ELSEVIER

Trends in Food Science & Technology 17 (2006) 331–336

TRENDS IN FOOD SCIENCE & TECHNOLOGY

EHEDG Update

Guidelines on air handling in the food industry

This article is an extended summary of the report prepared in consultation with the members of the Air Handling Subgroup of the European Hygienic Engineering & Design Group (EHEDG) in March 2005. This is the 10th in the series published in TIFS. The full report prepared by K. Brown (Chairman), K. Aichinger, D. Burfoot, A. Fahldieck, M. Freund, J.P. Germain, A. Hamer, I. Klemetti, N. Lacroix, S. Nakatani, G. Sasia, X. Sun, Ph. Van Beek, S. Wray, is available from CCFRA at pubs@campden.co.uk. Information about EHEDG can be found at www.ehedg.org. The production of EHEDG Guidelines is supported by the European Commission under the Quality of Life Programme, Project HYFOMA (QLK1-CT-2000-01359).

Introduction

The quality of air within factory buildings is controlled by many food manufacturers. Environmental air of a specified quality (temperature, humidity and particle concentration) and quantity (fresh air volume) is required for the comfort and safety of employees. For the manufacture of some products, it is necessary to impose additional controls on environmental air quality to reduce the possibility of contamination. Also, process air that comes in contact with food must be controlled.

The controlled properties of air, especially temperature and humidity, may be used to prevent or reduce the growth rate of some micro-organisms in manufacturing and storage areas. The particle content—dust and micro-organisms—can also be controlled to limit the risk of product contamination and hence contribute to safe food manufacture. Airborne contaminants are commonly removed by filtration. The extent and rate of their removal can be adjusted according to the acceptable risks of product contamination and also in response to any need for dust control.

0924-2244/$ - see front matter
doi:10.1016/j.tifs.2005.12.008

Objective of guidelines

These guidelines are intended to assist food producers in the design, selection, installation, and operation of air handling systems. Information is provided on the role of air systems in maintaining and achieving microbiological standards in food products. The guidelines cover the choice of systems, filtration types, system concepts, construction, maintenance, sanitation, testing, commissioning, validation and system monitoring. The guidelines are not intended to be a specification for construction of any item of equipment installed as part of an air handling system. Each installation needs to take account of local requirements and specialist air quality engineers should be consulted, to assist in the design and operation of the equipment.

Terminology

Standardised terminology used in this document is demonstrated in Fig. 1.

Role of air handling systems

Properly designed air handling systems control airborne particulates and odours and minimise the risks to products from airborne contamination by infectious pathogens (e.g. *Salmonella*, *Listeria*, *E. coli*) and toxigenic pathogens (e.g. *Staphylococcus aureus* and clostridia) and spoilage micro-organisms (e.g. yeast, moulds, pseudomonads and lactic acid bacteria).

In addition to control of airborne contamination, the following variables are important to the specification of the air handling system:

- *Temperature:* temperatures below 13 °C should only be used when higher temperatures would be prejudicial to food safety.
- *Air distribution:* to remove the heat imposed by the processes and people, to provide sufficient fresh air, prevent the ingress of airborne contamination and avoid regions of stagnant air.

Factors that affect the choice of air changes are as follows:

- Volume of the space;
- Cooling capacity (removal of heat);
- Number of people (fresh air requirement);
- Temperature differences with adjoining work areas;

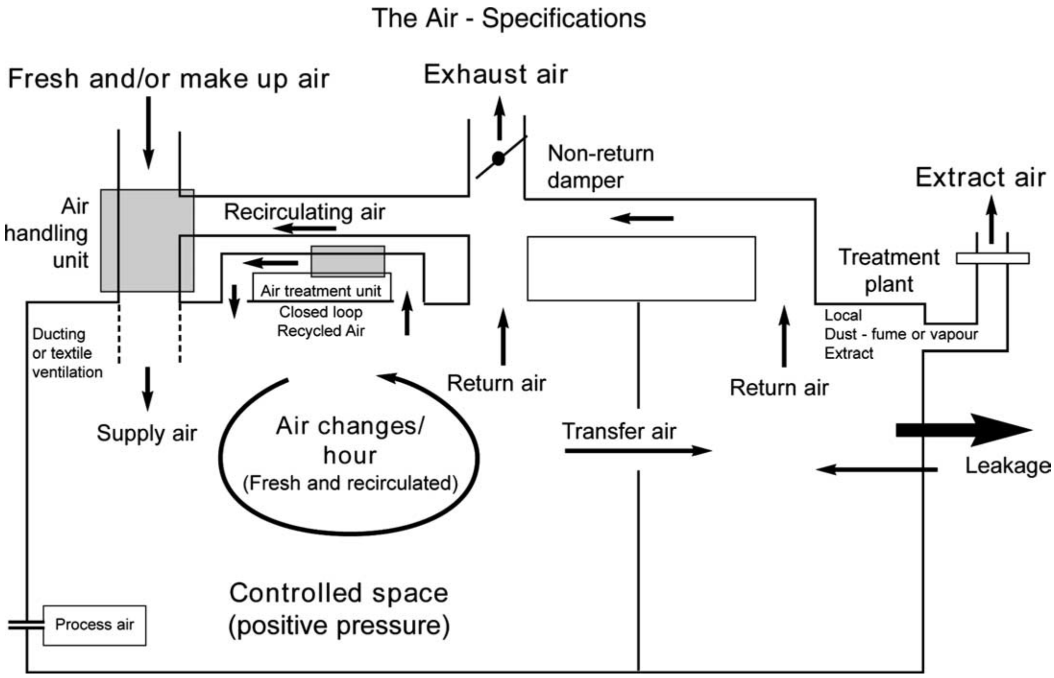

Fig. 1. Standardised terminology for environmental air at different stages. (*Source:* Unless otherwise stated, figures and tables reproduced courtesy of CCFRA.)

- Humidity and odour control;
- Over pressure required;
- Air quality required.

Irrespective of the air flow rate, care needs to be taken that the air is moving from high to low care areas or from low to higher dust loading areas.

Sources of airborne microbial contamination

In factories micro-organisms can be dispersed by aerosols consisting of particles dispersed in air. The particles are solid or liquid and may have micro-organisms inside or on their surfaces. Mould and bacterial spores are often airborne without being attached to dust or water droplets.

Aerosols may enter food production areas via drains, doorways and hatches, disinfection tunnels and compressed air supplies, or may be generated within the food production area during cleaning and washing operations. Other sources of airborne contamination include:

- Raw materials;
- Packaging;
- People;
- Poorly designed, cleaned or maintained air handling systems;
- Moving or rotating equipment.

The effectiveness of control of the main types of microbial contamination by environmental air handling is summarised in Table 1.

Differential operational states

Normal production

In the normal operational state, the air handling system will correctly distribute fully conditioned (i.e. filtered, controlled temperature and humidity) air into the production area at the required rate and recirculate it (typically 85% recirculation and 15% exhaust/replenishment) through the system.

Cleaning

The air handling system may need an additional operational state during factory cleaning, which will input filtered fresh air into the production area via the ducting, to maintain the overpressure and protect the filters from moisture damage, but will extract moisture-laden air directly to exhaust without re-circulation. If there is no extract system, then aerosols should be allowed to settle and appropriate drying and disinfection completed.

Non-production

During periods of non-production, if necessary, the air system will input filtered or fully conditioned air into the production area, to maintain a specified over pressure or temperature. This air can be recirculated at a very low rate, depending on leakage from the area, the heat load or loss from the system, ensuring that a positive pressure is maintained.

Maintenance

The air handling system should be designed to allow for service, e.g. filter changes, with a minimum of downtime

Table 1. Effectiveness of control by air systems of main types of contamination

Source of contamination	Mechanism of distribution	Effectiveness of control by air system	Risk to product safety
Raw materials (e.g. outer or raw product)	Micro-organisms carried on surfaces	Low	Medium to high
Personnel	On feet, clothing or poor personal hygiene	Low	Medium to high
Traffic	Trolleys and fork lift truck wheels	Low	Medium to high
Airborne	Fresh air	High	Medium
	Particles of dust or powder	High	Medium
	Aerosols from spray, splashes	Medium	High
	Pneumatic transport, overpressure, gas blanketing of product	High	High
Condensation	Contact	High (drying capacity)	High
Surfaces	Surface to surface contact	Low	High
Cleaning operations	Aerosols from hosing, brushing, vacuuming	High (removal rate and control of dispersion)	High
Equipment	Blow lines, exhaust from pneumatic systems and compressed air lines	High	Medium to high
Buildings	Leaking roofs, badly fitting windows or doors, poor design, construction or maintenance	Low	Medium to high

and ducting/production area contamination. The system design (for example, duplication of some equipment or ducts) may allow maintenance or repair without disrupting production.

Start-up

There may be a need for a special start-up procedure after maintenance, building work or other stoppages to remove particles and microbial contaminants from the air handling system and environment or to reduce the temperature of the work area.

System design concepts

It is important at the outset to define the risk category of product to be manufactured in the controlled area. This will determine the level of air filtration required and influence the design of the air handling system. It is essential to include in the design items that may have an influence on the controlled area, such as doors, inlet/outlet hatches and services.

Product risk categories

Food factories make products for a range of customer uses and storage conditions. Products range from low risk—ambient stable, packaged foods or those assured of a full heat treatment by the customer, to high-risk chilled and other ready-to-eat foods. The growth, survival or dispersion of hazardous micro-organisms may be influenced by the air system, which should:

- slow or prevent their growth in the manufacturing environment (e.g. by low temperature and/or humidity);
- prevent their ingress (e.g. by overpressure);
- remove particles which may carry them (e.g. by filtration);
- minimise cross-contamination (e.g. by correctly designed air delivery systems);
- if possible move the aerosols away from product using directional air;
- not act as a source of contamination (hygienic design and operation).

Medium risk or high care areas

For some types of products and processes such as sandwiches or salads, air quality is an important contributor to the overall product microbiological safety and quality. Practices relating to physical separation, personnel, materials, equipment and the environment are managed with the aim of *minimising* contamination. The air supply and handling system is likely to play a significant role in controlling risk.

High risk areas

Minimum-risk manufacture of some products, like cooked meat, requires that the stages of production directly affecting the microbiological quality of the final product are done in a physically separated area and that a high standard of hygiene relating to personnel, materials, equipment and environment are managed with the aim of *preventing* contamination. In this type of manufacturing area, the air supply and handling system is likely to play a critical role in controlling microbiological risks.

Aseptic systems

Aseptic filling systems are used for products that are usually microbiologically ambient stable in the final sealed package. Aseptic systems are required to operate to very high standards of microbiological safety to ensure minimum probability that product units will be contaminated. The air supplied should be filtered and equipment must be capable of being sterilised after each operating cycle, or when the integrity of the sterile zone is lost. Before production, the air system may be decontaminated using chemical sterilant which must be removed before production starts.

The volume of sterile air delivered by the air supply system must be sufficient to maintain an adequate over-pressure and outflow of air, usually specified by the manufacturer of the aseptic system. The air supply system must be adequate for all operating conditions, including, for example, draught, and movements in the operating area and opening of access to an aseptic room which may enclose the filler.

Air filtration

Air filter selection for environmental and process use is a critical part of ensuring final air quality in a food processing environment. In this section the types of air filters are described together with the filter grading and selection for food applications.

Environmental air

Environmental (fresh) air contains a wide range of dust particles, the majority of which are very small in size. Air also contains micro-organisms and gaseous contaminants which, in the case of food processing, must be controlled to a level determined by the risk to the product.

Millions of particles per cubic metre of air are present in environmental air at any time, and the level of air filtration required is determined predominantly by the need to protect the product, although protection of the air handling and process equipment are also very important considerations

Air filters installed in a food processing environment are usually of the barrier type, where dust particles and the majority of micro-organisms can be captured and retained in the filter media matrix. Filters are available to collect a wide range of particulate sizes. See Fig. 2.

Electrostatic filters

Air filters that collect and retain dust by means of an electrical charge can be divided into three types:

- Electrostatic air cleaners that are filter devices installed into air conditioning and ventilation systems.
- Electrostatic precipitators that are installed to collect such items as flyash from the extract air on power stations.
- Electret filters which are passive electrostatic filters.

Textile ventilation systems

Textile ventilation is an extremely efficient method of cool air distribution through circular or 'D' section food quality polyester or polypropylene 'socks'. These socks are suspended from the ceiling using a tracking system.

The air is distributed through the entire surface of the fabric. Owing to the pressure in the socks and the special weaving technique used, the air is diffused through the fabric at a low velocity, therefore preventing draughts from being created. Condensation on the socks can be prevented by controlling the relative humidity.

Process, transport and instrument air

Process air is delivered directly to the food product and pneumatic equipment. Air is an ingredient in many foods, for example aerated products, products moved using fluidised bed technology or products made by fermentation. Process air may also include modified atmosphere gases that come into direct contact with product. This air must be free

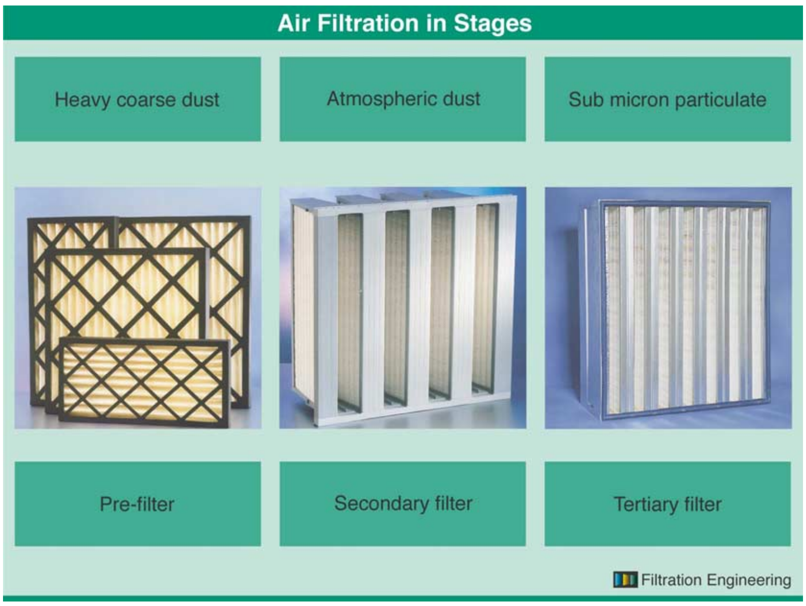

Fig. 2. Photographs of air filter types used for primary, secondary and tertiary filtration.

of chemicals (oil droplets, lubricants, odours, water vapour and additives) and foreign bodies (scale, metal, glass or plastic fragments), that must be removed by suitable traps (for water or oils), filters, scrubbers and screens.

Process air should also be of a microbiological quality compatible with the product and process parameters. In-line cartridge filters of suitable quality should be used when air is supplied from cylinders or compressors. They should be sited as near as possible to the connection to the machine and there should be adequate facilities for keeping them in a hygienic state—for example, by steam sterilisation.

Process air systems (pipes, fittings, and filters) may need to be designed, where necessary, for wet cleaning or steaming.

Dust control

Dust control for the food industry serves five major purposes:

- To protect the operator from inhaling fine particles.
- To prevent dust spreading in process areas and causing cross-contamination.
- To prevent accumulation of dust which may provide a substrate for growth of micro-organisms, and a supply of food for rodent and insect infestations.
- To prevent environmental pollution.
- To prevent explosion.

Types of dust control equipment

Various types of dust control filters and wet scrubbing devices are available. In general, for small dust particles with low inertia, impingement or entrapment filters will be required, whereas for large particles with high inertia, a cyclonic device may be used. Note that the filters used for dust control are quite different to those used for environmental air. Environmental air filters should not be used for dust control.

Humidity control

The relative humidity is the ratio (expressed as a percentage) of the pressure of the water vapour actually present to the saturation pressure at the same air temperature. It can be measured by several means including wet and dry bulb hygrometers and hair hygrometers. As temperature rises, the air can hold more moisture, but if this air then comes into contact with a cold surface, condensation will occur which may give rise to microbial growth, corrosion and other moisture related problems. Dry goods in particular may suffer if they absorb moisture from the air if the relative humidity is high.

Humidity problems in the food industry are generally caused by too much water in the air rather than too little. Humidification will increase relative humidity and moisture levels whilst dehumidification does the reverse. Both may be used in air conditioning systems.

Low humidity levels can cause problems with static electricity, can aggravate respiratory complaints and also increase product water loss.

Humidification

Humidification may be achieved by one of the following methods:

- Atomisation of water into the air flow by a rotor.
- Air washing by a spray.
- Evaporation from a rotating wheel partly immersed in a water tank.
- Injection of steam.

The two main types of humidifier used in food factories:

Atomising humidifiers. These create a fine mist of water droplets which is introduced directly into the air where it is evaporated.
Steam injection humidifiers. These use purpose designed steam distribution headers located in the airstream.

Dehumidification

Dehumidifiers remove water from the air. The most common method is to pass the air across a cooling coil and as the temperature of the air falls, the water condenses on the coils and then drains away. After the cooling coil, the air is then heated to bring it back to the required operating temperature. The main problem is again microbial growth in the water that condenses in the cooling system. The cleaning and disinfection of cooling coils must be included as part of the overall plant hygiene programme.

Failure to control humidity may result in water condensing on unwanted areas such as on extract grilles, refrigeration plant, process equipment, product and electronic components where microbial growth may again be a problem.

Maintenance and sanitation

It is important that the system has been properly designed and constructed to facilitate maintenance and sanitation operations. In particular, ducts should have sufficient access doors and hatches correctly positioned to facilitate cleaning, disinfection, hygiene testing and verification.

System hygiene is controlled by regular cleaning (and disinfection) of the system as appropriate to prevent the build up of dust, product or condensate that may provide a focus for microbial growth.

Cleaning

After installation, cleaning is required before placing the system into operation. Building works should also be complete to avoid contaminating systems with construction dust.

New air filters should be fitted when the air handling unit is cleaned. At no stage should systems be operated without filters fitted to avoid contamination downstream of the filters. If textile sock ventilation is used, this should not be fitted until the ductwork has been cleaned, otherwise debris will collect in the fabric.

Following cleaning to remove particulate material from ducts and air handling plant, systems should be disinfected. Care should be taken in the selection of disinfectants so they are compatible with materials used in the construction of the system.

Routine maintenance of the system

Air handling units and duct systems will require cleaning at regular intervals to maintain good hygiene conditions. Such work should be included in planned maintenance schedules or activated by a fall in hygienic conditions indicated by an air supply quality-monitoring programme.

Maintenance intervals will be influenced by:

- Quality and quantity of filters fitted to the supply system.
- Contaminants burden in fresh air.
- Product and contaminant burden in recycled air.
- Relative proportion of fresh and recycled air.
- Air velocity.
- Type of dust.
- Temperature and humidity.
- Duct material, construction and condition.
- Standard of hygiene required in the supplied area.

Methods of system monitoring

Physical methods

The following can be used to physically monitor the performance of air systems:

- Temperature measurement;
- Humidity measurement;
- Air flow measurement;
- Pressure measurement;
- Dust and particle measurement.

Microbiological methods for assessing airborne contamination

Ideally an aerosol sampler for microbiological assay should be capable of counting the total number of living airborne organisms in a unit volume of air as well as determining the number of viable organisms per particle and the size of the particles containing the organisms. However, none of the methods of sampling are able to achieve all of these in practice.

The following methods can be used:

- Sedimentation method;
- Impingement/impaction on solid or liquid media;
- Filtration methods;
- Electrostatic and thermal precipitation.

It should be appreciated that different methods of sampling will provide different estimates of airborne contamination.

Environmental impact

In addition to dust and *Legionella* control, there may be other considerations relating to air handling systems. These include those factors that may create nuisance to people living or working in the neighbourhood of the food-manufacturing site. The main complaints relate to odours and noise that may be generated from the air handling system.

Systems should be designed to:

- Be non-prejudicial to health or a nuisance;
- Prevent the emission of fumes or gases from the premises;
- Prevent the emission of dust, steam, smells or other effluvia;
- Prevent the creation of disturbing (high or low frequency) noise levels.

Definitions and air flow terminology

General terminology defined in the EHEDG Glossary apply to this guideline (see www.ehedg.org/glossary.pdf).

Useful websites

http://www.ashrae.org
http://bsonline.techindex.co.uk
http://www.campden.co.uk
http://www.cenorm.be
http://www.chilledfood.org
http://www.cibse.org
http://www.ehedg.org
http://eurovent-certification.com
http://eurovent-cecomaf.org
http://www.hmso.gov.uk
http://www.hse.gov.uk
http://www.hvca.org.uk
http://www.legislation.hmso.gov.uk