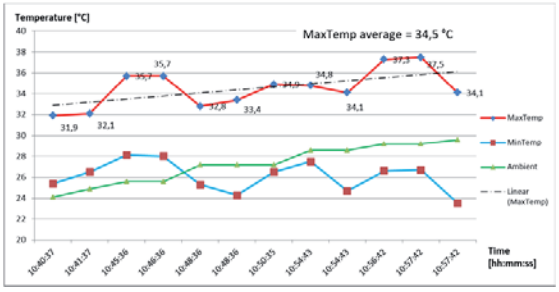

Fig. 7 Results of test No. 4 (10 July 2013 - morning)

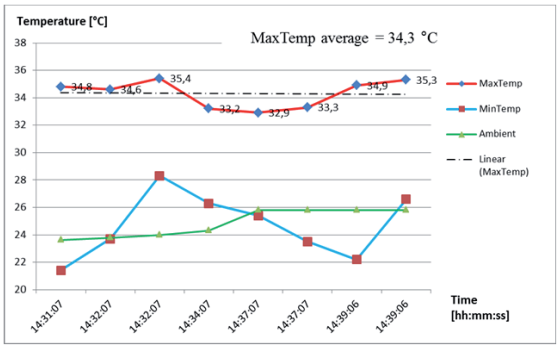

Fig. 8 Results of test No. 5 (10 July 2013 - afternoon)

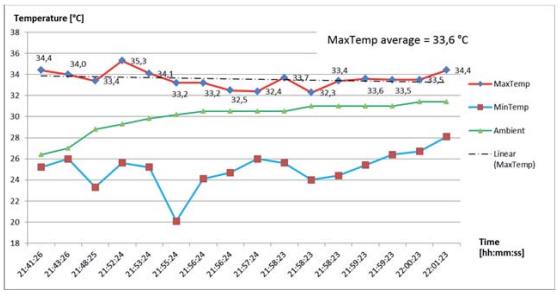

Fig. 9 Results of test No. 7 (10 July 2013 - night)

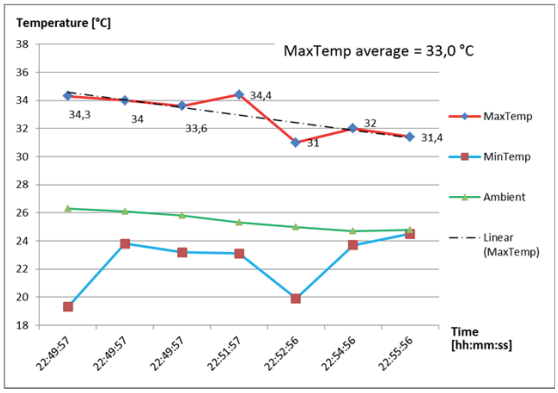

Fig. 10 Results of test No. 8 (10 July 2013 - night)

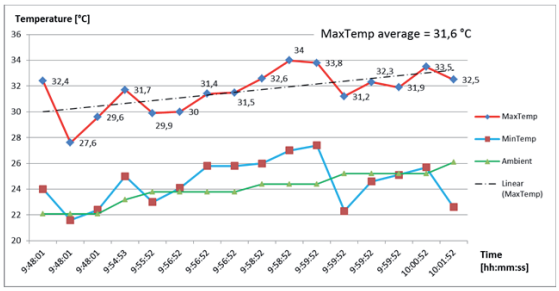

Fig. 11 Results of test No. 9 (11 July 2013 - morning)

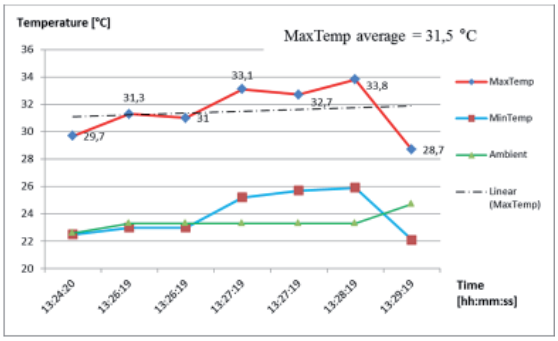

Fig. 12 Results of test No. 10 (11 July 2013 - afternoon)

From the measured values of maximum temperatures, averages in each test were calculated that are stated in graphs in Figs. 5 to 12. Their values are there in Fig. 13. The average maximum surface temperature of the chemical protective clothing from the selected tests is 33.0 °C.

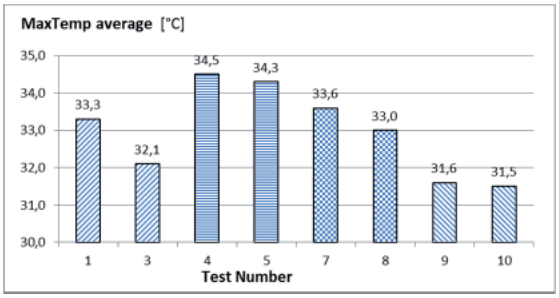

Fig. 13 Results of testing

Conclusion

The submitted results are burdened with uncertainties that are affected by the course and the demands of testing. If we wanted to eliminate these errors, it would be necessary to incorporate, in the framework of further experiments, a position for the thermal camera with the operator into the test. In the course of the test it would mean the following:

- to monitor only one selected tester (to make the evaluation of thermal images more accurate),
- to focus on specific clothing (to select critical points of the clothing with maximum and minimum values),
- to take only static images of the temperature field of the proband; best of all, from more sides.

The ideal thing for field measurement would be to get close, in the course of monitoring, to testing in laboratory conditions in a thermal chamber (Slabotinský et al., 2010). However, this cannot be achieved in real environments and testing of long duration. Just on the contrary, it would be interesting

to implement these tests in climatic conditions other than those in summer (temperature of +24 °C).

In the course of dynamic monitoring in a smoked building in night hours, with the use of the thermal camera but without the illumination of the site, orientation in the building was very difficult. For instance, the impossibility of making out the beginning of the staircase to the basement storey, corner and hand banister can lead, when passing through the building, even to an injury to the operator of the thermal camera.

The measured temperature fields and acquired values provide an initial idea of development in the maximum temperature on the surface of chemical protective clothing. This temperature can be, in the course of real intervention or training in an open space, the first external manifestation of excessive strain imposed on the intervening firefighter. Based on this information obtained by the thermal camera, the incident commander can carry out the correction for the length of firefighter's stay in the chemical protective clothing. Nevertheless, it is necessary to mention that development in the external temperature of the clothing surface will always be in relation with the ambient temperature.

Acknowledgments

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