Clean Air Technology Management In Hot And Humid Climates Such As The Gambia

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Abstract

Clean air technology management is one of the key requirements in research. Maintaining the technology is a major challenge in hot and humid climate like The Gambia. Situated at the mouth of the River Gambia, Medical Research Council Unit, The Gambia has been constantly improving its clean air systems that support and ensure safety around the medical research facilities.

The containment laboratories at the MRC Unit, The Gambia are now appropriately redesigned to prevent and control the exposure of laboratory workers, those around the labs and the environment to the biological agent used. PuriCore International in collaboration with local technologist at the MRC Unit, The Gambia were able to overcome the challenges by designing an efficient system and provided training for users as well as technologist to maintain the facility.

1 Introduction

PuriCore is an International company that acquired Labcaire Systems in August 2010, a company that has been in the Clean Air Technology business for over 30 years. PuriCore saw the need for the provision of appropriate Laboratory Containment Level 3 facilities in hot and humid countries and has since developed a unique systems that allow constant monitoring, ensure low energy consumption, and user maintenance friendly, thus providing 24/7 containment to research facilities and adequate protection to employees and others from Biological work with Biological agents which are capable of causing severe disease and propose a serious hazard to employees and surrounding environments. PuriCore manufactures all types of Microbiological Safety Cabinets, L.E.V.’s, Fume Cupboards, down flow Benches and specific bespoke equipment for both UK and International customers around the world today.

2 Background and Concept

While no specific air exchange rates are mandated in the relevant standards and guidelines for the design of Containment level 3 laboratories, the need to provide secondary containment to protect the external environment, by operating the containment at air exchange rates capable of dilution of the pathogenic aerosols within a realistic time scale is recommended. For example, at the rate of 12 air changes per hour, a spillage of 20ml of a log 10⁸ spores/ml of pathogenic material would be diluted 99.99% within 58mins and by a further 99.9% after another 35minutes i.e. the concentration would have dropped to 0.05spores/m³, the laboratory will be almost free of any air born spores. (mon) This suggests that air change rates of this order are acceptable but an important factor for consideration is the energy cost of pre conditioning the room make up air at this change rate. The mixing of supply and re-circulated room air is not permitted within a containment level 3 laboratory, therefore total loss systems are required with contingent operating costs. Reducing the high energy cost associated with laboratory environmental conditioning systems is now the subject of an initiative originated by the US environmental Protection Agency designated Lab 21 and this has also been adopted in the UK. Therefore, if the requirements to provide operator protection via primary containment and environmental protection via secondary containment could be separated without compromising safety, the number of air changes required per hour could be reduced to that required to achieve operator comfort conditions with a corresponding saving in energy costs. If ducted MSC’s were replaced with recirculation MSCs, an acceptable dilution rate and secondary containment could be achieve in the event of a spillage by filtration through the cabinet HEPA filters enabling the room air change rate to be determined on the basis of satisfying operator comfort conditions rather than secondary containment. The lab extract ventilation could be achieved by utilising a number of the existing MSC axial fans connected to the existing passive make up transfer grills with new HEPA filter box plenum chambers, or by installing purpose designed wall mounted HEPA filtered extract units in each lab, in either case controlled by differential pressure sensors.

3 Establishing Standards in Cat 3 labs Clean Air Systems

In 2006 the Biomedical Head of Department at MRC Gambia consulted Labcaire Systems to evaluate, Validation and Certify of all their safety cabinets in and around Gambia. From that point on extensive development of their facilities took place including significant replacement of MSC’s (Microbiological Safety Cabinets) that were over 20 years old in some cases and set out a plan for biomedical engineering Technologist to be trained as Service Engineers for the equipment on site.

In early 2010 Puricore was asked to come up with a project to design a system for a Category 3 facility at MRC Gambia, bearing in mind climate and conditions, after a system had proved costly and mainly ineffective in providing the necessary compliance for such a facility.
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Class I and Class II safety cabinets were used to provide inadequate negative pressures for Laboratories and when readings were taken and analysed provided very little containment and extensive running costs for MRC.

Q. What are the criteria for Category 3 Laboratories in hot and humid places?
A. The same as in the UK!

There was no difference in design or criteria with systems in the UK as temperature and humidity levels had not been taken into consideration, here’s where it began. Five main points were discussed as follows:-
1. What provisions would we need to build a Cat 3 Laboratory
2. How could we design a low maintenance system
3. How could we keep costs down
4. Environmental issues
5. Continued compliance and Validation

4 Conditions and Proposals

After inspection of a CAT 3 laboratory that had recently been installed at Fajara, it was found that the system could not cope with the sudden temperature drop from outside at 35-38°C to the level needed for a comfort zone in the laboratory of 21-23°C as in Figure 1.

Figure 1: AC units working flat out reducing air temp from 35-40°C to approx 23°C back out to atmosphere

The volume of air passing through the lab using a ducted fume hood and class II microbiological safety cabinets was causing a ‘rain’ affect in the laboratory itself and after major additions to the system (Extra AC building facility feeding the Labs) at a significant extra cost to the budget. This was overcome. Not only had the temperature and humidity not been taken into consideration the energy cost also increased having to run the extra AC facility.

Questions were asked by PuriCore:-
1. Why in such conditions were safety cabinets used as extract units for the Laboratory?
2. Why could the building not have had a separate filter extract system rather than a separate supply system?

Looking at the standards [the following four options were available to us:

4.1 OPTION 1

Retaining the existing ducted MSCs

Install a packaged air handling unit in the service loft space to cool and dehumidify the passive make up air supply. Locate a plenum chamber over the loft access hatch in the entrance corridor and replace the hatch with a transfer grille. Fit blanking plates over the existing ceiling mounted transfer grilles.

Install replacement double entrance doors with effective seals.

Install replacement lab and lobby doors with effective seals and fitted with transfer grilles complete with balancing dampers.

Install a differential pressure monitoring device in each lab with a signal output to an indicator panel and audible warning device with the ambient pressure sensor in the entrance corridor. If insufficient MSCs are operating to maintain the secondary containment at a minimum negative differential pressure of 30 Pa, the alarm will prompt the operators to switch additional cabinets on.

Advantages:
Minimum capital cost and disruption to the labs
High dilution rate for secondary containment achieved via the MSCs when operating

Disadvantage: The operating cost of preconditioning 18-27 air changes per hour for a 100% total loss system

The operating cost of running the minimum number of MSCs required to achieve the secondary containment when not all of the cabinets need to be in use for research Sustaining the secondary containment is subject to operator fallibility.
4.2 OPTION 2
Retain the existing ducted MCSs.

Install a packaged Air Handling Unit (AHU) in the loft space to cool and dehumidify the passive make up air supply. Locate a plenum chamber over the loft access hatch in the entrance corridor and replace the hatch with a transfer grille. Fit blanking plates over the existing ceiling mounted transfer grilles.

Install replacement double entrance doors with effective seals.

Install replacement lab and lobby doors with effective seals and fitted with transfer grilles complete with balancing dampers.

Install purpose design, wall mounted, HEPA filtered, packaged extract units in each lab controlled by a differential pressure monitoring device with the ambient pressure sensor in the entrance corridor. If insufficient MSCs are operating to maintain the secondary containment at a minimum negative differential pressure of 30 Pa, the wall mounted unit would operate.

**Advantage:**
High dilution rate for secondary containment retained without operating the MSCs continuously.

Negative differential pressure achieved at lower air change rate per hour by secondary extract units when MSCs are not operating.

Secondary containment maintained automatically

**Disadvantages:**
The operating cost of preconditioning 18 – 27 ACH for 100% total loss system when the MSCs are operating.

4.3 OPTION 3
Replace the ducted MSCs with recirculation MSCs

Install a packaged Air Handling Unit (AHU) in the loft space to cool and dehumidify the passive make up air supply. Locate a plenum chamber over the loft access hatch in the entrance corridor and replace the hatch with a transfer grille. Fit blanking plates over the existing ceiling mounted transfer grilles not required for lab extract.

Install replacement double entrance doors with effective seals

Install replacement lab and lobby doors with effective seals and fitted with transfer grilles complete with balancing dampers.

Replace number of the existing passive make up filter boxes in each lab with the purpose designed filter box/plenum chambers to enable the existing MSCs extract fans to be connected via new ductwork.

**Advantage:**
Lower operational cost as room air change rates during normal operation are base on the achievement of the operator comfort conditions rather that secondary containment.

Some components of the existing system can be reused

Acceptable dilution rate for secondary containment achieved via double HEPA filtration in the recirculation MSCs and the extract filter box/plenum units

Negative differential pressure achieved at lower air change rates per hour

**Disadvantage:**
Slight disruption of work
The condition of the existing facility may be poor affecting reliability.

4.4 OPTION 4
Replace the ducted MSCs with recirculation MSCs

Install a packaged Air Handling Unit (AHU) in the loft space to cool and dehumidify the passive make up air supply. Locate a plenum chamber over the loft access hatch in the entrance corridor and replace the hatch with a transfer grille. Fit blanking plates over the existing ceiling mounted transfer grilles not required for lab extract.

Install replacement lab and lobby doors with effective seals and fitted with transfer grilles complete with balancing dampers.

Install purpose design, wall mounted, HEPA filtered, packaged extract units in each lab with a nominal design duty base on achieving operator comfort conditions, 4 – 6 ACH but capable of achieving secondary dilution by purging the lab at a minimum of 12 ACH. The units would be controlled by a differential pressure monitoring device in each lab with the ambient pressure sensor and programmable controller in the entrance corridor. The controller would be programmable to maintain a minimum negative differential pressure in the lab of 30 Pa during normal operation with a manual override option to increase the fan speed and the lab if required.

**Advantage:**
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Lower operational cost as room air change rates during normal operation are base on the achievement of the operator comfort conditions rather that secondary containment

Acceptable dilution rate for secondary containment achieved via double HEPA filtration in the recirculation MSCs and the wall mounted extraction units.

Negative differential pressure achieved at lower air change rates per hour by wall mounted extract units highest capital cost option

Disadvantages:
Significant disruption to the labs

5 Conclusion

There are several aspects of the existing laboratory design that are cause for concern; the first is safety related in the lab. Secondary containment maybe compromised if some MSCs are inoperative as insufficient negative differential pressure is created. Conversely, when all the MSCs are operating in a lab, air change rates are higher than necessary to create comfort conditions for the occupants and cause a lab environment problem as the room split air conditioning system unit create local cold spots that dehumidify the ambient make up air creating precipitation.

A range of solution to these problems is offered but the introduction of an appropriate make up air preconditioning system is a prerequisite to all solutions proposed. An improvement to the lab containment could be achieved in a number of ways, each offering both advantages and disadvantages, but ultimately the option chosen relates primarily to whether a higher initial capital cost can be justified by lower whole life operating cost or that capital budget constrains will dictate the selection of a lower capital cost, higher operating cost option.

In Category 3 labs, negative pressure can be achieved by any one of the following:

1. extracting the laboratory air through independent ducting to the outside air through a HEPA filter (or equivalent)
2. extracting the laboratory air to the outside air with a fan and HEPA filter (Or equivalent) sited in a wall or window of the laboratory
3. ducting the exhaust air from the microbiological safety cabinet to the Outside air through a HEPA filter (or equivalent)
   i. ;
4. A safe variation of these methods.

At the time MRC Fajara were looking to refurbish there old Category 3 suite and using option a) we set about the task

6 Design, Low Maintenance, Costs and Environment

We kept the design as simple as possible which offered a very reliable and fully monitored system and knowing the climate through previous visits PuriCore were able to extract air at a considerable reduction (6AC/Hour) yet still keeping within the recommendations laid out by the British and European standards and recommendations committee [ref: ]. Using Puricore’s new design we could set any laboratory up without using 20-30 AC/Hour thus reducing running costs dramatically and using the system to provide energy efficiency at its highest. Laboratories could then choose what type of cabinets they needed for their specific work using double HEPA filtration, carbon filtration on both cabinet and extract to atmosphere.

Another feature of the design was the need for alarm points for continuous running of negative pressure i.e. maximum and minimum pressure levels, parameters, time delays for doors open and lockable entry to the facility. Pathogenic material within the laboratory was a point raised by the Head of Biomedical engineering at the time and an emergency contingency was put in place to double the air change per hour should an event occur by means of an override switch that put the extract on high, doubling the volume of air extraction.

It was decided that the Air inlet plenum would also have HEPA filtration protected with pre-filters, again avoiding the need to keep replacing the HEPA filters yearly and replacing the pre filters once every 3-6 months dependant on regular inspections and maintenance.

To avoid the need for a sudden temperature drop the temperature of the air would be dropped gradually (See Slide) avoiding the ‘rain’ effect and the build up in some cases of mildew in the old laboratories which can cause illness to the respiratory system in humans.

Another large saving in energy were the AC units in the lab which were running at 100% output trying to keep up with the need of a constant temperature of 23°c as seen in Figure 2.
By reducing the AC/hour and keeping within the guidelines the conditioning units were able, once down to the set temperature, to run 60-75% less by recirculation of the air within the room more efficiently.

A fumigation system was designed so the lab could be fully fumigated at weekends avoiding the need for any of the facility to be shut down, a simple modification to the system to extract the decontamination used could be fit within 5 minutes and dispersed safely above the buildings and into atmosphere.

Since this fumigation extract system has been designed Puricore have now under development their own decontamination system avoiding the use of Formaldehyde and using a cleaner and safer chemical. 

Continued Compliance and Validation

Slide 10

Once the system had been installed into one laboratory, two more systems were ordered and the facility at Fajara is now validated by their own biomedical engineers. MRC Biomedical engineers at Fajara were then trained on the following:

1. Category 3 laboratory maintenance and continued compliance
2. Safety cabinet testing and validation
3. Hepa filter testing
4. Fumigation procedures for both Lab and Safety cabinets
5. End user training and recognising the importance of continuous monitoring
6. QC procedures for continued compliance (Standards etc)

Whereas before the need for an engineer to visit from the UK for 2-3 weeks/year is now kept down to a minimum with a yearly quality control/update visit to re-certify all engineers to British and European standards.

Acknowledgements

The acknowledgement for funding organisations etc. should be placed in a separate section at the end of the text.

Thank you for your cooperation in complying with these instructions.

References

BS EN ISO 14644-5: 2004 Clean rooms and Associated Controlled Environments – Part 5: Operations

BS 5295-0:1989 Environment cleanliness in enclosed spaces

BS 5295-4: 1981 Specification for monitoring