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KEY PERSPECTIVES ON THE REGION'S HVACR INDUSTRY

APRIL 2007

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WAR ON GERMS: UV IN AHUS

FACE 2 FACE WITH GEORGE BERBARI OF DC PRO ENGINEERING

GB40

TECOM'S GREEN BUILDING DRIVE REPRESENTS A PARADIGM SHIFT IN THE REGION'S CONSTRUCTION SECTOR

PLUS: ASHRAE UPDATE, CONTRACTS' CORNER, EVENTS WATCH

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WAR ON

ULTRAVIOLET RADIATION IS AN EFFECTIVE AIR

Ultraviolet radiation inactivates microorganisms in AHUs. The in-airflow disinfection of air by UVC irradiation is a highly reliable, ecologically and economically efficient alternative to the air disinfection methods conventionally employed in AHU technology.

You will be aware of the successful use of UV irradiation in air handling units for disinfecting the water in air washers. With an ultraviolet unit, the supply airflow is treated directly by UVC irradiation. In combination with mechanical filtering, this process results in a substantial reduction of airborne microorganism counts while effectively counteracting bacterial growth in the air-handling equipment itself. This achieves a benefit where it matters most – that is, in hygiene applications, including hospitals, pharmaceutical industry environments and in all fields of foodstuff processing.

Direct exposure to UVC radiation has a negative effect on humans, causing dermal erythema (sunburn) and conjunctivitis (eye inflammation). Contained within the AHU, the indirect action of UVC on the supply air is uncritical, since no direct radiation is emitted into the air-conditioned room. Maintenance personnel are protected from inadvertent exposure by a door-operated switch.

OPERATING PRINCIPLE AND PRACTICAL VIABILITY OF UV AIR TREATMENT IN AHU SYSTEMS

UV rays consist of electromagnetic radiation in the wavelength range between 400 nm and 100 nm, covering the gap between X-rays and the short-wave visible light of the sun.

A sub-distinction is made between the following ranges...

UV A 400 - 315 nm
UV B 315 - 280 nm
UV C 280 - 200 nm
UV vacuum < 200 nm

Light quanta at 185 nm and below break down oxygen molecules into atoms, which will, then, reconfigure into ozone (O_3) molecules. For biological UV light applications, the wavelength range of interest is mainly that of UVC.

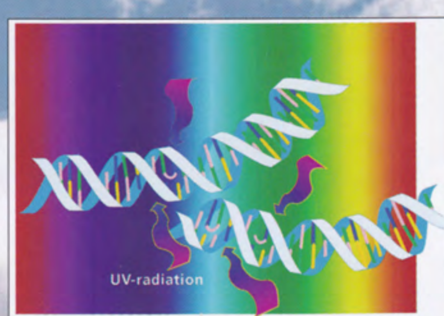


Chart 1: Effect of UVC to the DNA

For UV rays to act on biological matter, the key biological building blocks, namely

BY **DR CHRISTOPH KAUP**

GERMS!

DISINFECTION DEVICE IN AIR HANDLING UNITS

proteins and nucleic acids, must have an appropriate absorptivity. The absorption spectrum of the characteristic amino acids has its peak at about 280 nm; this (cumulative) maximum is also found in proteins and nucleic acids, where it lies in the region of 260 nm.

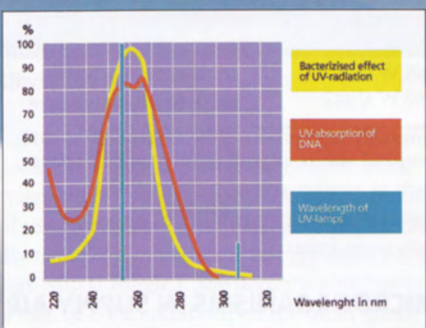


Chart 2: Destruction of microorganism – absorption to emission

Scientific tests have shown the bactericidal action of UVC and the absorption range of DNA (deoxyribonucleic acid) to peak at about 260 nm. This observation justifies the assumption that UV rays act on the cell core, and that radiation in the spectral range around 260 nm is basically capable of inactivating micro-organisms. We make use of this property to achieve a decontamination and sterilisation effect, which is to establish hygienic conditions that will prevent infections. Disinfection is the selective inactivation of microorganisms with the aim of preventing the transmission of pathogenic agents, resulting in an environment with a low microorganism count. Sterilisation refers to the destruction of all living microorganisms, giving rise to 'sterile' conditions.

An artificial radiation source particularly suitable for disinfection exists in the form of gas discharge lamps (low-pressure mercury lamps), which essentially yield spectral line emissions at a wavelength of 185 nm and 254 nm.

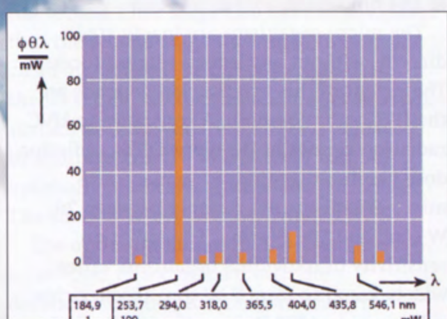


Chart 3: spectrum of a low-pressure mercury emitter

Since the photons (quanta of electromagnetic radiation) of the 185 nm spectral line carry sufficient energy to break down oxygen molecules, ozone will form as a result. Ozone is a powerful oxidant »

» which, although it has disinfecting properties itself, tends to irritate the human mucous membranes. The release of ozone is, therefore, undesirable except in exceptional cases, and should generally be avoided.

To prevent ozone formation, the radiation source can be shielded with a glass material that absorbs the 185 nm spectral line. The result is a UV lamp whose action is based exclusively on the emission of spectral lines at 254 nm.

The micro-organisms are inactivated directly, without any intermediate process. The extent of this inactivation depends on the UVC radiation dose. A resistance to UVC radiation cannot be developed. The radiation dose habitually employed to inactivate micro-organisms lies roughly between 20 W s/m_ and 100 W s/m_. The radiation sensitivity of individual organisms varies widely, ranging from 7 W s/m_ (Escherichia coli in air) to 1000 W s/m_ (fungi). Radiation doses are expressed as radiation energy per unit surface area, subject to the following equations:

- Radiation intensity (W/m2) = radiation energy (W) / surface area (m2)
- Radiation dose (W s/m2) = radiation intensity (W/m2) x exposure time (s)

In other words, the radiation dose is the product of the radiation intensity and the duration of exposure.

The term "D10" refers to a UV dose, which causes a 1-log reduction in a given initial micro-organism count -- that is which decreases the baseline germ population by 90% (to 10% remaining).

The table, below, shows the doses required to inactivate the most common micro-organisms found in hospitals ('hospital germs').

	90% disinfection 1 x D10 dose	99.9% disinfection 3 x D10 dose
Escherichia coli (in air)	7 W s/m2	21 W s/ m2
Legionella pneumophila	9 W s/ m2	27 W s/ m2
Staphilococcus aureus	22 W s/ m2	66 W s/ m2
Proteus vulgaris	27 W s/ m2	81 W s/ m2
Salmonella enteritidis	40 W s/ m2	120 W s/ m2
Pseudomonas aeruginosa	55 W s/ m2	165 W s/ m2
Bacterium subtilis	60 W s/ m2	180 W s/ m2

Table 1: Doses required to inactivate the most common micro-organisms found in hospitals

APPLICATION IN AHUs

The disinfection of air, that is a minimisation of the airborne micro-organism count, can basically be achieved by air filtering, UV irradiation, ozone treatment and chemical disinfectants. Depending on the requirement, it should be examined whether the use of ozone as an oxidant is feasible or, indeed, necessary. At any rate, elevated room ozone concentrations must be avoided. Areas susceptible to corrosion should be protected by ozone catalysts, if at all possible. In most cases, both ozone and chemical disinfectants are unacceptable due to toxicity effects in long-term operation. For this reason, it is strictly advisable to adopt a decontamination by UVC irradiation, in conjunction with mechanical filtering, in continuously operating AHU equipment. The benefits are obvious, especially in rooms occupied by people with an impaired resistance to disease. Such sites include intensive care units or children's hospital wards as well as busy public spaces, such as airport arrival halls and waiting areas, where the possibility of airborne infections exists.

MICROORGANISMS IN SUPPLY AIR

The presence of microorganisms in air supplied into a room may have diverse causes, ranging from bacteria in the outside air or (parts of) the re-circulated airflow to component contamination (humidifier, filter, etc.) or micro-organism growth on internal AHU surfaces.

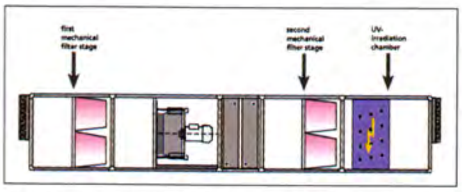


Chart 4: Graphic view of the UVC irradiation chamber in the AHU

CONTAINED WITHIN THE AHU THE INDIRECT ACTION OF UVC ON THE SUPPLY AIR IS UNCRITICAL, SINCE NO DIRECT RADIATION IS EMITTED INTO THE AIR-CONDITIONED ROOM.

Design (rating) specifications for UV disinfection components must take into account the required rate of disinfection. Depending on the range of micro-organisms encountered, a 90% (1 x D10) to 99.9% (3 x D10) inactivation should be envisaged to prevent mutation of the target organisms.

The irradiation chamber in an AHU should be generally dimensioned to ensure that the in-flow irradiation dose of (approximately 20 to 100 W s/m_) deactivates at least approximately 90% of all pathogenic organisms. Especially vegetative pathogens can be substantially reduced by UVC irradiation. On the other hand, UV irradiation cannot generally replace a discharge-side particle filter. UV inactivation is a supplementary step, particularly in those room categories in which a third-filter stage is not mandatory according to hygiene type units, as well as in systems with at least some exhaust air recirculation. Since this "physical" filter causes no pressure drop, the economic efficiency of the system is ensured.

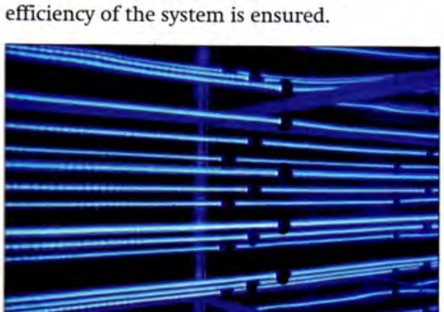


Chart 5: UV Unit

The combination with mechanical filtering produces a high degree of decontamination reliability. It is a fact that the separation rate of the mechanical filter deteriorates with the diameter of the target micro-organisms (they just "slip through"). The decontaminating action of UV irradiation, on the other hand, is inversely proportional to germ size; it becomes more effective the larger the diameter of the micro-organism.

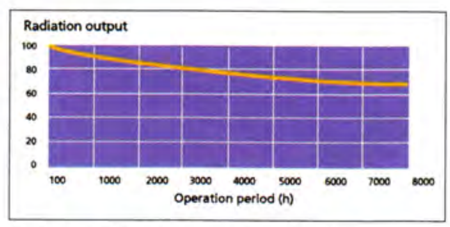


Chart 6: Radiation output of UV low-pressure lamps during operating periods

The service life of the UV radiation source amounts to about 8,000 - 12,000 hours. The average intensity drop after 8,000 hours is about 30%. The optimum ambient temperature for these lamps varies between 20°C and 30°C. The irradiation chamber should be arranged near the outlet of the AHU, not only for disinfection reasons but also because of the ambient parameters, commonly 22°C and 30 ... 60% relative humidity.

For optimum inactivation the inner shell of the irradiation chamber is made of a UV-reflecting, pre-treated material to ensure a high passive radiation dose.

The reflectivity of steel sheet is on the order of 25% to 30%; that of pre-treated aluminium reaches 70% to 75%. The passive radiation due to reflection can raise the radiation intensity by a factor of 1.2 to 1.85.

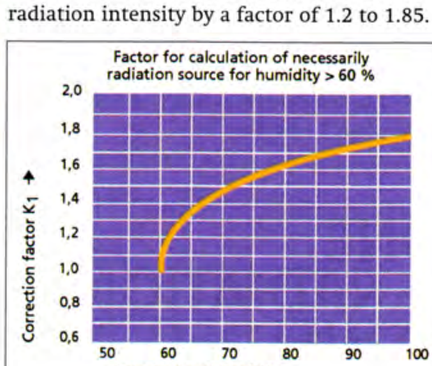


Chart 7: Relationship between reflection and required dose / Correction factor for determining UV source requirement / Correction factor / Reflectivity

Continuous monitoring of the UVC radiation intensity is necessary so that an adequate irradiation can be ensured at all times. For lamp monitoring, it is recommended that operating hour meters and ammeters are used. Alternatively, UV sensors may be used – these offer the additional benefit of being able to detect beam intensity losses due to shading, dirt and the such.

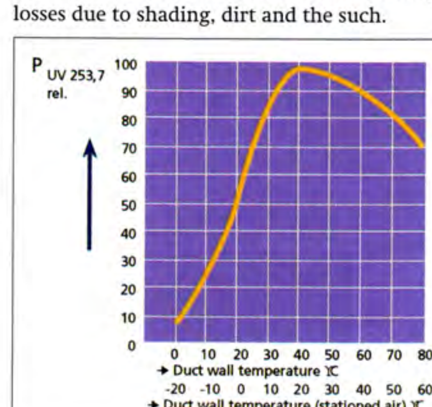


Chart 8: Relationship between UV output and duct wall temperature / ambient temperature

An arrangement directly downstream of the second filter stage also has the advantage that the second-stage filter medium on the clean-air side will be directly exposed to the UVC light, so that an additional filter surface decontamination effect is achieved; in addition, the UV source itself will be optimally protected against dirt particles. The shadow effect is, thus, avoided.

The optimum radiation dose should be selected in accordance with the decontamination requirement. The UV radiation intensity can be adjusted to the desired decontamination effect by sequentially energising or de-energising selected lamp groups as a function of the air velocity.

OZONE AS AN OXIDISING MEDIUM

Ozone, being an irritant gas, must be prevented from entering air conditioned »

» rooms occupied by humans. Nevertheless, the use of ozone-forming UVC irradiation units makes sense under specific conditions. For instance, if the air contains odourants, these can usually be oxidised by ozone. The process is referred to as "cold combustion".

In addition, ozone (O_3) is instable as a molecule. Its half-life at 20°C is about three minutes; it is further reduced in the presence of UV rays.

IRRADIATION INTENSITY AND DURATION

The term "D10" refers to a UV dose which causes a 1-log reduction in a given initial micro-organism count -- that is which decreases the baseline germ population by 90%.

Decontamination performance is also dependent on the concentration of pollutants in the air (shadow effect) and on the relative air humidity. At only 80% RH, the micro-organisms will already be surrounded by a skin of water, making them 50% less sensitive to UV irradiation than they would be in dry air. Air filtering is, therefore, mandatory to reduce the dust load and, hence, shadowing.

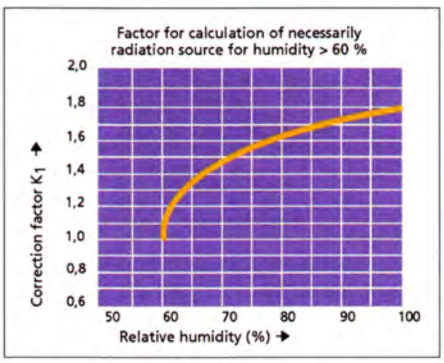


Chart 9: Relationship between relative humidity and required dose

CALCULATION EXAMPLE

A 90% disinfection rate is to be achieved in an AHU with a throughput of 6,000 _/h. Twelve low-pressure UVC sources with a rating of 60 W are arranged in three rows in the flow direction in a cross-section of approximately 1000 x 650 mm. The UVC radiation output (253.7 nm) is approximately 24 W.

A system using an UV-reflecting interior lining for the irradiation chamber raises the radiation dose by a factor of about 1.85. At an expected maximum air humidity of about 65%, a correction factor of 0.73 must be taken into account.

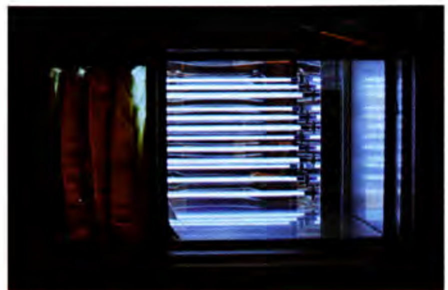
At an air velocity of approximately 2.5 m/s and a UV lamp length of 985 mm, we thus obtain a radiation intensity of 24 W / 0.6336 m2 = 37.9 W/m_. The result is a radiation dose per lamp of 37.9 W/m2 x 0.0644 s = 2.44 W s/m2 x 1.85 x 0.73 = 3.3 W s/m_, or a total radiation dose of 13.2 W s/m_ for four lamps per row. With an array of 12 lamps in three rows, the radiation dose -- and hence, the disinfection effect -- could be increased to 39.5 W s/m_. From the tables, you will see that at this rate, coli bacteria and legionellae are inactivated at a rate of 99.9%, while for salmonellae the disinfection rate is 90%. On the other hand, the energy consumption of the UV disinfection system would rise from 4 x 110 V x 0.67 A = 295 W to 884 W. You see how important it is to determine the optimum radiation dose according to the decontamination requirement profile. Moreover, the radiation dose can be adapted for the desired disinfection effect by sequentially activating or deactivating certain UV lamp groups as a function of air velocity, air temperature, and/or air humidity.

EXPERT OPINIONS AND TESTS

The effects of the UVC air disinfection unit on the concentration of bacteria (Micrococcus luteus) in the airflow of air handling systems are demonstrated by the tests and the expert's report prepared by the Berlin Institute of Air Hygiene, Professor Dr med. H Rüden and Dr-Ing M Möritz. An excerpt from this report, dealing with the effectiveness of a UV-UNIT air disinfection system in central AHUs, states as follows under Item 5 - Evaluation...

From the results of the orientation study conducted, it emerges that the UV-UNIT UVC air disinfection system, set to UV stage 3, almost fully eliminates bacteria from the AHU airflow (99.6%) while reducing the concentration of yeasts by up to 80m %."

TO PREVENT OZONE FORMATION, THE RADIATION SOURCE CAN BE SHIELDED WITH A GLASS MATERIAL THAT ABSORBS THE 185 NM SPECTRAL LINE.



Where, how

Some applications of UV radiation are...

- Foodstuff industry
- Bakeries
- Butcheries
- Beverage industries (juice)
- Dairy farms
- Pharmacies
- Tablet packaging units
- Clean rooms
- Hygiene
- Human hygiene
- Laboratories

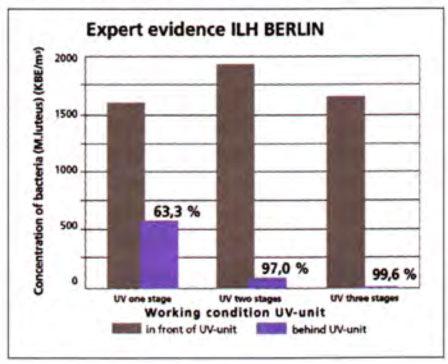


Chart 10: Effects of the UVC air disinfection units on the concentration of bacteria (Micrococcus luteus) in AHU airflows

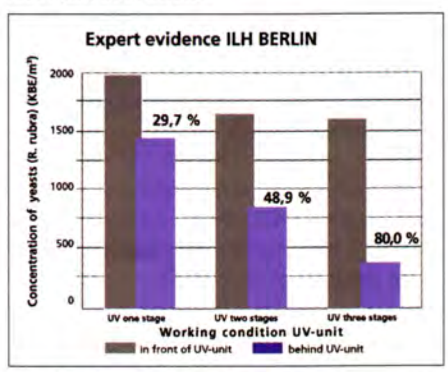


Chart 11: Effects of the UVC air disinfection units on the concentration of yeasts (Rhodotorula rubra) in AHU airflows

In charts 13, 14 and 15, the effect of the interaction between the mechanical filtering and the UV unit on germs can be shown.

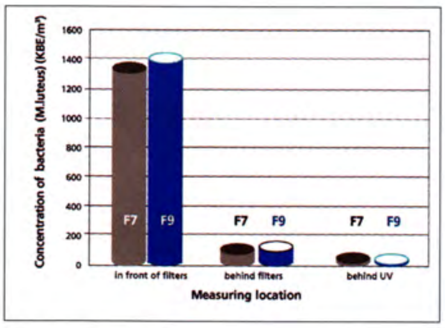


Chart 13: Effects of the UVC air disinfection units with the interaction of mechanical filters on the concentration of bacteria (Micrococcus luteus) in AHU airflows

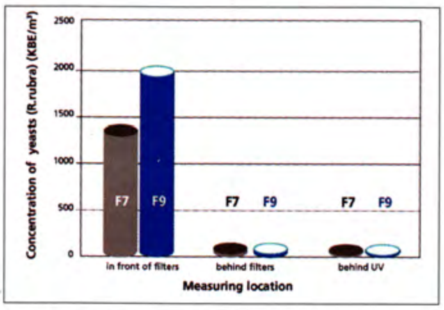


Chart 14: Effects of the UVC air disinfection units with the interaction of mechanical filters on the concentration of yeasts (Rhodotorula rubra) in AHU airflows

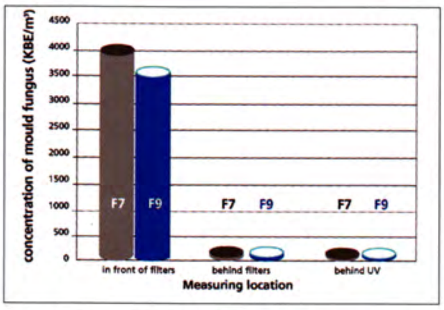


Chart 15: Effects of the UVC air disinfection units with the interaction of mechanical filters on the concentration of mould (fungus) in AHU airflows

At the end, a very high reduction of germs can be guaranteed. The combination between mechanical fine filters and UV units are comparable to a HEPA filterclass H14. ■

The writer is General Manager and owner of Howatherm, Germany.

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