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These comments are intended to encourage the review and discussion of several design options used in critical spaces.

**Bio Containment HVAC design**

Air Flow measurement and control are a major consideration for the HVAC design of the design and commissioning of BL 3, 3+ and 4 laboratories. In this paper we discuss some ideas concerning air flow measurement and control

Just to review some fundamentals let us present some definitions of Bio Containment Laboratories and  additionally suggest other groups which are also interested in Bio Containment facilities.

**The levels of laboratory are often defined as follows**

BSL-1   Normal laboratory with no special provisions

BSL-2  Moderate risk- use primary and secondary barriers and space pressurization

BSL-3  Agents pose an aerosol Risk. Significant emphasis on primary and secondary barriers

BSL-4  Agents are Lethal  with no known therapy

**There are several sources of good information concerning Bio Containment facilities**

- Industry conferences and seminars such as Labs 21 ( sponsored by the EPA) provide peer comments and recommendations.
- Various codes and standards and guidelines are easily available on the internet . Among the most prominent are Health Canada, CDC/ NIH " Bio Safety Guidelines, and ASHRAE Fundamentals Handbook
- Various equipment manufacturers and suppliers can offer specific suggestions when applying to their hardware. Some of the manufacturers  offer microbiological Hoods laboratory furniture,

control systems as well as air flow measurement and control components

Clearly BSL-3 ,BSL3 + and BSL-4 spaces do require specialized system design and hardware selection.

**Our interest in Bio containment facility design**

Our role in BSL3 ,3+ and 4 is as a designer and manufacturer of very accurate and time proven air flow measurement and control equipment for critical spaces. Our equipment is particularly suited for the BL spaces listed above as well as Pharmaceutical manufacturing facilities and Clean spaces

We are active in various technical committees and participate in seminars concerning critical spaces. We believe that we should share comments from these meetings as well as experiences from other projects for the benefit of others. We encourage additional comments from others.

Our underling goal is to help to design and deliver an HVAC system that operates in a predictable accurate manner. The following comments are offered for consideration by those interested in advancing the safety and efficiency of these critical spaces.

**May we share the following comments**

We believe that the commissioning requirements should be a fundamental portion of HVAC design and should be considered early on in the design process. Commissioning personnel can share their experiences which should help to minimize surprises. Some commissioning guidelines suggest that "the systems be subject to various operating and failure modes" which are often not clearly analyzed during the design process. We recall clearly the complaints from an experienced commissioning agent trying to obtain repetitive readings at lower (unoccupied ) flow rates using a well known sensing system . Left unresolved was the cause of the problem- the hardware, the system or the technical skills – or all three.

We encourage modeling the performance of these systems. CFD modeling of velocity contours under various loadings can provide some excellent advice. Example –Locations of Supply and exhaust points to manage room velocity contours. As a part of our services we use several simple models to help apply our hardware to real spaces- easy to make changes at this stage.

Other ideas follow which are specific to certain areas

- Air flow management schemes
- Control schemes
- Air Flow measurement and control hardware requirements.
- Failure of various HVAC components

**Air Flow Management Schemes**

1. When using volumetric offset the magnitude of the offset should be determined.This offset magnitude should be constant through occupied and (if included) unoccupied conditions. Possible measuring and control errors should be examined. These errors are easily modeled.

2. During normal “Steady State“ conditions room air flow patterns can be fairly easily evaluated. If emergency or purge requirements are included in the air flow design the steady state air flow patterns are significantly disturbed by the higher volumes of air. Air flow patterns and offsets should be evaluated during these “off design” conditions

3. A small secondary or trim valve can be selected to closely manage either the volumetric offset or the room pressure.

**Control Schemes**

1. Control loops must provide dependable and repeatable signals with enough processing speed to manage the offset. The “end to end” response time for the control loops and the control air flow control devices must be predictable enough to assure that the space does not go positive. The aerodynamics of the space are an important part of these determinations.

2. Feed back based directly on air flow should always be used because it directly determines the offset. Inferential feedback should not be used because it introduces another control variable which complicates control of the offset.

3. Possible field measurement errors should always be a part of the design calculations

## Air Flow measurement and control hardware requirements

Air Flow control

1. The method of throttling the air by the damper will determine the accuracy and the repetition of the damper performance. The air streams will follow the profile of the blades. Throttling should not create vortices (turbulent flow within dead spaces) on the leaving side of the blades These vortices are very hard to control and will contribute to hystersis and non linearity. Examples of blade designs which create hystersis are OBD and parallel blade damper designs.

2. The air flow control damper performance must be accurate and repeatable during the varying system pressures Example ---loads will vary in the space and the flow rates and offsets will have to vary accordingly. We often see space designs with a maximum flow rate of 4 times the minimum flow rate. These systems can be constant volume with a scheduled possible maximum constant volume and a scheduled possible minimum volume and the expected operating volume. The dampers and flow sensors must be able to operate accurately and independently of pressure changes within the duct work within this flow range. The dampers must be able to track at the high and low flow rate without compromising the amount of the offset. This accuracy and pressure independence should be established by either a witness test or modeled in software.

3. The air flow control device should be selected as close to midrange control pressure as possible and then compared to the characteristics of the transducer (actuator). Transducers (actuators) are often furnished by others and quite likely do not have the same characteristics (zero and span ) as the control device. Field calibration of an actuator can be time consuming as well as inaccurate. During selection the performance curves of both the actuator and the damper should be overlaid to assure accurate control at both high and low flow rates and duct pressures

4. Often a space has to be closed during operation to maintain validation of the performance of the HVAC system. Rather than closing the space one can independently confirm the proper operation of the HVAC system. One method to independently confirm system performance is to provide a simple “stand alone” air flow monitor with a local display and referenced to an independent location.

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**Failure of various HVAC components**
**(Emergency Power)**

Potential failure of terminal devices should always be a part of the design consideration. While the results of a single component failure can be estimated the extended effect on other devices should be well analyzed.

One common goal is to maintain a low level of control and try to continue some degree of safety until the failure is corrected.

A few of modes of failure and their potential results are discussed. There are more which should be considered and evaluated.

- Failure of a pneumatic signal between the transducer and the bladder damper will cause the damper to fail open. Modeling air change rates and room velocity contours with wide open flow can predict any undue exposure to unsafe conditions. Often a simple independent local pneumatic control loop can maintain partial control and some occupant safety.

- Failure of instrument air to the transducer
    a. Exhaust system

        Without a source of supply instrument air the transducer will continue to bleed exhausting the instrument air within the damper. The exhaust damper will become open and the space will become more negative

    b Supply system

        Without a source of supply instrument air the transducer will continue to bleed exhausting the instrument air within the damper. The supply damper will open fully and the space will become less negative

- Failure of an analog signal from the transmitter or to the transducer
    a. Transmitter

        If a failure internal to the transmitter the signal will fail to zero which will be received by the building computer and acted upon accordingly.

    b. Transducer

        If loop powered the analog signal will fail toward a no signal condition and the transducer valve will fail open (no pneumatic signal). The damper will then fail open with the resulting change in offset and space pressures.