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RESEARCH ARTICLE

APPLICATION OF NEW SOLUTIONS AIR SUPPLY TO A STANDARD OPERATING THEATRE, TWO-WAY LAMINAR CEILING PANEL

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ABSTRACT

The text is closely connected to another called, Airflow delineation modelling in a standard operating theatre". Negative effects on reverse flow in surgeries on the basis of applied measurement in practice using a mathemathical model of airflow delineation analysis. These airflows cause contamination of the operating area by particles coming from its surroundings, known as the self-contamination effect. Except for hygiene level 4 evaluation there is no operating standard for the theatre and its microclimating, let alone mandatory Czech legislation. In view of hygiene level evaluation in surgeries it is possible to use some of the methods set up for its design and operation. It is considered in the above-mentioned text among various standards at the section 54 as well for airflow profiles that shall not cause contamination of the protected room.

INTRODUCTION

The article deals with the idea and realization of a new method of supplying airflow to a standard operating theatre. The idea is the result of analyses of airflow delineation simulated by a mathemathical model, followed by its description and finally its application. The result is the production of a new end element for airflow supply known as the two-way laminar ceiling panel. In the conclusion is an evaluation of the the effeciency of the new element made on the basis of measuring particle concentration. The text is closely connected to another called, Airflow delineation modelling in a standard operating theatre. Negative effects on reverse flow in surgeries on the basis of applied measurement in practice using a mathemathical model of airflow delineation analysis. These airflows cause contamination of the operating area by particles coming from its surroundings, known as the self-contamination effect. Except for hygiene level 4 evaluation there is no operating standard for the theatre and its microclimating, let alone mandatory Czech legislation. In view of hygiene level evaluation in surgeries it is possible to use some of the methods set up for its design and operation. It is considered in the above-mentioned text among various standards at the section 54 as well for airflow profiles that shall not cause contamination of the protected room. The new large-area supply element has been designed for the elimination of the negative effect presented. There is a tendency for this element to converse airflow delineation in surgeries, thereby reducing airborne particle concentration in the operation area and increasing air quality in other words the value of hygiene level in existing surgeries. The element assembly was realised in working operating surgery. The study was conducted within the framework of Grant FAST-S-12-17 Systems engineering environment for sustainable construction and from Grant MSM6215648905 ´Biological and technological aspects of sustainability of controlled ecosystems and their adaptability to climate change´, funded by the Ministry of Education, Youth and Sports of the Czech Republic.

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MATERIALS AND METHODS

Theory

The academic approach to the subject matter, i.e. airflow delineation and air distribution in surgery including reverse flows identification and the self-contamination effect of the patient operating area, are described in the previous article, Airflow delineation modelling in standard operating theatres.
The example of airflow delineation for two-way laminar ceiling panel and for standard are displayed in Figures 1 and 2.
The product two-way laminar ceiling panel (Fig 3) is suspended 300mm under the ceiling compared to the standard one (see Fig 4). The reduced spacing between the two-way laminar ceiling panel and the operating table provides a reduction of airflow velocity at the exit of the laminar from the existing 0,2 to 0,25 m/s to 0,16 to 0,18 m/s.

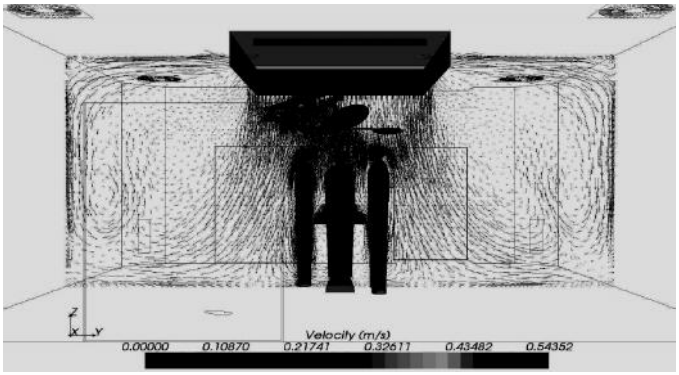

Fig. 1. Airflow delineation with two-way laminar ceiling panel

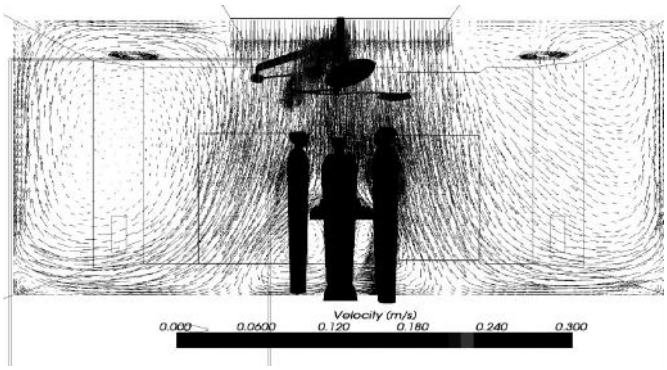

Fig. 2. Airflow delineation with standard laminar ceiling panel

There is no impairment of one-way airflow profile in the area o f the operating table by the reduced airflow velocity at exit of the two-way laminar ceiling panel based on a mathematical model, and surgeons do not feel such a draught. This can be worked out accurately using the index DR according ČSN EN 7730 [Čsn En 7730:2007], which is reduced from 16% to 12% with a reduction of velocity from 0,24m/s to 0,18m/s at 20°C and a turbulence intensity of 0,1. The model of course doesn't account for dynamic states caused by human movement. A reduction in airflow velocity of about 20% also means a reduction in the speed of cross flows around these moving obstacles. Although a negative effect on the hygiene of the operating area is not predicted, it is advised that further analysis be carried out. In further works it will be necessary to undergo critical investigation into present practice and tried and trusted airflow speed values.

Fig. 3. Two-way laminar ceiling panel

Fig. 4. Standard laminar ceiling panel

The amount of air reduced in the flow to the operating area is used for air distribution under the ceiling of the room in question, thus retaining energy intensity in the room from the point of view of air conditioning, as well as leading to a change of airflow delineation. As mathematical simulations of airflow delineation show, there is an almost complete elimination of reverse flows by air distribution under the ceiling, thereby eliminating particle contamination of the patient operating area. Another advantage of the new distribution concept is the fact that reduced concentrations of particles in the operating area increases the level of hygiene in the operating theatre.

Chart 1 - Cleaning class classification according ČSN EN ISO 1644

surgery	cleaning class according to ČSN EN ISO 14644	particulate count for existing cleaning class the size (µm)						
		inches valid for > 0,5 in ft^3	> 0,1 (m^3)	> 0,2 (m^3)	> 0,3 (m^3)	> 0,5 (m^3)	> 1 (m^3)	> 5,0 (m^3)
superaseptic	5	100	100000	23651	10176	3517	832	29
aseptic	7	10000	10000000	2365144	1017625	351676	83176	2925

Chart 2 - energy intensity of operating in surgery

surgery	air suply quantity (V_p)	exhaust air quantity (V_o)	waste heat recovery (ZZT)	heat requirement (Q_t)	cold requirement (Q_{ch})	steam requi-rement	electric power for engine fan	charges for average operatin hour
-	m^3/h	m^3/h	%	MWh/ year	MWh/ year	tonne/ year	MWh/ year	CZK/ hour
superaseptic	3600	3200	50	59,8	6,8	53	27	84
aseptic	2400	2100	50	40,4	4,6	35	16	52
theoretic saving	-	-	-	-	-	-	-	32

In theory it is thus possible to raise the level of aseptic surgery to superaseptic, as long as hygiene standards according to table 1 are met. That means in practice that the air only has to be changed 20 times per hour, instead of the generally accepted 30, resulting in cost reduction in air conditioning equipment as well as the running costs of surgery. Air conditioning equipment not only provides the desired value of hygiene space in surgery, but also configure parameters of temperature and moisture microclimate all year round. In the case of upgrading superaseptic surgery with air parameters like aseptic room, it is possible to reduce by 40% the operating costs for that air conditioning system, as presented in detail in chart 2.

Installation and practical measurement of two-way laminar ceiling panel

On the basis of the facts presented, the design of two/way laminar ceiling panel was implemented. The Czech Patent Office protects this product as utility design number CZ 17934 U1 – two/way laminar ceiling panel. Then standard laminar ceiling panels producer and installer ELFA ltd. Brno was contacted with an offer of cooperation on producing the prototype and installing the product to working surgery at a hospital in South Moravia. The firm has accepted both tasks.

In order to compare how the standard and the two-way laminar ceiling panels work, the hygiene measurement was carried out before and after installation of the new technology by Ing. Zuzana Mathauserová, a superintendent of The National Refernce Laboratory for dustiness and work environment from the state health institute. Parameters of the air conditioning system were the same regarding objectivity of measurement (including age and quality of filters in the third stage). The measurement was done in both cases after exchange and defectoscopy of the new filters. The measurement of the two-way laminar ceiling panel was carried out during routine operations in surgery defined as measurement during pilot plant. Basic value measurement was carried out without anybody in the room, so as to be ideal conditions for comparison, even though this measurement may not fully testify to characteristics of the room during operations. At present there is a tendency (Bruner 2005) to modify conditions for measurement up to operating conditions, which means with people as a source of heat, and particulate aerosol. These universal conditions are hard to set up with different people dressed in clothes of wearing degrees of cleanliness. Therefore test dummies are developed for simulating people as a standard source of contamination. That is technically possible but unworkable under Czech conditions. Therefore, a group of four

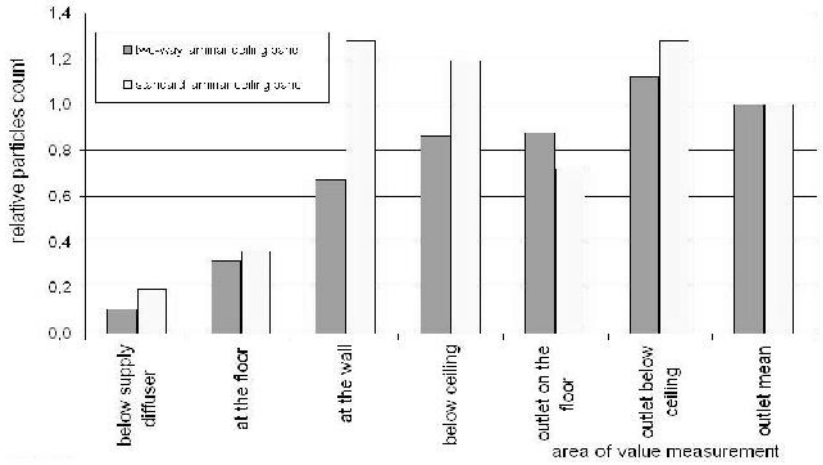

Fig. 5. ratio of particulate count from size 0,5 micrometer in surgery

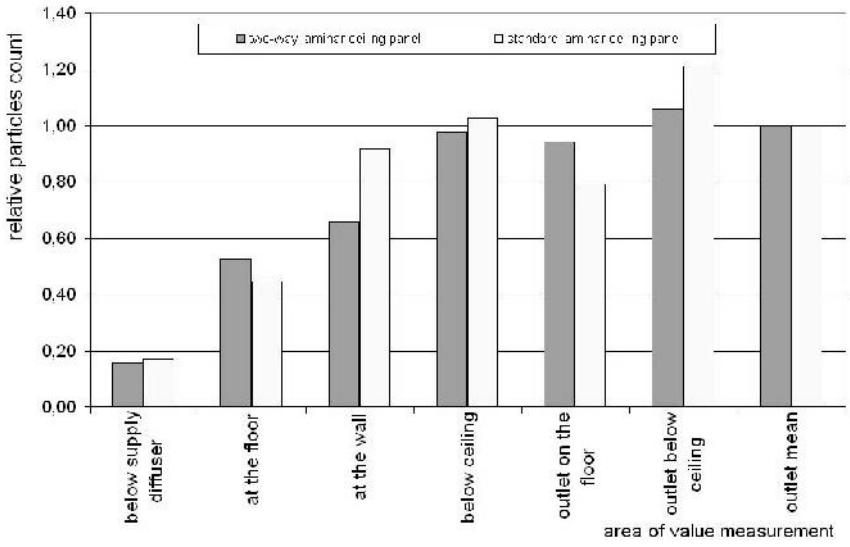

Fig. 6. Ratio of particulate count from size 5 micrometres in surgery

people wearing clothes and protective aids. This group was used as the control group. It is not completely objective, but it is a convenient method. These measurements are not the same in other rooms with other people in different clothes. It was, however, sufficient for a change in characteristics in one room with the same group. It is possible to detect places with higher and lower concentration of particulate sources only, because without people in the room with the particulate concentration in the room it is balanced by intensive air exchange. In the second measurement the room was less well cleaned at the start than in the first case, but measurement is always carried out in increasing concentration, i.e. firstly in the air supply, then the surrounding area, and lastly in the air outlet elements. Constant human presence gives measurements with more or less equal peripheral conditions. To reduce the influence of variable starting conditions, the number of particles was evaluated as standard as far as air quality is concerned. As a control a standard concentration in exhaust air is used. In both cases the value is 1. The ratio of particulate count in measuring point for other measured places is always the same for the standard laminar ceiling panel and the two-way model to particulate count in the exhaust air. Contamination of exhaust air including the effects of people and other sources in the room and as well as this there is a more useful system of air distribution reaching low particulate concentration in the protected surgery area with comparable air contamination. Evaluation is done for two groups of particulate size, smaller particulate from size 0.5 micrometres to 5 micrometres (chart 5) and bigger particulate with large caliber over 5 micrometres (chart 6).

There is contrast in the particulate count for various places in surgery. The particulate concentration is more than 5 times in space outside the operating area than in the area under the inlet element (standard laminar ceiling panel, two-way laminar ceiling panel). The ratio of substance concentration in the exhaust air and breathing zone (here in the operating area) defines ventilation efficiency, which is near value 1 according to standard ways of turbulent air distribution. Ventilation efficiency is higher by crowding out way of ventilation (for instance during surgery). For fine dust this efficiency has a value of 5 for standard and 10 for the two-way laminar ceiling panel). That means the value is double. There is not such a big contrast with large particulate. There is crowding out of particulate lower in the room with the two-way laminar ceiling panel. Total efficiency for the standard laminar ceiling panel has a value of 5, 9, for two-way it is 6,4. The reason for the difference in small and large particulate distribution will be in further research.

Air supplied by lateral slits under the ceiling dilutes the air under the ceiling outlet elements, which is why low concentration results are seen, whereas the standard version has them nearer the floor. Whereas it is possible to describe the air distribution top-down and up with standard, the air distribution is quasi down to down (and to sides).

RESULTS AND DISCUSSION

Measurement of particulate count is the main and objective indicator of air quality in surgery. Despite the fact that measurement was carried out under varying conditions, ratio evaluation proved the two-way laminar ceiling panel brings preferable particulate distribution in surgery because this system of air distribution reaches higher ventilation efficiency. Further research will be focused on specifying identification and particulate source quantification in surgery. Further development of a mathematical model could include two-way airflow with emitted particulate from internal sources, in particular, people.

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