An Examination of Air Handling Systems Installed in Jefferson Lab's End Station Complex

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I. INTRODUCTION

The air handling systems in Jefferson Lab's end station complex[1] are critical elements of both the life safety and machine safety systems. During the Lab's operational lifetime, as well as the recent upgrade period, significant modifications have been made to our electrical and mechanical infrastructure. In some cases, these changes have had unplanned impacts on the operation or reliability of the air handling systems installed in the experimental halls. Further, some planned changes to the system configuration have not been fully documented, or have resulted in portions of the existing documentation becoming invalid.

Because these mechanisms are key components in both the life safety and machine safety systems for the halls, it is essential to maintain a clear understanding of their capabilities and intended use. This document details the current configuration of the air handling systems in the end station complex and will provide a description of how the equipment is currently used. During the course of this discussion, any observed deficiencies in the existing configuration will be identified along with recommended corrective actions and alternative solutions for dealing with unexpected failures.

II. CURRENT CONFIGURATION

1. Types of Fans and Air Handler Units

The experimental halls and their truck ramps are each equipped with a variety of air handling systems, each of which serve different purposes. These systems are a) smoke removal fans, b) outside air supply fans, and c) climate control systems. The function of each of these systems is described in the following sections.

a. Smoke Removal Fans

The smoke removal fans in the halls and truck ramp are designed to exhaust air outward from the hall and draw fresh air in through the open truck ramp doors and the outside air intake dampers.

By design the smoke removal fans in the truck ramp are isolated from those within the halls. Because of the functional differences between the hall and truck ramp smoke removal fans, each type will be addressed separately in the following sections.

i. End Station Smoke Removal Fans

The smoke removal fans in each of the end stations are designed to remove at least 36,000 CFM of air when all fans are operating.

At least one smoke removal fan in each hall can be operated in low-speed mode using a switch located on the wall *(see Figure 1)*. When operated in low speed mode, it is not necessary to open the truck ramp doors.

Figure 1. Low Speed Fan Switch

All smoke removal fans in the hall are activated simultaneously by a "pull button" located at the bottom of the truck ramp *(see Figure 2)*. When this button is activated, the

[1] The end station complex includes Experimental Halls A, B and C which were part of the original CEBAF installation. Experimental Hall D is geographically separate from the original end stations and will be referred to as the Hall D Complex.

upper and lower truck ramp doors are automatically opened before the fans begin operating.

Note: The activation of the fans appears to be based on a timer that provides sufficient time for the doors to open. It is uncertain if there is an interlock that ensures the doors are open before the fans begin operating.

Figure 2. Smoke Removal Button

The smoke removal fans in each hall may also be independently activated from the fire alarm panel in the Machine Control Center *(see Figure 3)*. This panel is located in the computer room that is immediately adjacent to the main control room in Building 85. The fan control switches are labeled with the facilities device identifier for each unit. This requires the operator to have documentation to discern which dials are associated with each fan in each hall.

Finally, according to Section 15972 of the CEBAF Sequence of Operation document published on 12 October, 1990, the fans in all halls are automatically activated by ceiling mounted smoke detectors located at dome level. At the time of this document, Facilities Management believes that these smoke detectors have been removed from the system and that the smoke removal fans have **not** been reconnected to the new heat sensors and VESDA fire system.

Figure 3. Fan Controls in the MCC

ii. Truck Ramp Smoke Removal Fans

In each truck ramp there is one dedicated smoke removal fan. This fan is located at the bottom of the truck ramp and is activated by either a) the "pull button" at the top of the truck ramp, or b) a switch on the fire alarm panel in the Machine Control Center. The Sequence of Operation document (1990) does not identify any smoke detector based automatic activation for these fans, but does indicate that they can be automatically activated by the fire alarm system.

When activated, this system will automatically open the upper truck ramp door and will leave the lower truck ramp door closed. If the lower truck ramp door is already open, it will remain open.

Note: As with the end station smoke removal fans, it is uncertain if the truck ramp door and the smoke removal fans are connected via an interlock or if the operation of these systems is timer based.

b. Outside Air Supply Fans

One outside air supply or "fresh-air" fan is installed in each of the experimental halls. These fans are mounted at or near the ceiling and deliver 1,300 CFM of fresh air into the hall.

The outside air supply fans are required to operate continuously and their capacity is used to compute oxygen deficiency hazard (ODH) requirements for the hall.

c. Climate Control Systems

In addition to the fan systems described earlier, the halls are also outfitted with HVAC units that provide climate control. Unlike typical industrial HVAC systems that also provide fresh air, these systems can only condition and recirculate the existing air within the hall.

The units installed in the halls are a combination of direct expansion (DX) units, which rely on a separate heat exchanger installed on the exterior dome of the hall; and chilled water (CW) systems which rely on a large cooling tower located near the end station complex.

In concert, all three of these mechanical systems provide specific services to the hall to meet life and machine safety requirements as well as maintain a comfortable working environment. In the following sections the locations and capacities of the specific fan and climate control systems in each hall will be identified.

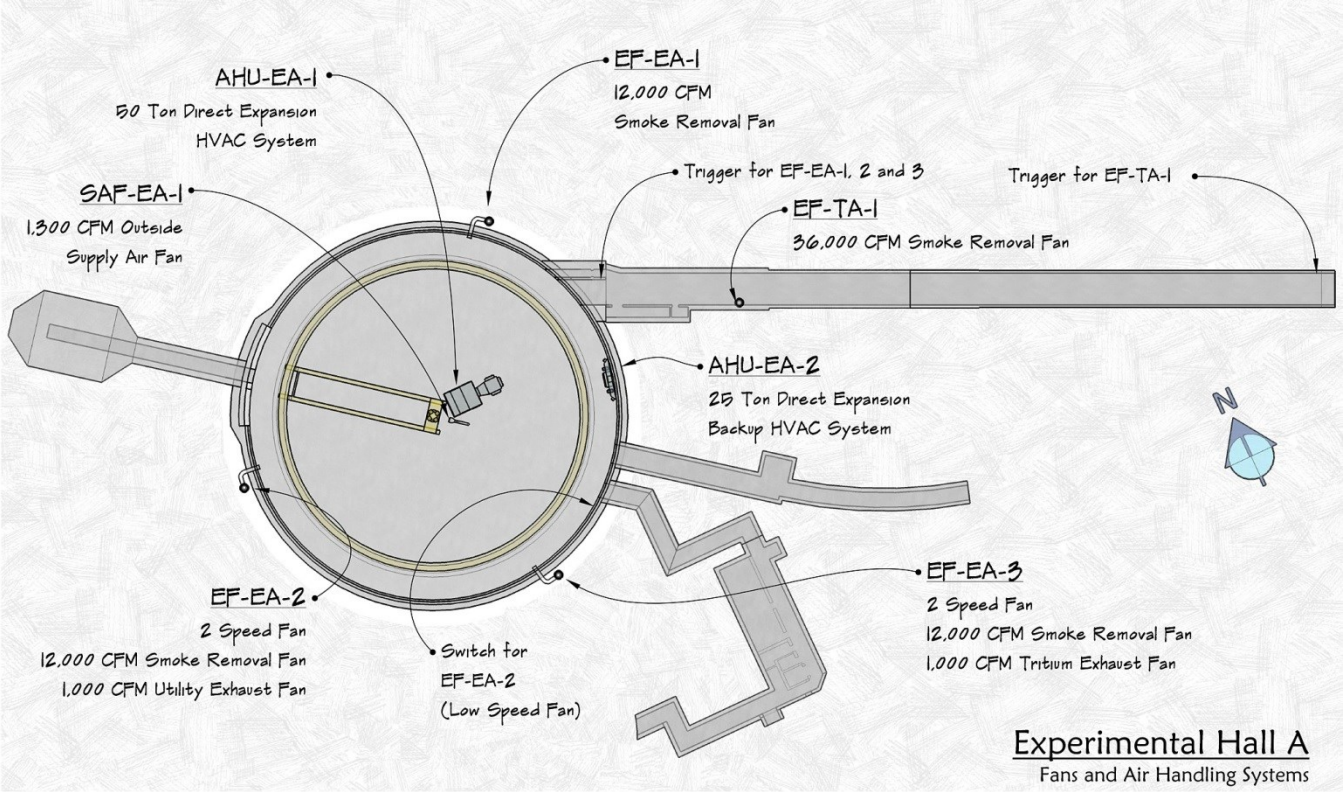

Figure 4. Systems in Experimental Hall A

2. Air Handling Systems in Hall A

Figure 4 shows the fans and air handling systems that are currently installed in Experimental Hall A. The following sections discuss their capacity, configuration and operation.

a. End Station Smoke Removal Fans

Hall A has 3 smoke removal fans that provide a total of 36,000 CFM of air flow when operating. The fans are collectively triggered using the pull button which is located outside the personnel door at the bottom of the truck ramp. They may also be triggered individually from the fire alarm panel in the MCC.

When activated these fans will automatically open the upper and lower truck ramps before beginning operation.

The following fans are included in this group:

i. EF-EA-1

Located on the north side of Hall A's exterior dome, this is a single speed fan that provides 12,000 CFM of air flow. This fan is supported by the Counting House generator.

ii. EF-EA-2

Located on the southwest side of Hall A's exterior dome, this is a two speed fan that provides 12,000 CFM of air flow for smoke

removal and 1,000 CFM of air flow when used as a utility fan.

A manual switch to activate the low-speed mode for this fan can be found in the hall at the location shown in Figure 4. This fan is supported by the Counting House generator.

iii. EF-EA-3

Also referred to as the *Tritium Fan*, EF-EA-3 is located on the southeast side of Hall A's exterior dome. It is a two speed fan that provides 12,000 CFM of air flow for smoke removal and 1,000 CFM of air flow in support of the tritium enclosure. A damper is installed that allows the fan to draw from the entire room when used for smoke removal, or from a smaller enclosure when required for tritium operations.

It should be noted that there is no independent switch for operating this fan in low speed mode. For low speed operations, the variable speed fan on the dome of Hall A will be dialed down while the air flow is measured in the hall with an anemometer. Once the proper air flow is achieved, the fan will operate in this mode until restored to normal operation. Like the others, this fan is supported by the Counting House generator.

b. Truck Ramp Smoke Removal Fan

The Hall A truck ramp has a single, 36,000 CFM smoke removal fan that is located near the bottom of the truck ramp. This fan is designated EF-TA-1 and can be activated by the pull-button near the personnel door at the top of the truck ramp, or from the fire alarm panel in the MCC.

When triggered, this system will open the upper truck ramp roll-up door before activating the fan. The lower door, unless already open, will remain closed. This fan is supported by the Counting House generator.

c. Outside Air Supply Fan

Hall A is supported by a single outside air supply fan that is mounted at the top of the dome near the HVAC system. The fan, shown in figure 4, is designated SAF-EA-1 and it provides 1,300 CFM of fresh air. The fan is designed to operate continuously and is the only regular source of fresh air exchange for the hall. This fan is currently supported by commodity power and has no generator support.

Note: This is the fan that is used for ODH calculations in Hall A.

d. Climate Control Systems

Hall A has two installed HVAC systems.

i. AHU-EA-1

Shown in figure 4, this is a 50 ton, direct expansion HVAC system that is mounted above the crane rails inside the hall. This unit provides continuous cooling to the hall, but provides no fresh air exchange. It is supported by a heat exchanger that is mounted on the exterior dome of Hall A (not shown in figure).

ii. AHU-EA-2

This is a backup HVAC system that is mounted on the northeast wall of Hall A. It provides 25 tons of cooling capacity and is used to support hall operations when the primary air conditioning system is being repaired or maintained. Like the primary system, this air conditioner also has a heat exchanger mounted on the exterior dome of the Hall.

This unit is normally NOT in operation.

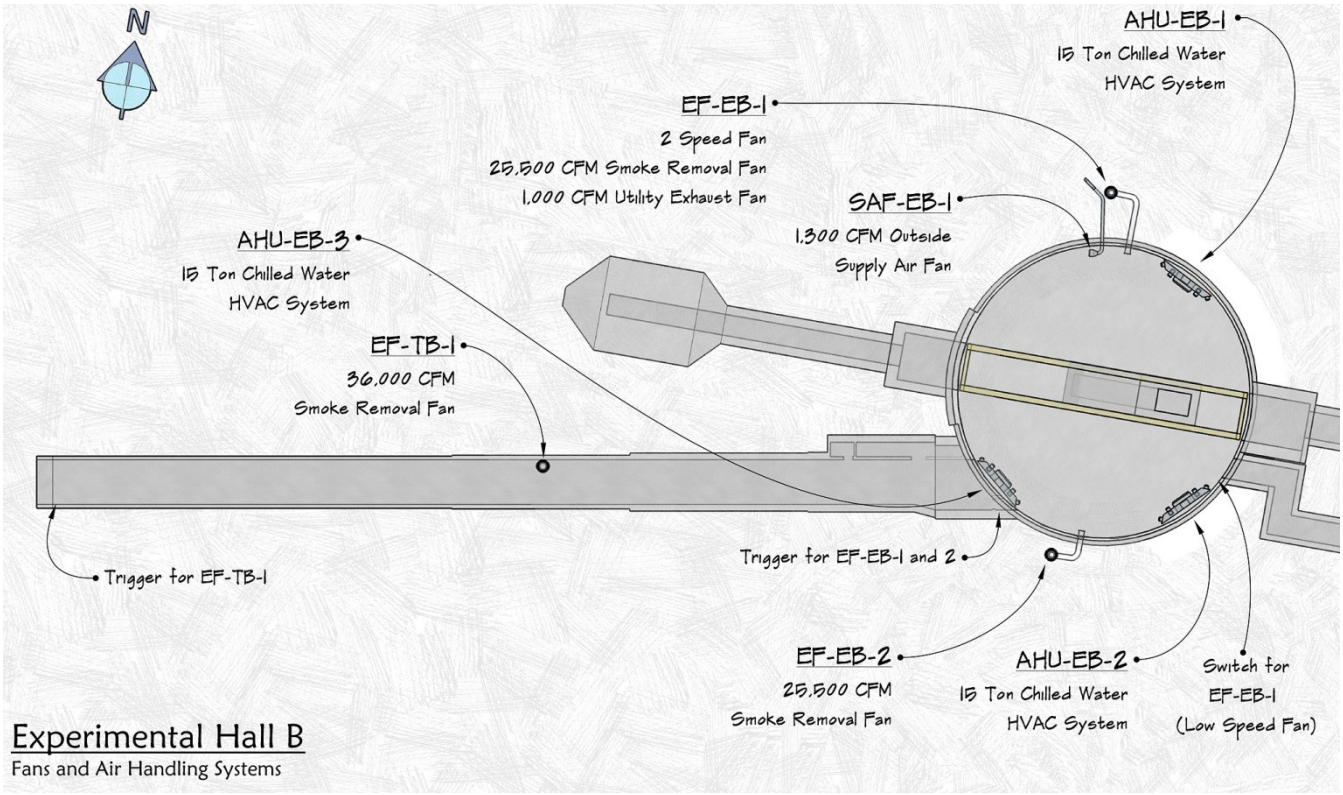

Figure 5. Systems in Experimental Hall B

3. Air Handling Systems in Hall B

Figure 5 shows the fans and air handling systems that are currently installed in Experimental Hall B. The following sections discuss their capacity, configuration and operation.

a. End Station Smoke Removal Fans

Hall B has 2 smoke removal fans that provide a total of 51,000 CFM of air flow when operating. The fans are collectively triggered using the pull button which is located outside the personnel door at the bottom of the truck ramp. They may also be triggered individually from the fire alarm panel in the MCC.

When activated these fans will automatically open the upper and lower truck ramps before beginning operation.

The following fans are included in this group:

i. EF-EB-1

Located on the north side of Hall B's exterior dome, this is a two speed fan that provides 25,500 CFM of air flow for smoke removal and 1,000 CFM of air flow when used as a utility fan.

A manual switch to activate the low-speed mode for this fan can be found near the entrance to the labyrinth as shown in Figure 5. This fan is supported by the Counting House generator.

ii. EF-EB-2

Located on the south side of Hall B's exterior dome, this is a single speed fan that provides 25,500 CFM of air flow. This fan is supported by the Counting House generator.

b. Truck Ramp Smoke Removal Fan

The Hall B truck ramp has a single, 36,000 CFM smoke removal fan that is located near the bottom of the truck ramp. This fan is designated EF-TB-1 and can be activated by the pull-button near the personnel door at the top of the truck ramp, or from the fire alarm panel in the MCC.

When triggered, this system will open the upper truck ramp roll-up door before activating the fan. The lower door, unless already open, will remain closed. This fan is supported by the Counting House generator.

c. Outside Air Supply Fan

Hall B is supported by a single outside air supply fan that is mounted on the north wall, near the exhaust port for the smoke removal fan. This fan, shown in figure 5, is designated SAF-EB-1 and it provides 1,300 CFM of fresh air. The fan is designed to operate continuously and is the only regular source of fresh air exchange for the hall. This fan is currently supported by commodity power and has no generator support.

Note: This is the fan that is used for ODH calculations in Hall B.

d. Climate Control Systems

Unlike Halls A and C, Hall B is supported by three continuously operating chilled water HVAC systems that provide redundancy in the event of failure or maintenance activities. These are:

i. AHU-EB-1

Shown in figure 5, this is a 15 ton, chilled water HVAC system that is mounted on the northeast wall, below the crane rails. This unit provides continuous cooling to the hall, but provides no fresh air exchange. It is supported by a cooling tower located adjacent to Building 92 (not shown in figure).

ii. AHU-EB-2

This is the second chilled water HVAC system. It is a 15 ton unit located on the southeast wall of Hall B, below the crane rail. It provides no fresh air exchange and is also supported by the cooling tower near Building 92.

iii. AHU-EB-3

The final chilled water HVAC system, is a 15 ton unit located directly above the truck ramp door on the southwest wall of Hall B. Like the others, it provides no fresh air exchange and is support by the cooling tower at Building 92.

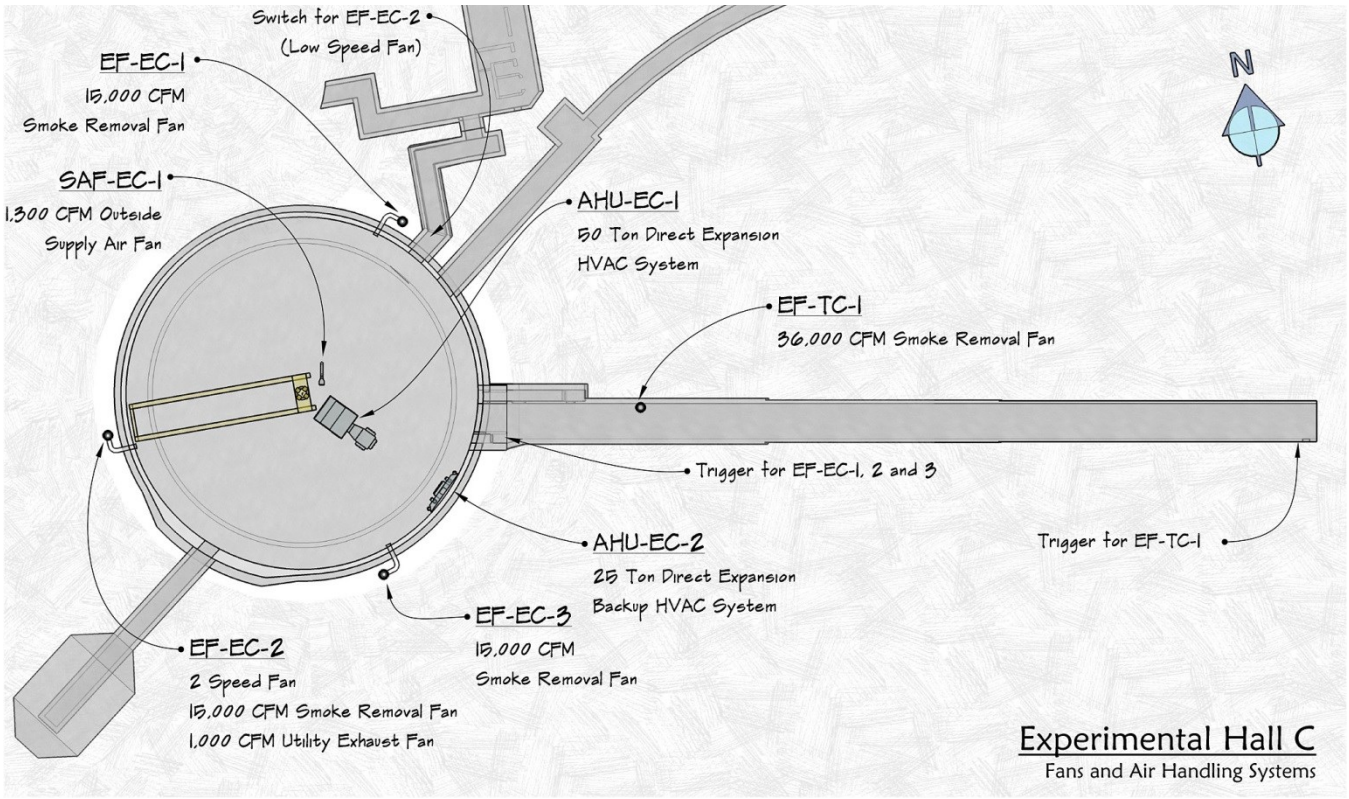

Figure 6. Systems in Experimental Hall C

4. Air Handling Systems in Hall C

Figure 6 shows the fans and air handling systems that are currently installed in Experimental Hall C. The following sections discuss their capacity, configuration and operation.

a. End Station Smoke Removal Fans

Hall C has 3 smoke removal fans that provide a total of 45,000 CFM of air flow when operating. The fans are collectively triggered using the pull button which is located outside the personnel door at the bottom of the truck ramp. They may also be triggered individually from the fire alarm panel in the MCC.

When activated these fans will automatically open the upper and lower truck ramps before beginning operation.

The following fans are included in this group:

i. EF-EC-1

Located on the northeast side of Hall C's exterior dome, this is a single speed fan that provides 15,000 CFM of air flow. This fan is supported by the Counting House generator.

ii. EF-EC-2

Located on the southwest side of Hall C's exterior dome, this is a two speed fan that provides 15,000 CFM of air flow for smoke removal and 1,000 CFM of air flow when used as a utility fan.

A manual switch to activate the low-speed mode for this fan can be found directly inside the labyrinth door as shown in Figure 6. This fan is supported by the Counting House generator.

iii. EF-EC-3

This fan is located on the southeast side of Hall C's exterior dome. It is a single speed fan that provides 15,000 CFM of air flow for smoke removal. This fan is supported by the Counting House generator.

b. Truck Ramp Smoke Removal Fan

The Hall C truck ramp has a single, 36,000 CFM smoke removal fan that is located near the bottom of the truck ramp. This fan is designated EF-TC-1 and can be activated by the pull-button near the personnel door at the top of the truck ramp, or from the fire alarm panel in the MCC.

When triggered, this system will open the upper truck ramp roll-up door before activating the fan. The lower door, unless already open, will remain closed. This fan is supported by the Counting House generator.

c. Outside Air Supply Fan

Hall C is supported by a single outside air supply fan that is mounted at the top of the dome near the HVAC system. The fan, shown in figure 6, is designated SAF-EC-1 and it provides 1,300 CFM of fresh air. The fan is designed to operate continuously and is the only regular source of fresh air exchange for the hall. This fan is currently supported by commercial power and has no generator support.

Note: This is the fan that is used for ODH calculations in Hall C.

d. Climate Control Systems

Hall C has two installed HVAC systems.

i. AHU-EC-1

Shown in figure 6, this is a 50 ton, direct expansion HVAC system that is mounted above the crane rails inside the hall. This unit provides continuous cooling to the hall, but provides no fresh air exchange. It is supported by a heat exchanger that is mounted on the exterior dome of Hall C (not shown in figure).

ii. AHU-EC-2

This is a backup HVAC system that is mounted on the southeast wall of Hall C. It provides 25 tons of cooling capacity and is used to support hall operations when the primary air conditioning system is being repaired or maintained. Like the primary system, this air conditioner also has a heat exchanger mounted on the exterior dome of the Hall.

This unit is normally NOT in operation.

III. AREAS OF CONCERN AND CORRECTIVE ACTIONS

The following observations are based on discussions with members of Facilities Management, Operations, and Safety Staff. They are ordered by priority based on their potential impact on life and machine safety.

1. Outside Air Supply Fan Reliability

The outside air supply fans are critical elements of each hall's personnel safety infrastructure. In order to maintain an ODH-0 environment in the end stations, these fans must be operating continuously. Additionally, because each hall will move from ODH-0 to ODH-2 within two hours of a fan failure, it is essential that the continued operation of these fans be monitored. To address these issues, the following corrective actions are recommended.

a. Generator Power for Outside Air Supply Fans

The outside air supply fans are currently powered by commodity power. This means that if power is lost to the hall, the outside air supply is stopped and staff members entering the hall or working there to correct the problem must exercise ODH-2 protocols. This issue can be corrected by connecting the outside air supply fans to the Counting House generator.

b. Outside Air Supply Fan Monitoring and Alarm

Currently there are no monitors installed to detect a failure of the outside air supply fan. Per Facilities Management (Carroll Jones), this can be corrected by adding an electrical current monitor to the fan's power source. If the fan becomes damaged or inoperable, the change in its power consumption will be detected immediately by the electrical current monitor – indicating a fault.

This current monitor should be configured to send an alarm through the existing communication system. At a minimum, these alarms should be sent to the Machine Control Center, the Hall Coordinator, Industrial Hygiene and Facilities Management, so that immediate corrective action can be taken.

c. Regular Outside Air Supply Fan Inspections

As part of the Hot Checkout program used when bringing the accelerator back online, critical systems are marked as 'not-ready' until they have been inspected. The outside air supply fans for each experimental hall should be included in

this list. The examination required to ensure the operation of these fans will be at the discretion of Facilities Management, as it may not necessarily require a hands-on inspection. Additionally, any routine maintenance should be included in the requirements for confirming the 'readiness' of the fans.

2. Contingency Planning for Outside Air Supply Fan Failures

The steps discussed for improving the reliability of the outside air supply fans cannot guarantee that there will never be a fan failure. Because of this contingency plans should be developed that address the following issues:

a. Continued Work in the Hall During a Fan Outage

A contingency plans should be developed and documented that allows work to continue in the hall while an outside air supply fan is offline for maintenance or repair. This plan should address the potential use of the low speed smoke removal fan for fresh air replacement, as well as operating under an ODH-2 protocol.

b. Hall Entry Following a Fan Outage

In some cases, the outside air supply fan for an experimental hall may fail during beam operations. In order to support the entry of staff into the hall following such an outage, a protocol should be developed that employs the existing smoke removal fans in concert with the ODH system to ensure the hall is safe for re-entry.

Once safe entry has been achieved, personnel in the hall can exercise the contingency plan for continued work during a fan outage that was discussed in the preceding section.

3. Confirmation of Smoke Removal Fan Configuration and Operation

In the development of this document, some questions have arisen regarding the configuration and operation of the smoke removal fans. The following issues should be confirmed and documented.

a. Operation of Low Speed Fan in a Closed Hall

Discussions with hall staff suggest that running the low-speed smoke removal fan with the doors closed creates a potentially hazardous condition. Specifically, the drop in pressure in the hall makes it difficult to open the personnel doors (which open outward). This may impact the ability of staff to exit the hall in the event of an emergency.

To address this, testing should be conducted to assess the extent of the problem. If a genuine risk is identified, then steps must be taken to either a) provide alternative makeup air flow when the doors are closed, or b) develop a procedure requiring some doors to be open when the low speed fan is in use.

b. Timing and Interlocking of Doors and Fans

Because the sudden drop in pressure can cause damage to the truck ramp doors if they are closed during operation, the sequence of operation between the doors and fans should be confirmed.

c. Automatic Fan Activation

There is a difference of opinion between the Facilities Staff and existing documentation regarding whether the smoke removal fans are automatically activated by smoke/heat detectors or the fire alarm system. If these fans are automatically activated by the fire alarm system, as existing documentation suggests, then this behavior should be confirmed and evaluated – as it may no longer be consistent with our current mode of operation.

d. Smoke Removal Fan Operating Protocol

While the smoke removal fans may be activated from either the halls or the MCC, there is currently no formal protocol for when or who is responsible for operating the fans. Facilities Management, in conjunction with Operations staff, should determine the conditions under which the MCC may be required to use these fans and provide appropriate training or documentation

e. Labeling and Documentation for MCC Controls

The fan control panel in the MCC currently provides limited information about the behavior of the fans when they are activated. In the event that this system will be used by Operations staff in the event of an emergency, the labeling should be updated to reflect the actual location of the fans and the sequence of operation –or- written guidance should be available at the panel.

f. Smoke Removal Fan Testing

The smoke removal fan switches should be tested at a regular interval to ensure that the fans and doors continue to perform as expected.

IV. CONCLUSION

While this document identifies a number of concerns that should be addressed, the priority and sequence of any required corrective action is at the discretion of Lab management. In many cases, however, a significant difference can be made by merely identifying and communicating the correct procedure for employing the existing equipment. Once an appropriate course of action has been selected and completed, a follow on document should be produced that identifies the resulting configuration of the air handling systems and their expected use during normal and contingency operations.

V. REFERENCES

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