Ventilation and Thermal Management of Stationary Battery Installations

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Abstract

The purpose of this paper is to review the recently published IEEE-1635/ASHRAE-21 joint standard on ventilation and thermal management of batteries in stationary installations.

The purpose of the document is to build a bridge between the battery system designer and ventilation system designer. As such, it provides information on battery performance characteristics that are influenced by the HVAC design with a focus on thermal management and gassing. It then provides information on battery performance during various operating modes that influence the how the HVAC system is designed. The most critical factors covered are battery heat generation and gassing (both hydrogen and toxic gasses). The paper will review the critical subjects in the document and provide an outline of the document contents.

Introduction

The Institute of Electrical and Electronics Engineers, Inc. (IEEE) Stationary Battery Committee was approached by the American Society for Heating Refrigeration and Air-Conditioning Engineers, Inc. (ASHRAE) in 2002 about the possibility of developing a joint standard on battery room ventilation. For ASHRAE the goal was to reduce the energy consumption that results from traditional battery room ventilation systems where all air exchanged and exhausted to the outside of the building. In addition, air flow rates were often based on over estimates of the air flow required to dissipate hydrogen gas during normal operation.

Some ten years later, in October 2012, the IEEE and ASHRAE completed a first of a kind joint project to address battery room thermal management and ventilation design. The purpose of this paper is to review the product of that project; IEEE Std 1635/ASHRAE Guideline 21, IEEE/ASHRAE Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications. For the course of the project, I had the privilege of being the IEEE chair. However, without the work of the ASHRAE chair, Mr. Deep Ghosh of Southern Co., we would not have succeeded.

The purpose of IEEE Std 1635/ASHRAE Guideline 21 is to build a bridge between the battery and ventilation system designers. As such, it provides information on battery performance characteristics that are influenced by the heating, ventilation and air conditioning (HVAC) design with a focus on operating temperature control. It then provides information on battery performance during various operating modes for use by the ventilation system designer. The critical factors covered are battery heat generation and gassing (both hydrogen and toxic gasses).

As with all IEEE standards, the ventilation and thermal management practices described in IEEE Std 1635/ASHRAE Guideline 21 represent the “best practices”. The recommendations were developed without consideration of economics. Economic considerations are discussed in Clause 8 and the ventilation system for a specific battery installation requires consideration of all issues, not just the technical issues discussed in Clauses 6 and 7 in the document.

Scope

The scope of IEEE Std 1635/ASHRAE Guideline 21 covers ventilation and thermal management of the following battery types in stationary applications:

- Vented (flooded) lead-acid (VLA)
- Valve-regulated lead-acid (VRLA)
- Nickel-Cadmium (Ni-Cd)

For each battery type, the technology and the design of the battery are described along with the environmental considerations.

Document Organization

The first three clauses of any IEEE standard contain the Overview, References and Definitions.

Clause 4: Battery safety hazards and considerations

This clause describes the safety issues that the HVAC design needs to consider. These are:

- Explosive gases
- Toxic gases
- Corrosive gases
- Acid vapor or mist.

These items are addressed in detail in the body of the document and the annexes.

Clause 5: Fundamentals

This clause provides a brief tutorial for the HVAC designer on the fundamentals of VLA, VRLA and Ni-Cd batteries. It describes the technologies, service types and the various installation designs used in stationary applications.

Clause 6: Heating, ventilation, and air conditioning

This clause provides a brief tutorial for the battery system designer on the fundamentals of HVAC design. It discusses the technologies, service types and the various installation designs used in stationary applications.

Clause 7: Environmental design

This clause, along with Annexes A and B is the heart and soul of IEEE Std 1635/ASHRAE Guideline 21.

Clause 7 provides detailed information on the following topics:

- Battery Operating Modes
- Heating, ventilating, and air-conditioning system design requirements
- HVAC system design for ventilation
- Integrated battery areas
- Controls and alarms
- Enclosure design applications

Clause 8: Economics

The type and cost of the HVAC system is closely tied to the cost and required reliability of the battery system. This clause discusses the factors that should be considered when designing a HVAC system for a battery installation.

Clause 9: Environmental management (operation and maintenance)

No discussion of environmental controls is complete without a discussion of the operation and maintenance cost of the HVAC system. This clause references the appropriate IEEE standards for battery maintenance and describes the type of inspections and maintenance that should be performed on the HVAC system as part of the regular battery maintenance program.

Environmental Design

As previously mentioned, Clause 7 and its associated annexes are the heart and soul of IEEE Std 1635/ASHRAE Guideline 21. As such, the balance of this paper focuses on the content and use of the information presented in this clause.

Battery Operating Modes

The information presented in section 7.2 addresses the five normal operating modes of a stationary battery. These are:

- Standby/float operation
- Accelerated/boost/equalize charging mode
- Discharge mode
- Bulk recharge mode
- Initial/freshening charge mode

Section 7.2, also address the following abnormal operating modes (failure modes) of a stationary battery:

- Thermal runaway
- Shorted cells
- Cell reversal
- Charger runaway

For each normal and abnormal operating mode, IEEE Std 1635/ASHRAE Guideline 21, provides information on the following three critical variables needed in designing the HVAC system:

- Flammable gas generation
- Toxic and corrosive gas generation
- Heat Generation

The variable information is broken down by the following battery types:

- Vented lead-acid (VLA)
    - Lead-calcium and pure lead
    - Lead-selenium
    - Lead-antimony
- Valve-regulated lead-acid (VRLA)
    - Lead-tin or lead-calcium absorbed glass mat (AGM)
    - Low antimony AGM
    - Lead-calcium gelled electrolyte (GEL)
- Vented Ni-Cd

The information is presented both as text and in a series of tables that provide equations on calculating the flammable gas, toxic and corrosive gas and heat generation. While it is recommended that these values be obtained from the manufacturer, if they are not available, then the equations provide a method for calculating a conservative upper bound for the each of the three variables considered in the HVAC design.

The equations in the tables are derived and example calculations are provided in Annexes A and B. Annex A, “Hydrogen generation in lead-acid and nickel-cadmium batteries” as the title suggests derives the equations used in the tables for hydrogen generation. Annex B, “Heat generation in lead-acid batteries” has an error in the title of the printed document in that it should have been “Heat generation in lead-acid and Ni-Cd batteries.” This annex derives the equations used in the tables for heat generation for both lead-acid and Ni-Cd batteries.

Annex E provides information specific to thermal runaway in batteries. Annexes D and F provide information specific to toxic and explosive gases while Annex C provides information on existing US codes and standards dealing with flammable and toxic gases associated with battery operation. It should be noted that during normal operating modes, toxic gases are not created by any of the covered battery technologies. However, during abnormal operation it is possible to generate toxic gasses and this subject is treated in detail.

Heating, ventilating, and air-conditioning system design requirements

Section 7.3 is the first major section for the HVAC system designer. This section provides the necessary guidance on how the HVAC system should be designed to manage the operating temperature, temperature gradient and provide adequate ventilation to dissipate potentially hazardous gasses.

The information provided on systems for heating and cooling covers the following subjects:

- Battery Installation Heat Sources
- Active Heating and Cooling System
- Passive Cooling
- Radiant Cooling

HVAC system design for ventilation

The subject here is dilution of hydrogen gas that is evolved during battery operation as well as temperature control. Section 7.4 covers both natural and forced ventilation. Natural ventilation can be thermally induced by hot air rising within an enclosure, or wind induced. Wind induced ventilation of a battery enclosure is not recommended.

Natural ventilation is the most common type used in both indoor and outdoor battery cabinets. Due to the low heat generated by battery systems during normal operation, dedicated battery cabinets require large openings both at the top and bottom to ensure sufficient air flow to dissipate hydrogen gas.

The area of designing a passive or natural ventilation system is covered in detail in the text. The equations for sizing the high and low exhaust openings and the inlet air openings are included.

The subject of forced ventilation is covered in less rigor but the basic principles of supply and exhaust fans, negative pressure and how to size the system based on the worst case scenario of battery operation are included.

Controls and alarms

One way to control the amount of air required to ventilate a battery space is to adjust the airflow based on the operating mode of the charger. Section 7.6 examines the use of controls to reduce the energy demands of the ventilation system.

Traditionally, charger controls have been used to:

- Control the charger output voltage based on battery temperature
- Shut down the charger on high output voltage
- Limit charger output current

The traditional controls are focused on prolonging battery life. IEEE Std 1635/ASHRAE Guideline 21 examines how the charger operating mode can be used to control the ventilation system. As an example, if the exhaust fan is a two speed fan, then during float operation and bulk recharge, the fan runs at low speed, while during equalize or initial charge the fan shifts to high speed based on a signal from the charger.

Another example would be the use of a hydrogen sensor. If hydrogen is sensed, then the fan speed would be increased to prevent a potential flammable/explosive mixture of hydrogen gas accumulating in the battery space.

Enclosure design applications

Section 7.8 provides information on the various types of stationary battery enclosure designs and provides recommendations on the type of ventilation normally used. Again, the purpose is to assist the ventilation designer in understanding the type of enclosure encompassed by the design.

Summary and Conclusions

As has been explained, IEEE Std 1635/ASHRAE Guideline 21 is a unique document. It seeks to bridge a gap in understanding between the designers of the two key elements of a stationary battery installation.

1. It provides significant information regarding battery gas evolution and how to calculate it. This is something that has been difficult to find in the existing literature. It also provides the technical basis in Annex A for how the gassing calculations were derived.
2. It shows that battery heat generation is relatively small during normal operation and provides a method to calculate it when it must be considered. This information had been difficult to find in the existing literature. Annex B provides the technical basis for how the heating calculations were derived.
3. It then provides guidance to the HVAC engineer on how to select and design a ventilation system appropriate for the battery installation.
4. Unlike most documents, it provides guidance on the economic considerations that need to be taken into account by the designers to provide a solution with the best life cycle cost for both the battery and HVAC system.

I am proud of the final product. IEEE Std 1635/ASHRAE Guideline 21 addresses areas of installation design that have been poorly documented. It provides significant information on how batteries perform in operation in a concise and easily understood manner. The technical background and information presented in the Annexes is valuable to both battery and HVAC engineers.

The challenges imposed by trying to do justice in a 6 page paper to a 108 page document that took 10 years to develop, are, to say the least, large. I encourage those involved in stationary battery installation design to obtain a copy of this document and keep it available and refer to it often. You will not be disappointed in the content or the technical quality of the information.

Acknowledgements

When it comes to publishing a standard, there is no one person you can point to and say "he/she did it". Every member of the working groups contributed and without the team work of those involved, we would not be here today. However, within any working group there are those persons who stand out for their contributions. The author wishes to acknowledge and thank the following members of the ASHRAE and IEEE working groups and IEEE staff who made the publication of IEEE Std 1635/ASHRAE Guideline 21 possible:

Mr. Curtis Ashton – Curtis is the principle author of Annexes A and B and section 7.2. I've never been able to figure out how he does what he does, but I'll always be grateful he was member of the team.

Mr. Steve McCluer – Steve is the glue that held the IEEE and ASHRAE working groups together. I don't know how he put up with Deep and me, but he was crucial in getting the document completed.

Mr. Deep Ghosh – ASHRAE Chair: When I lost direction or hope in finishing, Deep was always able to get me back on track. Without Deep, it is unlikely the IEEE would have reached agreement with ASHRAE.

Ms. Soo H. Kim – IEEE Staff: When we started, no one expected the difficulties we would encounter in getting the IEEE and ASHRAE to work together. Without Soo, the idea of the IEEE and ASHRAE publishing a joint document would not have happened.

Ms. Angelina Ortiz – IEEE Staff: When Soo was reassigned, Angelina took over. We still didn't have an agreement between ASHRAE and IEEE at the time, and it took a lot of effort to get it finalized. Through it all, Angelina was there providing resolutions to issues raised in getting the agreement approved by both the IEEE and ASHRAE.