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Ergonomic and Green Class II's

The modern Class II Microbiological Safety Cabinet, now regarded as probably the most common in-use Safety Cabinet employed around the world, is available with features meeting the stringent ergonomic and green requirements in many countries.

When considering the basic requirements of operator, product, and environmental protection, they are the cornerstone of the modern scientific research laboratory where sterility and safety is paramount.

When considering the purchase of a Class II Cabinet, it is important to consider a number of issues to ensure the supplied unit meets the demands of users, purchasers and maintenance personnel.

Points such as good ergonomics, low noise levels, low maintenance and running costs and ease of use, are all considered as basic requirements and manufacturers approach these issues in a variety of ways. Getting these wrong can mean higher costs coupled with operator fatigue leading to research delays and increased downtime.

This article aims to give guidance to those new to the business or involved in the design and installation of Class II Cabinets into new or existing facilities and discusses the cabinet features in relation to operator safety, ergonomics and environmental impact.



Background

Class II Microbiological Safety Cabinets– can be described in EN 12469:2000 as “A Safety cabinet with a front aperture through which the operator can carry out manipulations inside the cabinet and which is constructed so that the worker is protected, the risk of product and cross contamination is low and the escape of airborne particulate contamination generated within the cabinet is controlled by means of an appropriate filtered internal airflow and filtration of the exhaust air”.

Designs may differ according to which National Standard

is followed. Cabinets sold throughout Europe must follow EN 12469:2000 where generally there is a 30% of total air volume inflow with 70% of air re-circulation inside cabinet and 30% exhaust back to the room or to an extract system (Via HEPA or ULPA filters).

Cabinets sold into America must follow the NSF 49 classifications and the A2 design is similar to the European EN design as above.

For the purposes of this article, comments and discussions will relate to cabinets conforming to EN 12469 only.

¹HEPA = High Efficiency Particulate Air (filter)

²ULPA = Ultra Low Particulate Air (filter)

Class II Cabinet Specifications and Air Flow

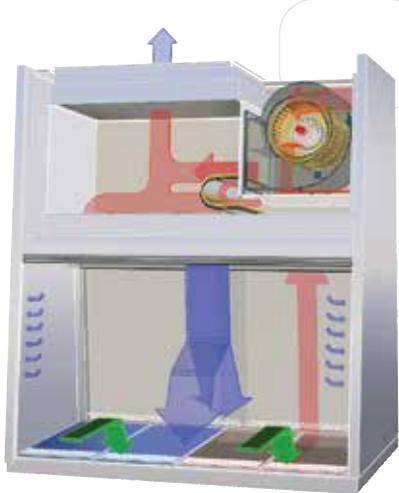


Fig 1

Class II Cabinets are designed such that an inward airflow along the front edge of the cabinet, through an opening of between 160mm and 250mm high will give a protection to the operator against airborne contaminants generated by the working process. This air is drawn in and down into the intake grilles as shown in Figure 1. The air is then drawn under the work surface to the rear of the cabinet and up into the fan system where it is split, such that approximately 70% is re-circulated downwards through the Main HEPA filter and 30% exhausted through the exhaust HEPA filter into either the laboratory or via a duct system to atmosphere.

The inflow air is perhaps the most important factor in the design of a Class II Cabinet since it determines the safety of the operator.

EN 12469:2000 specifies that the inflow should be greater than or equal to 0.4m/sec and that the downflow should be between 0.25 and 0.5m/sec.

A typical air flow pattern is shown in Fig 1.

When designing a new laboratory facility, consideration should be given to the method by which the cabinets will exhaust, whether it be back to the room or to the outside via either a hard duct or thimble duct system.

On commissioning a new cabinet, EN 12469 states that the volumetric airflow rates should be measured and that

³A KI test is a test method using a Potassium Iodide aerosol generated inside the operating cabinet to mimic a biologically hazardous aerosol and the result should confirm that the cabinet containment meets the minimum required level.

manufacturers' specifications should be met.

It is also recommended that an optional retention factor test should be carried out to ensure the Aperture Protection Factor is achieved. In the UK this is mandatory and a KI test is always carried out to guarantee the safety of the operator. (See Figure 2)



Fig 2

It should be remembered that whilst manufacturers test their cabinets prior to release from the factory the inflow rate at the final sited position could require resetting to ensure containment is maintained as a result of influences from surrounding equipment, airflows, personnel movement, etc.

There is often a misunderstanding between users and suppliers over how effective these inflows are and what outside forces can influence and / or negate them.

Cabinet Site Position

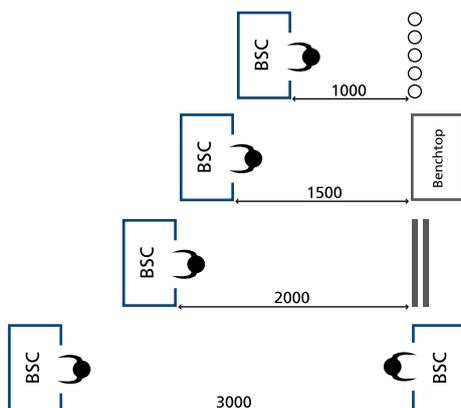


Fig 3

The position of the cabinet in the laboratory can have a marked effect on the performance as it can be strongly influenced by surrounding equipment, walls, benches, laboratory through traffic, and of course room air handling systems.

There are guidelines available in the UK for instance, from BS 5726:2005 offering information on siting cabinets, which take these factors into consideration and if followed will ensure the cabinet offers maximum protection.

Figure 3 shows a copy of part of the BS recommendations.

Room Heights

The floor to ceiling height of the laboratory where the cabinet is to be sited should also be considered, especially if the cabinet is to go on to a laboratory bench rather than a support frame. It is important to measure the available space accurately and allow for any ceiling mounted lights which may impinge on the space or any air-conditioning vents (see below).

If the cabinets are to be re-circulating (returning the exhaust air to the laboratory) then a space of around

200mm should ideally be left above the exhaust filter to allow this air to return unhindered and for the fitting of any fumigation top boxes as well as any periodic service testing. For cabinets placed against a wall, it is better to allow a small space behind to ensure the exhaust air can flow down behind the cabinet unhindered. This is especially true if cabinets are placed side by side or if other equipment such as incubators or refrigerators is placed nearby.

Air Conditioning Units and Room Make-up Air



Fig 4

When designing a new facility great consideration must be given to not just the cabinet siting for laboratory through traffic and surrounding equipment but also the siting of any air-conditioning inlet and exhaust vents.

Any diffusers that direct air down or across the front of a cabinet are likely to create turbulence and therefore potential loss of containment. It is therefore necessary to ensure the cabinets are tested when all personnel are in the laboratory and all A/C systems are running as intended.

Room A/C systems whether cassette type, split or wall mounted can nowadays be particularly fierce and it is important to evaluate where the air is moving within the room to ensure cabinet positioning is as safe as possible.

A/C units with automatic vents circulating the air around the room are particularly difficult to control apart from closing off some vents which of course can have a detrimental effect on the room conditions and can be upsetting to the laboratory personnel, especially in hot summers or hot climates.

When there is a need for make-up air to be supplied into the laboratory, such as with ducted cabinets, care must be taken to ensure the inflow diffusers are positioned so as not to create turbulence across the cabinet inflow area. Ceiling mounted diffuser grilles should ideally be adjustable so they can direct the air away from the cabinets if necessary and common "swirl" type diffusers (fig 5) should never be used as they create a high level of turbulence which can be highly detrimental to Class II cabinet containment.

Whilst it is recommended that air speeds within a room should be kept below 0.3m/sec., there is little quantified information as to how far cabinets should be from air inlets. The safest option is to carry out smoke tests to visualize air flows or a KI test on installation to ensure the cabinet containment is not compromised. Distances of at least 1.5 meters diagonally from the AC unit should be considered as a minimum but even this may be too little if the airflow is very strong.

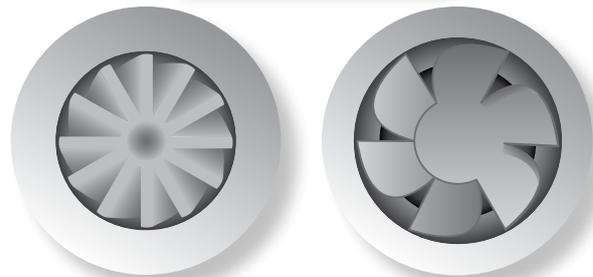
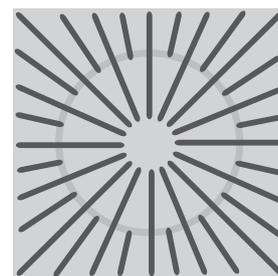


Fig 5

Using Cabinets Safely

To ensure the containment barrier is maintained during operations within the cabinet:-

Cabinet Work Surface Grilles



Fig 6

In order for Class II cabinets to guarantee both operator and product protection it is important to ensure the inflow air grilles along the work opening, and return air grilles at the side and rear of the work area are kept clear of obstructions. Blockages will create turbulence with potential loss of both sterility and containment.

Users should avoid rapid arm movements during working periods, especially when entering or exiting the work zone since this can drag in / out air and particulate material.



Fig 7

For safety, well machined and hand deburred grilles are far safer than machine punch finished grilles which can lead to torn gloves and cuts or abrasions to personnel during routine cleaning if not totally smooth.

Some manufacturers have designed arm rests for the users so that their arms sleeves can be slightly raised above the inflow grilles and still allow sufficient air to enter the cabinets. These items offer both a more comfortable working environment as well as aiding containment. Care must be taken if using external, slot in type arm rests to ensure they are cleaned prior to use so as to avoid introducing potential contamination into the work zone.

Safe and Efficient Interior Lighting



Fig 8

All Class II cabinets come with standard fluorescent tubes built in and consideration should be given to where the light tubes are positioned and how easy they are to replace in the event of a tube failure, as well as their carbon footprint. High intensity low wattage tubes are now available and cabinets offering such components should be considered.

Light tubes should be positioned under an external lift-able canopy for safe and simple replacement when required. If the light tubes are placed inside the working zone, below the HEPA filters, then replacement would require the removal of any protective sheet and potentially the work area to be fully decontaminated before any work is carried out. In some cases this will mean a full cabinet fumigation, unnecessary for externally mounted tubes.

Whilst UV lighting is not recommended for use in Safety Cabinets under all major international standards, if it is fitted then the tube should be positioned so as not to disturb the laminar down flow or create any turbulence over the work area when the cabinet is in normal use. If mounted correctly disturbance will be kept to a minimum.

Energy consumption of these tubes is generally around 15-30W but may need consideration if used regularly, especially for longer periods overnight as is common. It is recommended that tubes be replaced after approximately 2000 hours use to ensure the irradiation level is maintained. If mounted correctly disturbance will be kept to a minimum. (see figure 8)

Correct Posture and Front Window Designs

Many Class II Cabinets now employ designs with angled front windows which give ergonomically better seating positions leading to safer and more comfortable operation. The ergonomic design of the environment around the cabinet as well as the cabinet itself plays an important part in ensuring operator safety.

Ergonomics can be described as "The study of peoples' efficiency in their working environment" so any laboratory equipment with an ergonomic design must be conducive to efficient use.

This is an especially important consideration if the user is to be seated for long periods, particularly when handling potentially hazardous biological samples. Angled window designs, when taken together with the arm rests mentioned above, ensure that muscular strains often created across and around the shoulders and neck by incorrect posture are alleviated. Less fatigue leads to a safer working environment.

Correct posture can be achieved by having the upper body position as upright as possible with relaxed tension-free upper arms. When seated the thighs should be under the cabinet and the lower arms should be resting on the arm rests. Operators should ensure that in the seated position they also support their legs, ideally by placing them on the floor or by using a footrest, such that weight is removed from the lumbar region of the lower spine area.

Thought must also be given to the simplicity of front window cleaning as well as sealing for full cabinet decontamination and fumigation when necessary. Designs can be hinged, manually sliding or motorized sliding.

Manually hinged windows were once common but now tend to be going out of fashion due to the requirement of a special "Night Door" to close off the working area. These items can easily become damaged and can often be cumbersome to fit with the result that they are left off, which is extremely bad practice, or worse, lost, meaning that there is nothing available to cover the work area when the cabinet is not in use. Sliding windows, therefore, are a major leap forward in terms of safety and security.

Sliding windows approach the cleaning issue by having mechanisms for fully hinging open or sliding down to allow access to the upper sections.

Fully hinged designs that hinge open outwards and upwards should be counterbalanced with gas dampers to prevent injury to operators when raising them and to ensure they do not drop down during cleaning. If windows need to be held up for the fitting of support bars or brackets then consideration must be given to potential injuries to the cervical spine area of the neck whilst tilting the head back to see where to locate such items. Ergonomically these are not good designs.

Consideration must also be given to the potential risk of any material falling downwards into the face of the personnel cleaning the window especially if hazardous

aerosols have been generated within the work area prior to cleaning and a full decontamination has not been carried out.

A better alternative is to have a window that can be slid downwards past the front edge of the cabinet so that the top part of the window is then accessed from above (see figure 9). This allows a complete clean down of all window areas without the risk to the operator.



Fig 9

Window sealability during fumigation is another main consideration, and with sliding windows it is important to check that they are able to be sealed easily either with a built in seal or by the use of sealing tape. The former design is often preferred since it obviates the necessity for taping the window, although some form of top plate or fumigation box must be fitted to prevent loss of fumigant to the surroundings via the exhaust filter where cabinets re-circulate back into the laboratory. Window seals can also prevent the ingress of particles around the side edges of the window caused by the venturi effect of the downflow air.



Fig 10

Figure 10 shows a typical cabinet with motorized front sash and aerosol tight window seal.

Sliding windows without any form of seal need to be taped securely, especially across the top where the window raising mechanism is placed. Care must be taken to ensure there are no leaks around this area which will be hidden when the window canopy is closed down.

Shatterproof glass should be used at all times with, if possible, a frameless lower edge for good visibility.

Side Windows or Not?



Fig 11

Many manufacturers offer Class II Cabinets with glass side windows and the advantage of this is to offer more natural lighting giving users a more comfortable working environment as well as allowing viewing of the work procedures for training, etc.

Pre-drilled holes allow for pass through of cables, vacuum lines, etc. as well as allowing service fixtures to be fitted easily.

Work Surfaces - Single or Multi-piece?



Fig 12

From an ergonomic viewpoint multi-piece work surfaces are far better as they are lighter to lift for cleaning, can be bagged and removed for autoclaving if required and are available in different sizes to suit most applications.

One-piece work surfaces however, are heavier, more cumbersome to lift and remove for cleaning; but do often have the advantage of containing spillages.

Whichever type is chosen, it must be stressed that a full clean down should be carried out periodically with the work surfaces being removed so the under troughs of the cabinet are also cleaned and disinfected.

Fan Systems

Due to increasing "CO₂" legislation in many countries, Class II manufacturers are now offering lower energy more economical fan systems in a move to reduce energy costs. Whereas high energy demand AC fans were originally employed, new designs employ EC or DC fans with a number of user benefits.

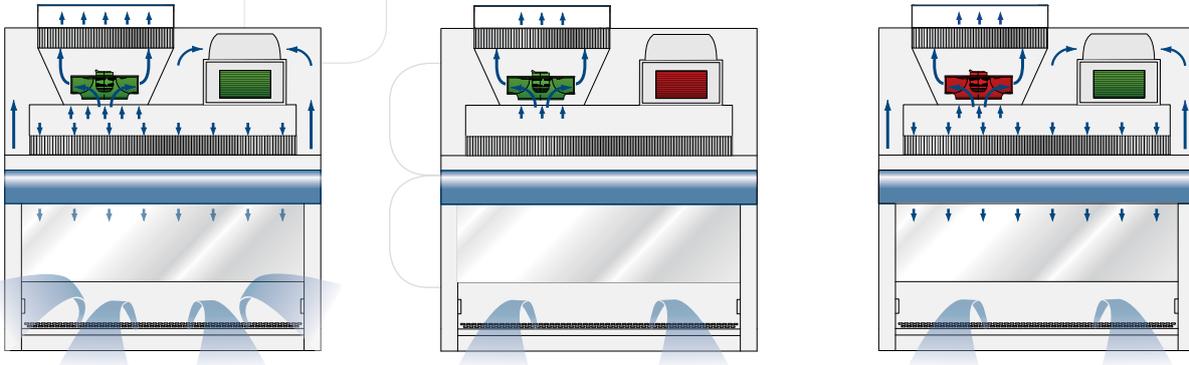
With EC technology, AC from the mains is converted to DC via proprietary electronics which enables up to 90% efficiency to be reached across a very wide speed and load range. This not only saves up to 66% of the energy demand of conventional AC fans but also produces less heat output for cooler working conditions and significantly lowers noise levels. Since the fans can also be run at higher speeds than conventional systems they can deliver higher torque and therefore extend HEPA filter life by maintaining constant flow at higher pressure losses. This lengthens the lifetime of the HEPA filters and reduces general maintenance costs. Energy

consumption can be as low as 170W and 0.7A for a 4ft cabinet with a dual fan system fully operational under normal conditions.

Many cabinets now offer dual fan systems in an attempt to ensure more balanced and even airflows with one manufacturer offering a design that guarantees operator protection in the event of a fan failure. If the exhaust fan fails the main supply fan maintains inflow to provide a level of protection; if the supply fan fails, downflow to the work area is suspended and the exhaust fan maintains inflow for operator protection. (See figure 13).

Dual Fan System

Provides the maximum possible level of safety by enabling safe cabinet shut down in the event of a single fan failure.



1A: Under normal operation with both fans operating (1a) the supply fan creates a negative pressure surrounding the contaminated positive pressure plenum and pushes air across the supply and exhaust filters. The exhaust fan boosts the air pressure through the exhaust filter to create better inflow and operator protection. Supply and exhaust fans automatically operating at reduced speeds extend fan life.

Fig 13

1B: If the supply fan fails (1b), downflow to the work area is suspended. The exhaust fan still provide inflow to the cabinet to help maintain containment. The control panel warns of downflow failure.

1C: If the exhaust fan fails (1c), the supply fan continues to provide inflow to the cabinet and downflow to the work area. The control panel warns of inflow failure.

When comparing energy consumption and "Green" credentials of manufacturers it is important to compare like with like. It is important to know cabinet inflow air speeds and downflow speeds as well as what is operational or not (are lights on and sockets powered or not??) Does the cabinet have a single or double exhaust filter (a requirement under UK regulations if working with Cat 3 material on re-circulating cabinets)?

Some manufacturers offer a "low energy" stand-by situation but these should be treated with caution. If they are designed to operate with the front window at the normal working height then there is a potential risk that operators who are unaware of the cabinet design may work with an incorrect inflow, even if the lights may be off and the alarm flashing or muted. This

is highly dangerous.

Designs that have the window fully closed or closed to a small opening offer a better solution although it must be remembered that when a window is raised to the working height and the fans speed up to normal operating speeds, time must be allowed for the airflows to stabilize before working; otherwise there is still a risk of losing containment. Periods of 3-5 minutes should be allowed for this.

With low energy cabinet designs it is better to leave them running continually through out the day, if in constant use, rather than switching on and off frequently.

Sound Levels

With the advent of lower energy EC and DC fans the sound levels of cabinets have been much reduced as motor noise is reduced. Sound is a major consideration for a comfortable working environment. The main noise level is produced by the air flowing around the cabinets rather than the motor noise. Higher inflow and downflow speeds increase wind noise. Lower speeds lessen the noise, but the speed cannot be reduced below the minimum safety levels otherwise containment is lost.

International standards state that the sound level of a cabinet should not exceed 65dB(A) when the

A-weighted sound pressure level generated by the background is around 55dB(A). Most cabinets today have levels well below this figure but it is important to understand what they mean.

The decibel level is a measurement of sound pressure and being a logarithmic scale sounds are not recorded linearly. The human ear can detect a wide level of sound vibrations, but on the decibel scale a 1dB change is imperceptible, a 3dB change is barely perceptible and 5dB change is noticeable. 10dB is a doubling of sound levels.

Ducted Cabinets

When exhausting a cabinet to atmosphere, three options are available for consideration:

Hard ducting with constant room extract
Hard ducting with room bypass extract
Thimble ducting

Whenever a Class II cabinet is exhausted to atmosphere, there must be thought about the make-up air to the room to ensure the cabinet operates correctly. This make-up air can be supplied via a simple passive flow system, whereby air is taken from the corridor or surrounding areas and drawn into the laboratory through door grilles, or it can be supplied by an active system whereby conditioned air is fed to the room via a ventilation system external to the room. Whatever system is chosen, the decision should be based on a risk assessment for the work to be carried out and within the financial constraints of the budget. The cost of conditioning the air and then losing it via the exhaust ducting when the extract is on can be considerable if large numbers of cabinets are involved.

Passive systems are best for single use hard ducted cabinets in general laboratories where make-up air can be supplied through door grilles. When the cabinet is switched off, no supply air is necessary.

Active systems are best for systems with thimble extracts or by-pass extracts where there may be a requirement to have the room under negative pressure at all times, whether the cabinet is switched on or not.

Thimble extracts are becoming more popular as they are relatively simple to install and operate and do not require a number of dampers as is the case with conventional by-pass systems which often open and close according to the cabinet usage.

A thimble will be extracting all the time and ideally will have a 10%-15% higher extract rate than the cabinet extract volume to ensure the room is kept under negative pressure as well and to account for any changes to the cabinet inflow speeds.

Fumigation and Decontamination

Decontamination or full fumigation of safety cabinets as opposed to daily clean down and disinfection before and after working, should be carried out periodically in accordance with local country regulations in force at the time.

Traditionally this has been to boil off formaldehyde inside the cabinet, generally overnight and either neutralise it after the dwell time with ammonia or vent the gas to atmosphere through an extract system.

More recently, the use of vapourised hydrogen peroxide has been offered with savings on both time and environmental damage when compared to formalin.

Whichever system is chosen, thought must be given as to how the cabinets are to be vented after the fumigation

is complete and a full risk assessment and methodology should be in place.

Ducted systems are perhaps the most convenient since the extract fans can be used in the normal way to vent the cabinets.

Re-circulating cabinets will require more thought as to coverage of the exhaust filter and safe removal of the fumigant.

With all cabinets however, it must be ensured that cabinets are fully sealed and there is no risk of leakage back to the laboratory.

Summary

It can be seen, therefore, that the modern Class II Safety Cabinet is a well proven piece of equipment that offers laboratory personnel not just safe and comfortable working conditions, but also savings on energy and running costs with low maintenance leading to less down time as well as a low carbon footprint.

Specifying features as discussed will help organizations and users meet their green targets.

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