FIRE AND SECURITY CONSULTING SERVICES
http://fscs-techtalk.com

17 McKenna Court
NOOSAVILLE
QUEENSLAND, 4566
AUSTRALIA

Phone: +61 (0)7 5455 5148, Mobile: 0409 399 190, Email: rafoster@bigpond.net.au

BATTERY CHARGING FACILITIES IN BUILDINGS – A FIRE ENGINEER'S PERSPECTIVE – V2

Introduction

Fire and Security Consulting Services (FSCS) has recently been requested to provide advice on the requirement for the proper design of battery storage and charging facilities in buildings, with particular emphasis on warehousing. It should be noted that this paper is prepared in respect to Queensland legislation although other States and Territories have similar, if not identical legislative frameworks.

Whenever I am engaged as a Fire Engineer to either provide BCA compliance advice or to prepare an Alternative Building Solution, my attention is immediately focuses on any mention of the storage and/or use of flammable or combustible liquids and gases or batteries and/or battery charging. This latter issue is because of the propensity for batteries, when being charged, to release hydrogen gas.

Accordingly I address such hazards under in the *International Fire Engineering Guidelines* - *Section 1.2.6 (Review of hazards)* and the *Building Code of Australia* (BCA) *Part E1.10 Provision for special hazards.*

The information contained in this paper is provided to support the designers of buildings and the associated services relating to battery charging and to enable informed and supportable decisions to be made.

A further important issue is that Building Certifiers and QFES Building Approval Officers should be empowered with sufficient knowledge so that they can properly review any proposed design that includes forklift battery charging *stations* or *rooms.*

This paper uses terms describing the types of battery installations and it is considered that at this point it would be proper to define those terms.

1. Primary batteries are non rechargeable types which are discarded after use.
2. Secondary batteries are rechargeable and can be further categorised into:-
   a. Stationary (fixed) battery installations powering emergency equipment or used an Uninterruptible Power Supply (UPS) for computer installations or the like; and
   b. Traction (forklift) batteries.

This paper primarily addresses rooms or areas in a building used for charging forklift batteries. Such a building can be the entire building or part thereof in Classes 6, 7b and 8 buildings as defined in Part A3 of the BCA. In preparing this paper, it has become apparent that all the issues that are required to be addressed for the charging of traction batteries in a dedicated room, also apply to stationary batteries.

Accordingly the process in Sections 5 to 8 and Section 14 can be used in the assessment of rooms where secondary batteries, used to power emergency or essential equipment and the like, are sited.

Legislation

There is a hierarchy of compliance for any building thus:-

1. Compliance with the Queensland Workplace Health and Safety Regulation; and
2. Compliance with the Queensland Building Act 1975; and
3. Compliance with the Building Code of Australia (BCA); and
4. Compliance with Australian Standards as referenced in the BCA and all other relevant Standards referenced therein.

Whilst the majority of building professionals will focus on the requirements in the BCA, it should be remembered that the Queensland Work Health and Safety (WHS) Regulation addresses safety in workplaces and is the primary legislation covering the operations within a building or on a work site.

The WHS Regulation also addresses the *design* of certain facilities where *hazardous materials* are used and stored. Note that the WHS regulation Part 51(2) (c) defines a battery room as a *hazardous area* and accordingly, readers should note that Section 5 and **Appendix A** to this paper form an integral part of the building design process.

In addition to the safe operation of a workplace, the WHS Regulation discussed in Section 5 of this paper also places responsibility on *designers* to design a safe *plant*, which is further defined as a *structure*. Accordingly builders and designers, including Consultants, have an obligation to fulfill the appropriate design functions in terms of electrical safety as discussed in Section 6 and ventilation appropriate to hazardous atmospheres as discussed in Sections 5 and 7 in this paper.

Building Code of Australia Issues

BCA Part C2.12 requires separation of *battery rooms* from the rest of the building with construction having an FRL of 120/120/120. This requirement does not properly address the important differences between the types of secondary batteries as defined under 2a and 2b above. Furthermore 'The Guide to the BCA" makes unsupportable statements of intent that such separation will limit the effects of an explosion within the battery room.

This separation requirement has been subject of much discussion in the warehousing industry with opinions from Building Certifiers leaning towards a mandatory requirement and owners / operators leaning towards its omission. Consequently this paper will provide the necessary information and means of analysis so that a rational decision can be made with respect to an *appropriate* level of separation.

Contents

FSCS is of the opinion that to properly understand the issue, it is necessary to understand all the issues relating to the subject. This paper contains the following sections, each being addressed as a separate subject:-

1. The types of forklifts used in the industry; and
2. Motive power - the types of battery powered forklifts and the types of batteries used; and
3. The hazards associated with battery charging including fire history; and
4. The Regulatory requirements in terms of safe operation of forklifts; and
5. The Regulatory requirements in terms of Workplace Safety where toxic or asphyxiant atmospheres may be present **§ - Appendix A**; and
6. The Regulatory requirements in terms of fire and/or explosion potential initiated by electrical equipment; and
7. Ventilation of battery rooms **§ - Appendix C**; and
8. Referenced Legislation ; and
9. International Codes and Standards **§ - Appendix B**; and
10. International Risk Management and Insurer viewpoints **§ - Appendix D**; and
11. The Building Code of Australia.

Items marked **§** include an Appendix which provides further information on the subject and the basis of the FSCS discussion in the relevant section in this paper.

Following on from the above, this paper discusses the following design issues and provides technical advice as how to comply with the requirements.

12. Discussion on the available options for battery charging rooms; and
13. Discussion on the available options for distributed forklift charging facilities; and
14. Certification, commissioning, documentation and maintenance; and
15. Conclusions.

Stakeholders

With any new development it is important that all stakeholders in the project be represented in the design of the battery charging facilities, the following are considered to be the minimum required so that the end project is capable of being certified:-

1. The **Client**, being either the owner or its representatives. The client's requirements are paramount and any history of existing facilities should be sought as they will be a factor in the design of the building and the forklift facilities.

   The client should advise the project team the following:-

   - What type of battery powered forklifts are to be used; and
   - The supplier of the forklifts; and
   - The type and capacity of the batteries to be used, vented sealed lead acid or VRLA; and
   - The number of forklifts to be accommodated for; and
   - The proposed use in terms of shifts and charging protocols; and
   - The number of persons working within the battery or service room / are; and
   - The preference for central or distributed charging; and
   - If central charging, whether the batteries will remain in-situ or removed; and
   - If the building is to be sprinkler protected, does the client have a view on omitting sprinklers from battery rooms. – See **Note 1** below

   Note 1 – Section 12 in this paper discusses sprinklers.

2. The **Client's Insurer**. The insurer may have specific recommendations for battery rooms. Any US based insurer is likely to base their recommendations on the FM Global requirements set out in its Loss Prevention Data Sheets. Likewise European insurers will typically have similar recommendations; Zurich Risk Engineering being typical. Both their recommendations are addressed in Section 10 and **Appendix C** of this paper

   Their interests in terms of insurance of the equipment and the building need to be addressed otherwise the Client may end up with a building that cannot be insured.

3. The **forklift supplier**. Often warehouse owners will lease or rent forklifts. In that case, the Company supplying the forklifts will invariably have a viewpoint on battery charging requirements. Their commercial interests in terms of proper use and maintenance of their equipment may have an impact on the building design.

4. The **Building Certifier**. A Building Certifier is required to be appointed and under the Queensland Sustainable Planning Act and section 247 "*Role Of Assessment Manager*" states that "*The assessment manager for an application administers and decides the application, but may not always assess all aspects of development for the application*".

   The Certifier reviews and advises on all aspects of the project in respect to the requirements of the Building Act 1975 and the Building Code of Australia and subsequently issues a "Certificate of Classification which permits occupancy of the building.

   The Certifier may not always be conversant with all aspects of compliance and issues like Queensland Workplace Heath and Safety Regulations and the Queensland Electrical Safety Regulations in respect to hazardous are assessment and electrical installations. In that case the Certifier may rely on the recommendations and documented designs from the appropriate RPEQ engineers on the project team.

   It must be remembered that not only does the Certifier have a statutory role in the process, but he is also a "servant of the project" and must always act in the best interests of the client.

5. The **Building Approval Officer** from Queensland Fire and Emergency Service (**QFES**) acts as the referral authority under the Sustainable Planning Regulation which requires that building work which is assessable under the Building Act 1975, be referred. This includes any building where an Alternative Solution is proposed or any building where a "special fire service" is required to be installed under the Building Code of Australia
6. The **design team** should have either in-house engineers or external Consultants experienced in the design of hazardous area electrical and ventilation systems. They should be Registered Professional Engineers (RPEQ) in either electrical and / or mechanical services and understand the requirements for proper documentation of all designs as referenced in the various Codes and Standards and, as required under the Queensland Professional Engineers Act and in particular the "*Code Of Practice For Registered Professional Engineers*".
7. **Peer Review Engineer**. There are occasions where the Client or Building Certifier may feel that a Peer Review is warranted. In that case, guidelines and conventions should be set. The Institution of Engineers *Society of Fire Safety* has a *Code of Practice for Fire Safety Design, Certification and Peer Review* which is recommended.

Related FSCS Publications

The following papers on the FSCS web site **http://fscs-techtalk** may be useful in the background of this paper:-

1. "*Building Certification*" This paper addresses the detailed requirements for certification of the design and installation of certain systems relating to fire services as required under the Queensland Building Act 1975 and the Queensland Building Regulation 2006.

   Section 14 in this paper provides additional information relating to certification relating to electrical safety, ventilation and Workplace Health Regulation requirements.
2. "*Ballarat School of Mines Tafe Curriculum*". Module 16 – "Explosion Suppression Systems" provides background information regarding explosions.
3. "*Rick Foster (at Arup) Warehousing*" is a paper I prepared as a Consultant to Arup. It addresses the differences between custom designed warehouses where proper consideration is made to BCA requirements and speculative built buildings which end up being used as warehouses with unlimited type, height and volume of stored goods. This disconnect poses an incredibly difficult problem for the Regulatory Authorities.
4. "*Fire Resistance – A Fire Engineer's Perspective*", in particular the difference between a *fire wall* and a "*wall with an FRL*".
5. "*Multiple Jet Controls in Fire Protection Systems*"

Executive Summary

Trusting that the reader has perused the introduction, the following is a summary of the remaining parts of this paper.

This paper lists all the referenced and relevant Legislation including Australian Standards and Codes. European and International Codes and Standards are also listed.

- Battery powered forklifts come in various types and sizes and often small units like pallet trucks are overlooked in the design of a building.
- Two types of batteries dominate the market, standard vented lead-acid and valve regulated lead-acid (VRLA). The important difference is that the VRLA battery recombines the majority of Hydrogen gas evolved during charging. Whilst this recombinant feature is recognised in the European Standards on battery room design, the current Australian Standard makes no distinction.

- The predominant hazard during charging is the evolution of Hydrogen (H_2) gas, usually during the latter stages of charge. Whilst some might consider this as a minor hazard, the hazard is required to be addressed in the design of a building where forklift batteries are charged.
- Whilst the majority of fires involving forklifts are related to issues other than the battery system, there is sufficient evidence to show that considering the very high currents involved in the DC supply system on the forklift, fires from damaged and short circuited cables do occur.
- The Queensland Work Health and Safety Regulation (WHS) is the primary legislation in relation to the safe operation of forklifts ***and*** the safe design of buildings where they are used. Considering the discharge of Hydrogen during charging, the WHS specifically defines such areas as hazardous areas.

  The WHS does not consider Hydrogen as a toxic substance but as an asphyxiant and the WHS Regulation requires a minimum of 18% oxygen in the building.

  The WHS requires an assessment of ignition sources in a hazardous area.
- The Queensland Electrical Safety and associated Regulation provides for the compliance of the design and installation of electrical installations. This includes for the proper "Hazard Classification" of areas where battery charging may take place.

  The explosive limits of Hydrogen in air range from 4% $^{v}/_{v}$ Lower Explosive Limit (LEL) to ~75%$^{v}/_{v}$ Upper Explosive Limit (UEL). The requirement is that the concentration of hydrogen shall not exceed 4% $^{v}/_{v.}$

  Whilst the quantity of Hydrogen evolved in battery charging may be considered by some to be small and therefore negligible, failure to assess and document the hazardous area compliance is an offence.

  This paper explains the methodology of assessment and examples of compliance.
- Ventilation of battery rooms and other associated areas is a mandatory requirement under the preceding Acts and Regulations. Failure to assess, document and provide the required ventilation is an offence.

  This paper explains the methodology of acceptable designs and provides examples of compliance.
- This paper discussed the failure of Australian Standards to maintain ventilation technology methods and suggests adoption of **E**uropean **N**orm Standards as being more appropriate; and
- There is often a requirement that the building design to meet the particular requirements of an Insurer. Two examples of typical requirements (FM Global and Zurich Risk Engineering) are provided in an Appendix.
- The requirements in the Building Code of Australia are reviewed with particular attention to the requirements in Part C2.12 and the differentiation between a room containing batteries required for the safe functioning of the building and a room containing batteries required for operations carried out within the building.

  In this respect, FSCS contends that whilst fire separation off the first instance is warranted, fire separation in the second instance is neither achievable nor warranted. Compliance with the mandatory hazard classification, ventilation and electrical installation will provide for better risk control than a wall which, in the event of a Hydrogen explosion, will fail and cause more damage and life safety issues.

  This paper supports the omission of fire rated bounding construction except where required to separate sprinkler protected areas from non sprinkler protected areas.

- This paper provides various examples of battery charging areas with both dedicated room and shared rooms with service equipment.

  Construction requirements are discussed with particular emphasis on fire separation in a sprinkler protected building where a Client elects not to have sprinklers in the charging area. Not withstanding this, FSCS sets out a case to consider sprinkler protection.

- This paper considers how distributed charging stations can be incorporated into a building design and although considered minor, requires the formal assessment and documentation of ignition hazards and Hydrogen ventilation. This paper supports the installation of multiple distributed charging stations providing certain design criteria are met.

- Certification, commissioning, documentation and maintenance are addressed with the most important issue in the building design being the proper documentation of all related designs which will result in the proper certification of the building. Maintaining these records is imperative for future conformance and compliance.

  Whilst there are no specific areas in the Australian Standard on maintenance of the required ventilation systems, FSCS has suggested adoption of existing standards of similar installations.

- **FSCS concludes that:-**

  1. Distributed charging stations are not prohibited under the BCA and in the opinion of FSCS, are permitted subject to the requirements in Section 13 in this paper being addressed; and
  2. For battery rooms, this paper substantiates the reasoning that BCA C2.12 should NOT apply to traction batteries (forklifts and the like) because these batteries are NOT emergency equipment and that the hazards are adequately addressed in the recommendations.
  3. Notwithstanding that this paper substantiates the omission of protection under BCA C2.12, fire rated bounding separation of non sprinkler protected areas from sprinkler protected areas is required under AS2118.1 – the Australian Automatic Sprinkler Standard.
  4. As discussed in Section 11 in this paper, fire separation with an FRL of 120/120/120 as required under BCA C2.12 and defined in the "Guide to the BCA", will <u>not</u> protect *the other parts of the building* in the event of an explosion in the battery room.
  5. FSCS advises that meeting the Legislated requirements in terms of Workplace Health and safety, Electrical safety and compliance with the ventilation and safety requirements therein will provide a degree of protection i<u>n excess</u> of what would be achieved if BCA C2.12 was complied with, e.g. a wall with an FRL which would certainly fail. The resulting risk to occupants from an explosion and subsequent structural failure are greater than from fire spread.
  6. FSCS is of the opinion that meeting the applicable Codes and Standards referenced in this paper in respect to eliminating fire and ignition hazards, reduces the fire hazards in a battery charging room to a level which requires no fire separation from the rest of the building.

Now noting the phrase in BCA clause to C2.12 (b) (iv) which reads:-

> <u>*Equipment need not be separated with (a) if the equipment comprises-*</u>
>
> <u>*(iv) Equipment otherwise adequately separated from the remainder of the building.*</u>

FSCS contends that where "**adequate separation" of hazards** is provided and can be demonstrated such; the resultant arrangement is a DtS design.

1 - Types of Forklifts

Forklifts commonly use either a compression ignition engine using diesel (distillate) fuel, a spark ignition internal combustion engine using LPG (propane) fuel or batteries. Fore the purposes of this paper, only electric forklifts will be addressed.

The type of forklift used will invariably be related to the type of materials being handled, the majority will be traditional fork lifts, having two blades suitable for positioning under the goods, usually on a pallet. Other types may have a single “spike” for end on lifting of rolled paper or carpets, “clamps” for lifting single drums or rolled paper on end.

Because of the load on the fork revolves around the front wheel axis, forklift trucks are manufactured with the batteries, located at the rear so they act as a counterweight.

Figure 1 below is a regular forklift, Figure 2 a high lift “picker” unit where the operator sits or stands within the raised part of the lift, and Figure 3 is a pallet truck where the operator either stands on or walks behind the machine.

Figure 1 - Regular Forklift

Figure 2 – High Lift Picker

Figure 3 –Pallet Truck

Explosion proof rated electric forklifts are also manufactured in such a manner that they will not produce a spark during normal operation. Forklifts manufactured to this standard are usually used in facilities where creating a spark could cause an explosion such as an oil refinery, chemical plant, fireworks or ammunition manufacturing facility. It is very important to install an explosion proof rated battery into an explosion proof rated electric forklift otherwise the explosion proof rating of the forklift will no longer be valid.

2 - Motive Power & Battery Types

Electric forklifts and the like are powered by heavy duty industrial batteries, sometimes called traction batteries, usually made up of high amp hour 2 volt lead acid cells assembled in series in a case in quantities to add up to the forklift operating voltage, be it 12 volt, 24 volt, 36 volt, 48 volt or 72 volt. Most are 36 or 48 volt.

Electric forklifts are invariably used on warehouses storing foods, clothing and the like which need to be protected from particulate contamination. Additionally, cold stores and cool rooms invariably use electric forklifts.

Batteries are usually installed in removable trays made up of the required number of cells. Figures 4 and 5 below show a battery tray (18 cell 36 volt) and the removal / replacement of the tray.

Figure 4– Battery Tray

Figure 5 - Tray Replacement

Types of Batteries

At this point it is considered appropriate to differentiate between the types of battery installations. So that Primary and Secondary batteries in a stationary configuration can be discarded from the discussion.

Research by FSCS into the battery market reveals that:-

- 80% of batteries used by their major clients in Queensland, being Bunnings, Woolworths, Parmalat and Smiths, are the conventional vented lead-acid batteries. This information is provided by Toyota and Century / Yausa.
- The majority of forklifts are rental units, which drive the type of batteries being used – see below.
- VRLA batteries are significantly more expensive than sealed lead acid batteries.
- Opportunity or fast charging reduces the available charging cycles in both sealed lead acid and VRLA batteries.
- The USA Market is increasingly using VRLA batteries where the forklift is owned by the operator.
- In the USA, VRLA and gel / mat batteries are increasing being used in foodstuff warehousing and manufacturing facilities due to their reduced contamination potential.
- VRLA and gel / mat batteries require reduced spill control facilities and reference to the *International Fire Code* in **Appendix B** shows the benefits, for US users with mat or gel type batteries.

Vented Lead-acid forklift batteries are a popular maintenance-free option for use in controlled working environments as they can operate in any position. The acid inside the forklift battery is made into a gel and sealed inside the cell. Valved cell caps allow for venting during charging resulting in the discharge of water vapour and hydrogen gas.

Valve-Regulated Lead Acid (VRLA) are low-maintenance lead-acid rechargeable batteries. Because of their construction, VRLA batteries do not require regular addition of water to the cells. VRLA batteries are commonly further classified as Absorbent glass mat or Gel batteries. These batteries are often colloquially called sealed lead-acid batteries, but they always include a safety pressure relief valve. As opposed to vented (also called flooded) batteries, a VRLA cannot spill its elecrolyte if it is inverted. Because VRLA batteries use much less electrolyte (battery acid) than traditional lead-acid batteries, they are also occasionally referred to as an "acid-starved" design.

The name "valve regulated" does not wholly describe the technology; these are really *recombinan*t" (see below) batteries, which means that the oxygen evolved at the positive plates will largely recombine with the hydrogen ready to evolve on the negative plates, creating water—thus preventing water loss. The valve is strictly a safety feature in case the rate of hydrogen evolution becomes dangerously high.

Recombinant Batteries are batteries in which, under conditions of normal use, hydrogen and oxygen gases created by electrolysis are converted back into water inside the battery instead of venting into the air outside of the battery.

Absorbed Glass Mat or Gel Batteries (AGM) are sometimes used for forklifts. This technology is sealed and maintenance free, however are almost twice the cost of flooded lead-acid batteries. By using absorbed glass mats between the plates, the batteries recombine the oxygen and hydrogen inside the cells and lose almost not water during use and charging.

Lithium-ion Lithium metal polymer Batteries are beginning to be popular for vehicles but still do not have the time and power capacities for forklifts.

3 - Charging Hazards & Fire History

At this point, and as an introduction to the charging hazards, it seems appropriate to comment that the BCA makes no distinction between VRLA batteries, which are sealed and release little or no hydrogen under conditions of normal use, and vented batteries, which continually release up to 60 times more hydrogen gas than a VRLA battery under float-charging.

Battery Handling Hazards – During battery handling and watering of cells, whether by automatic or manual means, staff are required to wear personal protective equipment (PPE) which include the following acid resistant (splash) items:-

- eye protection
- full-face protection
- protective gloves
- rubber chemical apron
- steel-toed shoes / boots

Additional PPE includes an eye wash station placed within 10 seconds of the battery charger.

Charging Hazards – During battery charging, oxygen and hydrogen are released and the resultant risk is required to be assessed as discussed below.

The published paper *Hydrogen Gas Management for Flooded Lead Acid Batteries* by Carey O'Donnell and Michael Schliemann - Mesa Technical Associates, Inc. - Hoppecke Batterien Gmbh & Co KG cites the following in respect to hydrogen discharge:-

The level of the resultant gas volume generated by the decomposition reaction depends on temperature and pressure. For normal ambient temperatures of 25°C, and normal pressure of 0.1013 MPa (1 atmosphere), the amount of created gas is 0.4564 litre of hydrogen gas per overchagarged 1Ah capacity.

The IEEE 484(§) norms confirm this value in " ... 5.4 Ventilation - Maximum hydrogen evolution rate is 1.27 x 10-7 m^3/s per charging ampere per cell at 25 °C at Standard pressure. The worst-case condition exists when forcing maximum current into a fully charged battery. ...

Whilst the remainder of this section is particularly intended for central battery charging rooms, the same principles also apply to distributed charging stations in a building. In that case the assessment of the hazard classification and in particular the limits of the "hazard zone" around the charging station are important to address.

Figure 6 below shows a typical battery charging room where the forklifts are driven into the room to effect battery tray removal and replacement. Note also that batteries in smaller powered pallet trucks are being charged without removal from the truck.

Figure 6 – Typical Battery Charging Room –

Note both ducted and natural ventilation which probably are ineffective in the shown configuration.

Other Hazards – Spills of and discharges of airborne sulphuric acid occur during watering of cells are likely to be highest during hot periods due to higher evaporation rates.

Fire History - Australia

There is little recoded evidence of fires attributed to forklifts in Australia, most fire reports will have focused on the subsequent involvement of the building structure or goods contained in a fire.

Fire History - International – The data collected by FM and NFPA does not differentiate between the various types of motive power, i.e. diesel, propane or electric.

FM Global in its Property Loss Prevention Data Sheet 7-39 reported that:-

Over 800 losses involving lift trucks were reported to FM Global during a recent 20-year period (1989 to 2008). The vast majority of these incidents have been the result of impacts, including collapse of racking, damaged process equipment, broken service lines (water, electricity, and gas) and water damage from broken sprinkler systems.

Fire History - USA – The NFPA ‘Industrial Loader and Forklift Fires’ report says that:-

“Between 2003 and 2006, US fire departments responded to an estimated average of 1,340 structure and vehicle fires per year where industrial loaders, forklifts and related materials handling vehicles were directly involved.”

Almost two-thirds of these incidents were classified as vehicle fires with fires starting in the running gear area or wheel area. An unclassified mechanical failure or malfunction was a factor in 27% of these fires. Electrical failures or malfunctions contributed to 26%. Leaks or breaks were factors in 14%. The other third involved flammable or combustible liquid gas, pipes, or filters as the ignition point. In one-quarter of these incidents, electrical wire or cable insulation was first ignited.”

4 – Safe Operation of Forklifts

Workplace Health and Safety Queensland addresses the safe operation of forklift trucks in the following publication:-

http://www.deir.qld.gov.au/workplace/hazards/plant-and-structures/forklift/operation/index.htm#.U-2KN1w_6aw

Operational hazards associated with the operation of electric fork lift trucks and pallet handling equipment are almost exclusively due to impact of the vehicle with steel pallet racking. Impacts are exacerbated by the presence of loose wiring on the truck which can be shorted out due to impact.

Figure 7 below shows a damaged power cable underneath a forklift after it was re-routed during maintenance. This caused a short circuit of the batteries.

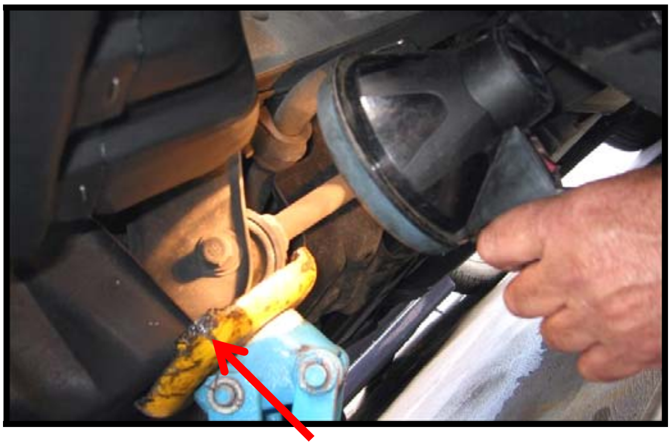


Figure 7 – Damaged Power Cable

An interesting anecdote from the USA was sent to me during my research on this paper. One warehouse owner, exasperated at the amount of damage from collisions with racking, gave each driver the responsibility for his own forklift with the proviso that each selected a different paint colour. The drivers eagerly adopted the suggestion and painted their forklifts with a myriad of different colours.

The warehouse owner reported that within weeks, damage ceased because the drivers cottoned on to the fact that they left colour evidence behind after each collision! He also reported that there was a significant change to the staff attitude to safety.

Often forklifts are misused with resultant operator injury or equipment damage. Figure 8 below shows gross misuse of forklift**s** to transfer an airconditioning condenser unit to a high level in a building during construction!

Figure 8 – Misuse of a Forklift

5 - Workplace Health and Safety Regulations

The Queensland Work Health and Safety (WHS) Regulation addresses safety in workplaces and is the primary legislation covering operations within a building or on a work site. With respect to battery rooms, the WHS addresses the potential for either toxic or asphyxiant. Further information regarding this issue is included in **Appendix A**.

Of particular interest to the building designer are Part 3.1 – *Managing risks to health and safety*; Part 49 – *Ensuring exposure standards for substances etc, not exceeded*; Part 50 – *Monitoring airborne contaminant levels*; Part 51 – *Managing risks to health and safety*; Part 52 – *Ignition sources*; Part 64 – *Duty to eliminate or minimise risk*; Part 71 – *Specific control – atmosphere* and Part 72 – *Specific control – flammable gases and vapours*.

There a number of issues within the WHS that requires careful analysis because incorrect interpretation may lead to unnecessary compliance costs.

1. The WHS regulation Part 52 addresses ignition sources in hazardous atmospheres to be addressed. Compliance with this part may be satisfied by addressing the requirements in Sections 6 and 7 in this paper.
2. The WHS regulation Part 51(2) (c) defines a hazardous atmosphere as one where the concentration of flammable gas in the atmosphere exceeds 5% of the Lower Explosive Limit (LEL) of the flammable gas. For Hydrogen with an LEL of 4% by volume, this equates to a concentration of Hydrogen of 0.0025% or 20ppm. Compliance with this part may be satisfied by addressing the requirements in Sections 6 and 7 in this paper.
3. The WHS regulation **Part 72(i)** requires the concentration of flammable gas in the atmosphere of a ***confined space*** to be less than 5% of the Lower Explosive Limit (LEL) of the flammable gas. For Hydrogen with an LEL of 4% by volume, this part of the WHS requires the concentration of Hydrogen not to exceed 0.0025% or 20ppm.

Some Certifiers and Building Approval Officers have an expectation that **Section 72 (1)** is required to be complied with. This is not so as a battery room or charging area does not fall within the definition of a ***confined area***.

However as discussed in **Appendix A,** a minimum Oxygen percentage of 18% by volume is required to be maintained in a workplace and compliance with the requirement to maintain a minimum of 18% oxygen by volume can be effected by ventilation as discussed below and in Section 7 of this paper.

Hazard Reduction and Control methodologies include ventilation of the charging area such that the atmosphere within the charging area, be it a confined room or designated area in an otherwise open space, contains a minimum of 18% Oxygen by volume as discussed above.

This may meet WHS regulation Part 51(2) (c) in terms of ensuring that the atmosphere is not hazardous. However no ventilation system can guarantee that "blind" or "dead" areas of a compartment do not contain an air-hydrogen mixture within the LEL (4%) and UEL (74%) limits of Hydrogen. Consequently WHS regulation Part 52 which addresses ignition sources in hazardous atmospheres can only confidently be met by adopting design measures described in Sections 6 and 7 in this paper.

An example of "blind" or "dead" areas is shown in Figures 11a and 11b in Section 6 in this paper.

6 – Hazardous Area Classification & Electrical Equipment

Hazard Classification

In the first instance, the designer is required to assess the hazardous nature of the area. For the purposes of this paper, a hazardous area is a space, either confined within a building or compartment **or** occupying a defined volumetric space in the atmosphere where a flammable gas occupies, or may under certain circumstances, occupy that space. Note the discussion under dot point 3 in Section 5 of this paper.

The Electrical Engineer is required to make and document the assessment of hazardous area in respect to its classification of Zone 0, Zone 1, Zone 2 or Non Hazardous as appropriate. Even when the compartment or area is deemed to be non hazardous, the assessment process must be properly documented in accordance with Section 7 of AS/NZS 60079.10.1 and filed with the final building approval documentation. This assessment needs to be carried out in conjunction with the ventilation assessment and design as discussed in Section 7 of this paper.

To recap the physical properties of Hydrogen, it is useful to document the definition of *flammability*. The *flammability* of the substance is defined as that percentage by volume in air that, when an ignition source of sufficient energy such as a spark is present, will cause conflagration of the air / gas mixture.

The *flammable* range is expressed as % Lower Explosive Limit (LEL) and % Upper Explosive Limit (UEL). For example, Hydrogen has a LEL of ~4% and a UEL of ~75%.

If the concentration of gas in air is below the lower explosive limit (LEL) then the mixture is said to be too "Lean", if higher then too "Rich".

Two additional properties are attributed being:-

- Density, being whether the gas is lighter or heavier than air, hydrogen being lighter than area and therefore will rise to the upper limits of a confined space; and
- Ignition temperature, for hydrogen being ~560^{o}C. For comparison, a car spark plug generates a temperature of ~750^{o}C and lightning ~5,000^{o}C.

In hazardous areas one is more concerned with a flammable gas/oxygen mixture which, if the properties are right, will result in uncontrollable burning, i.e. an explosion.

As discussed in Section 5 of this paper, the WHS regulation Part 51(2) (c) defines a battery room as a hazardous area and therefore the appropriate “Zone” must be selected.

With respect to hazardous areas, Australia has adopted the International / European Standard IEC 60079-10-1, Ed.1.0(2008) publishing it under the title of **AS/NZS 60079.10.1**, This Standard provides for a more realistic assessment methodology with more appropriate issues being addressed.

Many practitioners will be familiar with the AS2400 superseded series of Standards where classification of hazardous areas was effected by assessment of the estimated frequency of flammable gas release rates; however the current requirement is an assessment and classification of hazardous areas using AS/NZS 60079.10.1 – *Explosive Atmospheres – Classification of areas – Explosive gas atmospheres*.

As discussed in Section 7 of this paper, the quantities of hydrogen gas produced and discharged from vented battery cells is minor. However if discharged into an unventilated room, the resultant concentration would soon reach the LEL of 4% and a flammable or explosive atmosphere would soon be formed.

Consequently the hazardous area assessment must take a realistic approach and in the opinion of FSCS, the following point should be considered:-

Section 6 of AS/NZS 60079.10.1 addresses ventilation and it is the opinion of FSCS that the hazardous area classification should be based on the ventilation achieving as achieving at the worst, Zone 2 with areas local to the battery cells as Zone 1.

Note that as advised in AS/NZS 60079.10.1, Zone 0 can only exist within the vessel or enclosure containing the material that if discharged, will produce a hazardous atmosphere. Whilst this advice is useful, it is not entirely true because the atmosphere within such a vessel or enclosure I likely to be too "rich" and outside the flammability limits (>UEL) for the material.

Should ventilation be relied on to achieve the appropriate zoning, the reliability of the ventilation system is required to be addressed in terms of dual fans, fan fail interlocks and gas detection etc. as discussed further in Section 7 of this paper.

To assist the Electrical Engineer in the task of hazard classification, EN 50272-3 *Safety Requirements For Secondary Batteries And Battery Installations - Part 3: Traction Batteries* provides for the assessment of Zone pertaining to a battery as having an exclusion zone, being Zone 1, for a distance "d" equal to 0.5 meters however as Hydrogen is lighter than air, most Electrical Engineers use a probabilistic approach and extend the Zone 1 area upwards to a point where there is an obstruction which can accumulate the gas or to a point where it can reasonably assumed that the gas has been diluted and to an extent where it is below the LEL. Figure 9 below shows this approach and Figure 10 shows an illegal design where the battery tray is virtually beneath electrical equipment and next to a petrol generator!

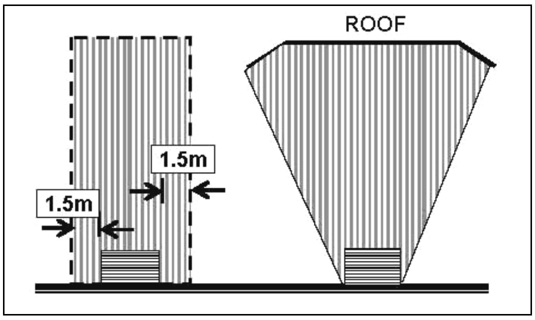


Figure 9 – Extent of Zone 1

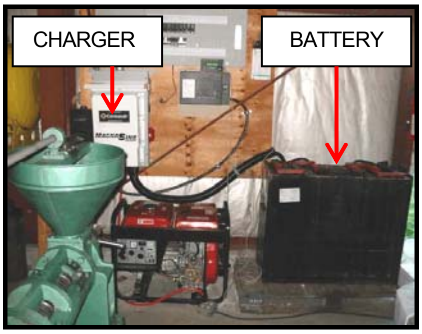


Figure 10 – Unlawful Installation

As discussed in Section 13, the type of assessment where a 0.5m exclusion zone may well be useful when distributed charging stations are used.

Gas or vapour released into the atmosphere can be diluted by dispersion or diffusion into the air until its concentration is below the lower explosive limit. Ventilation, i.e. air movement leading to replacement of the atmosphere in a volume around the source of release by fresh air, will promote dispersion. Suitable ventilation rates can also avoid persistence of an explosive gas atmosphere thus influencing the type of zone. Even if ventilation is used to reduce the hazard classification to a "safe" level, there should be a degree of caution as to the efficacy of the ventilation system. Figure 11a below shows that in the opinion of FSCS, there may areas within the compartment which is not purged by the ventilation system. Accordingly, as shown in Figure 11b, the ventilation duct outlets and inlets should be arranged to minimise areas not properly ventilated shown coloured pink.

Figure 11 b shows that even with this attention to design, there may still be unventilated areas, and these should be assessed as Zone 1.

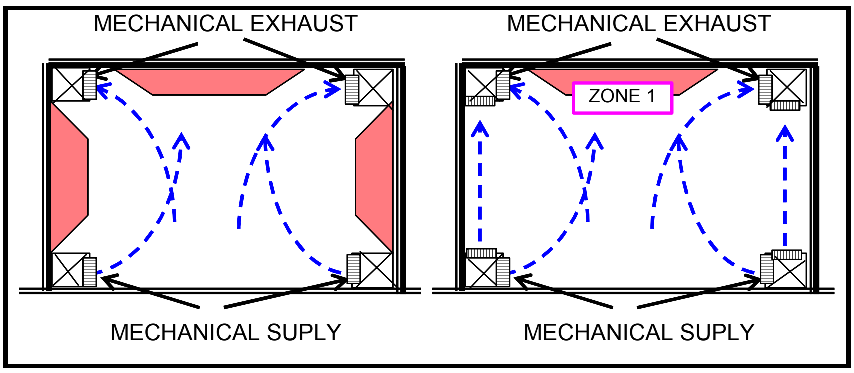


Figure 11a – Unventilated Areas Figure 11b – Resultant Zone 1 Area

With natural ventilation as shown in Figure 12 below and where the inlet and outlets are on opposite sides of the room and at low and high level respectively; there will be areas not properly ventilated shown coloured pink.

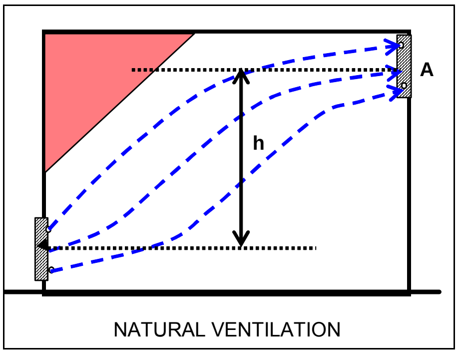


Figure 12 – Natural Ventilation

Electrical Equipment

Where electrical equipment is used in hazardous areas, the requirements for that equipment are addressed under the (Queensland) Electrical Safety Act and Regulations which cite AS3000.

AS 3000: 2007 – *Electrical Installations.*

Section 7.7 of this Standard addresses electrical installations in hazardous areas – specifically explosive gas such as Hydrogen produced in the charging of batteries.

and

AS/NZS 60079.14 – *Explosive Atmospheres – Electrical installations design, selection and erection.*

These Standards contains the specific requirements for the design, selection and installation of electrical installations in hazardous areas.

Where ventilation is used for achieving a safe atmosphere, electrical equipment in any remaining areas as discussed before and shown in Figure 11 should be rated for the appropriate Zones.

Table 2 below shows the applicable designations. Note that an assessment under AS/NZS 60079.10.1 for a battery charging room or area will not result in a Zone 0 classification.

SELECTION OF APPARATUS	
ZONE 0	
Ex ia	Intrinsic safety
Ex s	Special protection (approved for Zone 0)
ZONE 1	Zone 0 protection techniques
Ex d	Flameproof
Ex ib	Intrinsic safety
Ex p	Pressurisation for Zone 1
Ex p1	Purging for Zone 1
Ex m	Encapsulation
Ex e	Increased safety
Ex v	Ventilation for Zone 1
Ex s	Special protection for Zone 1
ZONE 2	Zone 0 and Zone 1 protection techniques
Ex n	Non incendive
Ex p	Pressurisation for Zone 2
Ex p1	Purging for Zone 2
Ex v	Ventilation for Zone 2
Ex s	Special protection for Zone 2

Table 2 – Electrical Equipment Designations

For a Zone 1 area, **Flameproof** equipment is usually used for wiring connections, junction boxes, certain heat detectors, power switches ***(Note 1)***, lighting, door release solenoids, Emergency Lighting ***(Note 1),*** EXIT signs ***(Note 1)***, occupant warning horns ***(Note 1)***, ventilation fan motors ***(Note 2,*** and the like and the enclosures meet the Standard by providing a "flameproof" enclosure to the standard **"Ex-d"**. This is essentially obtained by a robust enclosure with jointing surfaces of such a nature that if a gas permeated into the enclosure and was ignited by a spark within that enclosure, it will not rupture, nor will flame and heat escape via the joints.

These enclosures are usually fitted with unusually shaped bolts or fixings requiring a special key to undo the access points. The enclosure will be marked as complying with AS 2380.1 **Ex-d** or similar acceptable standard.

Note 1 – Non flameproof equipment can be installed lower down in the room within the “safe” non hazardous area, otherwise Intrinsically Safe sounders as described below can be used.

Note 2 - Ventilation fans (in exhaust mode) are required to have flameproof motors, or have the fans outside the compartment with adequate shaft seals. One thing often forgotten is the requirement for the fan to have non sparking blades.

Where fire detection systems are installed, it should be noted that detectors are generally not available as **Ex d**. Consequently Intrinsically Safe detectors are required to be used.

Intrinsic safety equipment can only be used for equipment with small current requirements such as smoke and heat detectors, some low current piezo sounders and “Metron ®)” MJC piston actuators. Intrinsic Safety should be regarded in a different light from the other protection methods. It differs from the various "enclosure" methods in that instead of attempting to minimise the chance of electrical ignition or contain its effects, it says that, by getting well below an established parameter we can substitute zero for a probability. Figure 13 below shows the principle and Figure 14 a typical Intrinsically Safe circuit diagram.

The equipment will be marked as complying with AS 2380.1 **Ex-ia** or **Ex-ib** or similar acceptable standard.

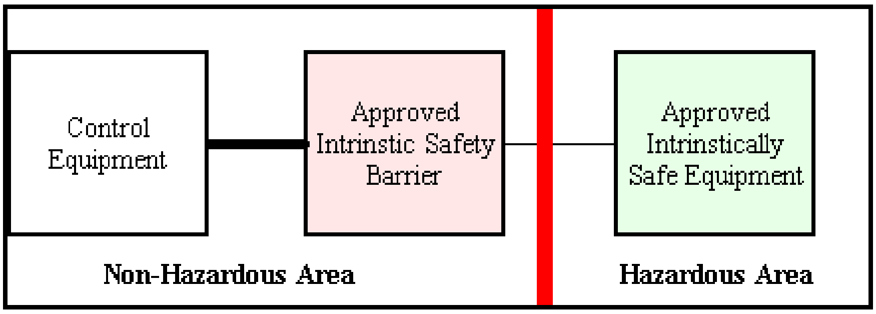


Figure 13 – Intrinsic Safety

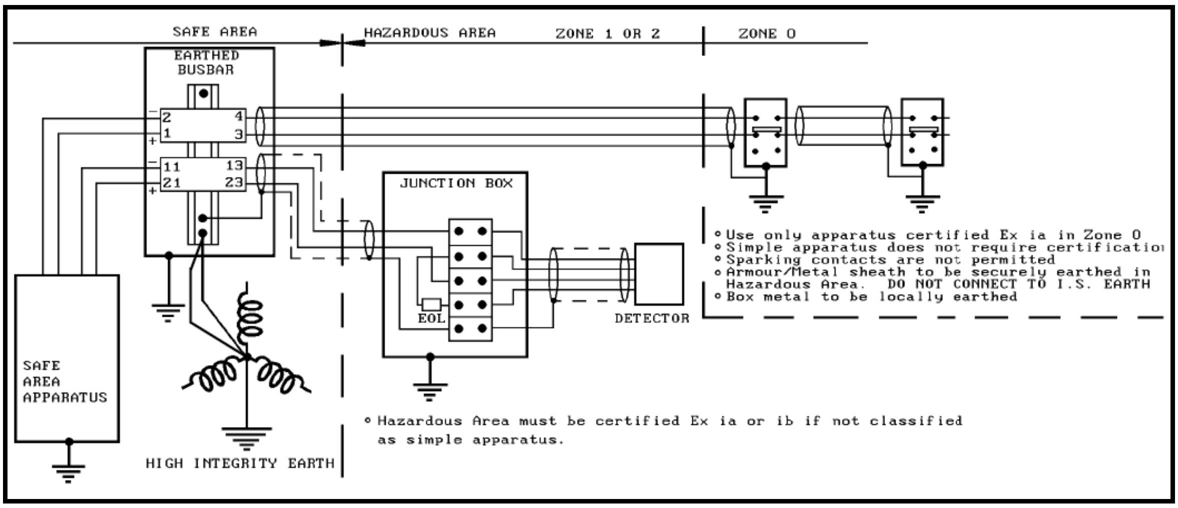


Figure 14 Typical Intrinsically Safe Circuit for Fire Detection Equipment

7 – Ventilation of Battery Rooms

General

Three assessments for ventilation in battery or forklift servicing rooms are required to be considered.

1. The **Queensland Workplace Health and Safety Regulation** requires a minimum 18% $^{v}/_{v}$ Oxygen in any workplace. Considering that the composition of air (neglecting elements below 1.0%) is 79% $^{v}/_{v}$ Nitrogen and 21% $^{v}/_{v}$ Oxygen, the resultant Oxygen percentage can be calculated when the maximum allowable 2% $^{v}/_{v}$ Hydrogen is introduced into the compartment. Neglecting the “free efflux” effect when a certain portion of the hydrogen may be discharged by the displacement effect, the resultant Oxygen percentage will be 20.58% $^{v}/_{v}$, thus meeting the 18% $^{v}/_{v}$ minimum required.
2. **EN 50272.3** calculated exhaust rate as discussed below required meeting the requirement in **AS 3011** that the average hydrogen concentration by volume in a battery room or enclosure be maintained below 2%v/v. This is required to meet the electrical safety requirements discussed in Section 6 in this paper.
3. **AS`1668.2** as referenced in BCA Part F4.5 requires mechanical ventilation to ensure acceptable standards of health and amenity. This is the primary <u>BCA adopted Australian Standard</u> for ventilation in buildings and sets out recommended practices for the ventilation of contaminants from within buildings. AS1668.2 also references AS2676 as referenced in Section 8 of this paper.The Standard sets out various methods of calculating the required ventilating rates and is generally based on the number of persons accommodated, the type of activity, whether low, medium, high or very high and the compartment temperature. The type of ventilation may be natural, mechanical or a combination of both. Often a combination of mechanical supply and mechanical exhaust is used.

Ventilation of battery rooms must address the propensity of a compartment having a toxic or asphyxiant atmosphere as discussed in Section 5 and **Appendix A**. Compliance with 1668.2 <u>may</u> meet the requirements where:-

- The minimum 18% $^{v}/_{v}$ of oxygen discussed in Section 5 of this paper; and
- The required ventilation as discussed in Section 6 of this paper **for** hazardous area classification where **AS 3011** requires that the average hydrogen concentration by volume in a battery room or enclosure be maintained below 2%$^{v}/_{v}$
- The ventilation capacity for a battery room where Hydrogen gas is evolved is dependant on the number of battery cells, the number of cell trays being charged, the type of battery cells and charging rate in Amps.

Ventilation of battery rooms can be calculated by reference to the formulae in both ***AS 2676.1****(vented cells) and* ***AS 2676.2****(sealed cells (VRLA))* where in clause 3.3.2 for mechanical ventilation, is used to calculate the minimum exhaust ventilation rate required to maintain hydrogen concentration below 2% $^{v}/_{v}$.

q_v = $0.006nI$ where

q_v = the minimum exhaust ventilation rate, in litres per second

n = the number of battery cells

I = the charging rate, in amperes – **Note 1**.

Note 1 – Yausa Batteries advise this as being the charging current delivered to the cells during the gassing stage (Ah x 10%).

For natural ventilation, AS2676.1 and AS2676.2 in clause 3.3.4.2 both refer to the minimum cross-sectional area of the required apertures as:-

A = $100q_v$ where

A = the minimum area of the apertures, in square centimeters

q_v = the minimum exhaust ventilation rate, in litres per second (see Clause 3.3.2)

With natural ventilation, an air velocity of at least 0.1 m/s is assumed to flow through the apertures.

Natural Ventilation

Where natural ventilation is used, the required capacity can be calculated by reference to the formulae in both ***AS 2676.1****(vented cells) and* ***AS 2676.2****(sealed cells (VRLA))-*

Example 1 - Using the AS2676 calculation for a battery room 10m x 5m x 4.4m containing 10 vented lead acid **or** VRLA battery trays each with 24 25AH cells (total 600AH), we get the following result for ***qv***:-

qv = .006 x 24 x 2.5 = **0.36l/s** x 10 batteries = **3.6l/s** plus a safety factor of 5 = **18l/s**

If we add a safety factor as determined in the **EN 50272.3** methodology, **qv = 18l/s**

For natural ventilation the minimum size of inlet and outlet *apertures* is determined from,

A* = 100*q*v**, where ***A = the minimum area of the apertures, in square centimeters; and

***q*v** = the minimum exhaust ventilation rate, in litres per second

the resulting areas of the inlet and outlet apertures is **360cm^2** or **0.036m^2**. However if we apply a safety factor of 5, the resulting areas of the inlet and outlet apertures is **1,800cm^2** or **0.18m^2**.

The "text book" calculation for "stack effect" ventilation is:-

Qstack =	Cd*A*[2gh x (Ti-To)/Ti]^0.5, where	
Qstack =	volume of ventilation rate (m³/s)	
Cd =	0.65, a discharge coefficient.	= 0.65
A =	free area of inlet opening (m²), = area of outlet opening.	= 0.036 **or** 0 0.18
g =	9.8 (m/s²). the acceleration due to gravity	= 9.8
h =	vertical distance between inlet and outlet midpoints (m) say	= 2.8
Ti =	average temperature of indoor air (K) 30^{o}C	= 303^{o}K
To =	average temperature of outdoor air (K) 27^{o}C	= 300^{o}K

Typical values for this example follow. See also Figure 12 for "h" and "A".

For this example without a safety factor,

Qstack = 0.054m^3/sec = 54.8l/s

And where a safety factor of 5 is applied:-

Qstack = 0.274m^3/sec = 274l/s

Stack effect ventilation is an especially effective strategy in winter, when indoor/outdoor temperature difference is at a maximum. Stack effect ventilation will not work in summer because it requires that the indoors be warmer than outdoors, an undesirable situation in summer.

With natural ventilation as shown in Figure 12 in Section 6 in this paper where the inlets and outlets are on opposite sides of the room and at low and high level respectively as recommended in AS2676, there will be areas not properly ventilated shown coloured pink.

Natural ventilation may be used but as advised in a commentary in AS1668.4, "*The dynamics of these systems rely on very small pressure differentials caused by wind and air density, which makes the effect difficult and complex to predict".*

FSCS considers that because of the doubts raised as to the adequacy of natural ventilation and that it is imperative to achieve a Hydrogen concentration below 2%$^v/_v$ to satisfy the Hazardous Zoning requirements discussed in Section 6 in this paper, natural ventilation cannot be substantiated.

Mechanical Ventilation

Where mechanical ventilation is used, the required capacity can be calculated by reference to the formulae in both ***AS 2676.1****(vented cells) and* ***AS 2676.2****(sealed cells (VRLA).*

Example 2 - Using the AS2676 calculation for a battery room 10m x 5m x 4.4m containing 10 vented lead acid **or** VRLA battery trays each with 24 25AH cells (total 600AH), we get the following result for ***qv***:-

(q_v= 0.006 x N X A)

qv = .006 x 24 x 2.5 = **0.36l/s** x 10 batteries = **3.6l/s**

However if we apply a safety factor of 5, **qv = 18l/s**

In the "Discussion on Australian Standards" in Section 8 of this paper, the unsubstantiated use of a single method of ventilation calculations across a range of Australian Standards is discussed. The outcome is that this paper recommends the use of ***EN 50272-3*** for calculating mechanical ventilation as referenced below.

FSCS considers that because it is imperative to achieve a Hydrogen concentration below 2%$^v/_v$ to satisfy the Hazardous Zoning requirements discussed in Section 6 in this paper, and the AS1668.2 fresh air requirements discussed hereafter, calculations using **EN 50272.3** dependant on the type of batteries should be used.

The required ventilation can be determined from **EN 50272.3** dependant on the type of batteries. The Standard states that the necessary ventilation airflow for a battery location or compartment shall be calculated by the following formula, note that this formula differentiates between vented / sealed lead acid batteries and VRLA batteries and the method of charging.

I have used a programme called "BatteryMV calculator' for ease of calculation which provides a text file output. I have made a "screen dump" of the display adjacent to each calculation.

Q = v * q * s * n * Igas * Cn / 100 [m^3/h], resolved as 24 * 0.00042 * 5 * n * Igas * Cn / 100

Giving the final formula as:-

Q = 0.05 * n * Igas * Cn / 100 [m^3/h]

Q = Ventilation air flow [m^3/h]

v = Necessary hydrogen dilution factor 24

q = $0.42 * 10^{-3}$ [m^3/h] generated hydrogen

s = Safety factor: 5

n = Number of cells

I gas = Current producing gas during the gassing phase of charge [Amp/100Ah] - See Table below.

C n = Nominal capacity [Ah]

Charger characteristic	I gas : vented cells	I gas : valve regulated cells
IU: Voltage limit = 2.4V/cell	2	1
IUI: No voltage limit	Max 6	Max 1.5
W: Taper charging	Typical values in the range of 5 to 7	---

- In battery rooms, areas and enclosures, air inlets and outlets are required, each with a minimum free area of opening calculated by the following formula: - Area = 28 * Q [cm^2].
- For the purpose of this calculation the air velocity is assumed to be >0.1 m/sec.
- Large and well ventilated rooms shall have a free volume of at least 2.5 * Q [m^3].
- The air inlet and outlet shall be located at the best possible location to create best conditions for exchange of air, i.e. openings on opposite walls with a minimum distance apart of 2 m when openings on the same wall.

Example 3 - For 10 <u>vented</u> lead acid battery trays each with 24 25AH cells (total 600AH) in a room 10m x 5m x 4.4m

Using **EN 50272.3** and the calculator referenced for **traction batteries** with a charging limit of 2.4v/cell.

No. of Cell/Battery = 24

No. of Battery = 10

Space taken by batteries = $2.0m^3$

Rated capacity of battery = 600 Ah

Charging current, Igas = 0.02 A/Ah

H2 release rate = 0.00042 m^3/h

Hydrogen produced = 1.2096 m^3/h

Nett Room Vol = 218.00 m^3

% of Hydrogen gas in room

after 1 hour without ventilation = 0.5549 %

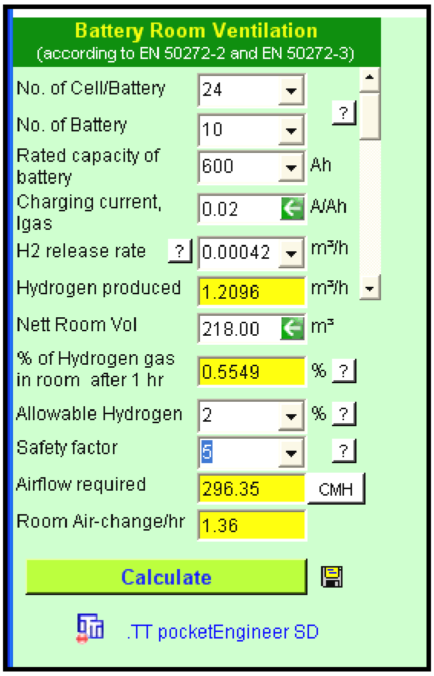
Allowable Hydrogen = 2 %

Safety factor = 5

Airflow required = 296.35 CMH

Room Air-change/hr = 1.36

This equates to **82.3l/s**



Example 4 - For 10 **VRLA** lead acid battery trays each with 24 25AH cells (total 600AH) in a room 10m x 5m x 4.4m

Using **EN 50272.3** and the calculator referenced for **traction batteries** with a charging limit of 2.4v/cell.

No. of Cell/Battery = 24

No. of Battery = 10

Space taken by batteries = $2.0m^3$

Rated capacity of battery = 600 Ah

Charging current, Igas = 0.01 A/Ah

H2 release rate = 0.00042 m^3/h

Hydrogen produced = 0.6048 m^3/h

Nett Room Vol = 218.00 m^3

% of Hydrogen gas in room

after 1 hour without ventilation = 0.2774 %

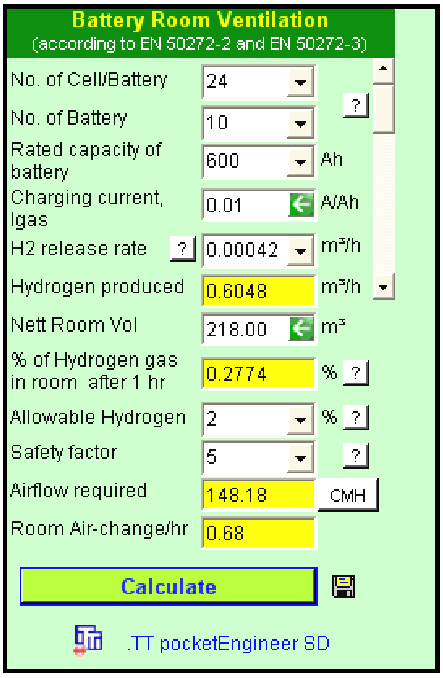
Allowable Hydrogen = 2 %

Safety factor = 5

Airflow required = 148.18 CMH

Room Air-change/hr = 0.68

This equates to **39.22l/s**



This example demonstrates that VRLA batteries evolve ~50% Hydrogen than vented lead acid batteries.

Therefore for the referenced room where **traction (forklift) batteries** are charged, a ventilation of **82.32l/s** is required where vented lead acid batteries are used**.**

Typical room arrangements

Typical room arrangements where service areas may or may not be adjacent to battery charging rooms, or where combined EN 50272 / AS1668.2 / Smoke Exhaust systems are discussed below.

Where a room is used for forklift maintenance and the charging of batteries as shown in Figure 15 below and 19 in Section 12, the required quantity of fresh air for health and amenity based on the *required rate* in litres/second per person is required to be supplied into the room. **See Note 1**.

Where separate but adjoining rooms are used for forklift maintenance and the charging of batteries as shown in Figure 16 below and 20 in Section 12, the required quantity of fresh air for health and amenity based on the *required rate* in litres/second per person is required to be supplied to each room.

FSCS advises that the number of people should be based on the population density as specified in BCA Table D1.13 which, for a workshop or plant room, is one person per 30m^2.

FSCS considers that taken from AS1668.2, the *required rate* should be that at 27^{o}C and for both Battery charging rooms, service areas and combined charging rooms and service areas should be 12l/s representing high activity.

With all of these designs, the resultant pressure in the compartment is required to be negative, i.e. the exhaust rate shall exceed the supply rate.

For the arrangement as shown in Figure 15 below, $\mathbf{QV_{exhaust}}$ is the ruing minimum requirement in respect to Hydrogen ventilation. $\mathbf{QV1_{supply}}$ and $\mathbf{QV2_{supply}}$ are required to be calculated separately. Noting the AS1668.2 requirement that there is a requirement for a negative pressure to be maintained in the room, $\mathbf{QV_{exhaust}}$ should be increased appropriately.

As an example if the area of the room is 300m^2, the required exhaust rate to maintain the concentration below 2% is ~80l/s. For AS1668.2 ventilation the deemed number of persons will be 10 (300 / 30). Thus for 10 persons the required ventilation rate will be 12 x 10 = 120l/s. **See Note 2 in Summary**.

This calculation means that the supply is greater than the exhaust and therefore as discussed; the exhaust rate needs to be increased to ensure a resultant negative pressure. FSCS suggest a 25% increase therefore the new exhaust rate will be 150l/s.

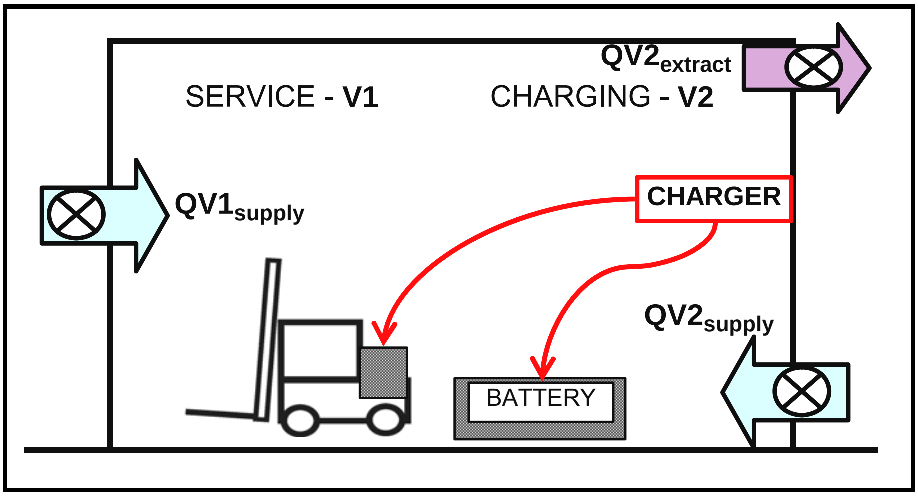


Figure 15 – Combined Service & Charging Area

For the arrangement as shown in Figure 16, $\mathbf{QV_{exhaust}}$ is also the ruing minimum requirement in respect to Hydrogen ventilation. $\mathbf{QV1_{supply}}$ and $\mathbf{QV2_{supply}}$ are required to be calculated separately. Noting the AS1668.2 requirement that there is a requirement for a negative pressure to be maintained in the room, $\mathbf{QV_{exhaust}}$ should be increased appropriately to accommodate the leakage between rooms.

FSCS is of the opinion that the momentary opening and closing of the “fast open” door will not have any significant effect on disturbing the required negative pressure in the charging area.

A similar calculation can be made as before with an allowance for leakage. As Fire Engineers, FSCS frequently has to address smoke leakage through apertures around doors and the like and suggests that based on the Warrington *Fire Research* test programme on smoke doors, leakage rates for a door assembly using *AS/NZS1530.7: 1998 Smoke control door and shutter assemblies-Ambient* were in the order of $30m^3$/hour with a Δp of 25Pa pressure differential, equating to ~8.3l/.s. In the absence of any guidance in AS1668.2, FSCS considers that this can be used as a conservative estimate for a "fast shut" door as shown in Figure 20 in Section 12.

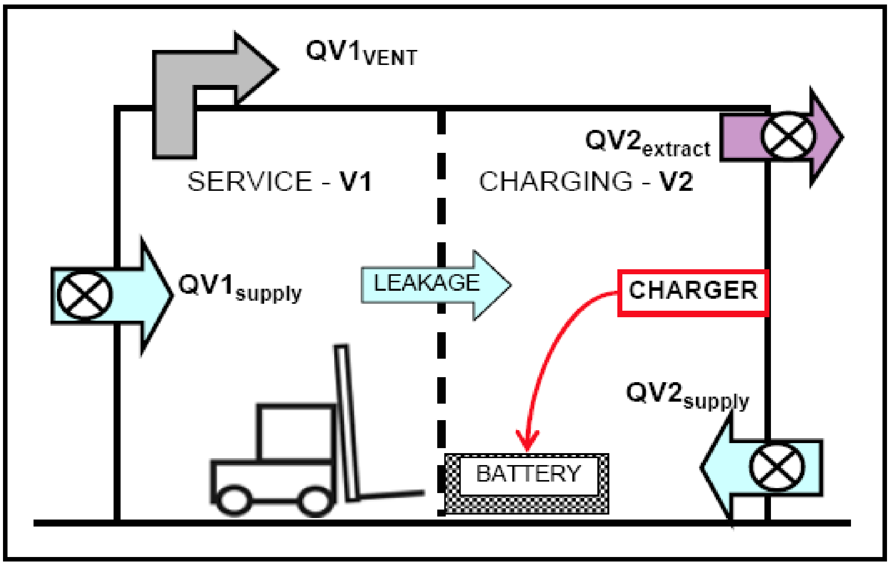


Figure 16 – Separate Service & Charging Areas

Summary of Ventilation System Recommendations

The outcome is that this paper recommends the use of ***EN 50272-3*** for calculating mechanical ventilation.

Considering that hydrogen is lighter than air, FSCS recommends that the ventilation system should:-

- The exhaust fan and fresh air supply air fan shall generally be in accordance with BCA Specification E2.2b, in particular the following:-
  - ➢ Where the room is sprinkler protected, have the fan capable of operating at 200°C for not less than 1 hour; and
  - ➢ Where the room is not sprinkler protected, have the fan capable of operating at 300°C for not less than 30 minutes; and
  - ➢ Have any high temperature overload devices such as thermistors in the motor windings, overridden; and
  - ➢ Notwithstanding any requirements in AS1668, not have a smoke detector in the air inlet to shut down the system.
- Be a such that the air supply and exhaust provides a combination of displacement, dilution and purging; and
- High level exhaust calculated in accordance with AS/NZS 60079.1and the hydrogen release rates as calculated using EN 50272-3; and
- Low level fresh air supply calculated in accordance with AS1668.2 as discussed earlier which will be dependant on whether the service and charging rooms are separated; and
- The exhaust rate to be increased so that air drawn from adjacent compartment(s) is accommodated and the battery room functions at a negative pressure; and
- The system should result in a negative pressure in the battery room or service room / battery room as appropriate; and

- Notwithstanding the latest AS1668.2 relation on the location of exhaust outlets in relation to openings in the building, designers should note that the discharge from a ventilation system will contain hydrogen within the flammable limits and the location should be at least 6.0m above any fresh air intake for any system in the building; and

Other design features required to ensure a robust system design include:-

- Notwithstanding the BCA in Part E2.1 advising that "*The smoke exhaust and smoke-and-heat vent provisions of this Part **do not apply** to any area not used by occupants for an extended period of time such as a plant room **or the like**.",* an assessment must be made as to the combined use of the charging room as a service area. Therefore, where smoke exhaust is required, the design requirements in AS1668.1 should be used. The design should address the combined requirements of AS/NZS 60079.1, AS1668.1 and AS1668.2 by using a "purge" system as described in Section 7 of AS1668.1, however it should be noted that the AS/NZS 60079.1 and EN 50272 requirements take precedence; and
- Extract and supply fans to be running at all times that battery charging is in progress – see **Note 1**; and
- AS 3011 requires that where a fan is used an airflow sensor is installed to raise an alarm if the airflow falls below the required level; and
- Fan fail interlocks to shut down battery charging. As a safety function, many users design the ventilation system with air flow monitors so that if the air exhaust is interrupted either due to fan / power failure or obstruction, the charging process will be automatically stopped, thus ceasing the production of Hydrogen gas; and

  This shut down feature is sometimes thought to be counter-productive as interrupting battery charging mid charge may reduce battery life; and
- Where a Fire Indicator Panel (FIP) associated with an AS1670.1 detection or occupant warning system is provided, a manual shut down trip shall be provided and
- Power supply to the fans should be from the Essential Services section of the main switchboard with separately labeled switches; and
- Wiring to the fans shall meet the requirements in Appendix E of AS1668.1. Types WS54 or WS55 shall be used as appropriate.

Note 1 Where the battery charging room is shutdown for periods but is communicating with a service area as shown in Figure 16, FSCS considers it acceptable for the ventilation system to be designed for the AS1668.2 and smoke exhaust system (if applicable) alone. Such a design may use variable speed drive (VSD) fans as discussed in Note 2 below.

Notwithstanding the above, it is insufficient to have the ventilation system start on detection of Hydrogen. By the time the fans are up to speed, flammable / explosive pockets of Hydrogen may have already formed.

Where distributed charging stations are used, the quantum of hydrogen being released is usually insignificant in relation to the volume of the warehouse in general. FSCS has been advised by Toyota that where "opportunity charging" in distributed charging systems is used, e.g. at lunch breaks, hydrogen is released at the maximum rate from unvented (VRLA) batteries and will be approximately the same as from a vented lead acid battery.

Note 2 Where the required smoke exhaust capacity is greater than the combined requirements of exhaust and AS1668.2 supply, FSCS considers that it will be acceptable for these fans to have variable speed drives providing all the other system requirements are met.

Summary

Figures 18 and 19 in Section 12 of this paper show three alternative forklift charging options with appropriate ventilation systems.

The total ventilation capacity to be provided is required to be the greater of:-

1. The AS1668.2 health and amenity requirements; and
2. The AS/NZS 60079.10.1 requirements for ensuring the dispersing, dilution and purging of the atmosphere for hazardous area classification; and
3. The **EN 50272.3** requirements to keep the atmosphere below $2\%^{v}/_{v}$. FSCS considers that this Standard, having the various options of cell and charging type, is more appropriate than the ***AS 2676.1*** or ***AS 2676.2*** ventilation methodology.

Notes re the Battery Calculator

Visit the website http://pocketengineer2.sharepoint.com/Pages/battMV.aspx and an online calculator of the following can be downloaded for a price of US$9.90.

Please note that if and when you download this .exe file, any aggressive virus protection programme must first be exited because the provider has not established a safe history with Norton 360 and other software. After downloading and unzipping the file, set your virus protection to accept the programme.

This “BatteryMV” calculator provides for multiple options and details are provided in the User Guide provided with the calculator. Calculations for both stationary and traction batteries can be effected and the calculated results can be saved as a text file. I have taken a “screen dump” print of the calculator presentation of the results and placed it alongside each text result to show what appears on the calculator screen.

The “BatteryMV” calculator has limits of 15m x 15m in floor area. If you want to assess a floor area greater than 225m^2, set it up as a 10m x 10m room and interpolate the answer as CMH (M^3/hr) per 100m^2.

EN50272 recommends a safety factor of 5 for land based equipment and 10 for water vessels (ships).

8 – Referenced Legislation & Standards

Queensland Legislation

In addition to **The Queensland Work Health and Safety (WHS) Regulation** addressed in Section 5, the following are relevant.

Building Act 1975 – This Act regulates the building construction process and is the Statutory Instrument that adopts the Building Code of Australia.

National Construction Code (NCC) – Building Code of Australia (BCA) – The BCA provides prescriptive or *Deemed to Satisfy* (DtS) requirements for the design of the building by either detailing specific details or referencing appropriate Australian Standards. Where the Client considers that that meeting the DtS requirements is inappropriate, overly onerous or restrictive to the design intent, the BCA DtS requirements allows Alternative Solutions to be implemented. The process assesses the proposed building design to address compliance with the Performance Requirements of the BCA or compares the proposed building with a comparable DtS building.

Building Regulation 2006 – This Regulation provides for the administration process in building construction and, of particular relevance to this paper, the requirements for designers and installers to provide Form 15 and Form 16 respectively attesting to the compliance of their designs or installation as appropriate.

Building Fire Safety Regulation 2008 – This Regulation provides for the implementation of required maintenance for prescribed fire safety systems and the provisions for egress from a building.

Queensland Electrical Safety Act – This Act and associated Regulation provides for the compliance of the design and installation of electrical installations.

Queensland Development Code - *Part 6.1 Maintenance of fire safety installations.* Commonly called QDC MP6.1

Sustainable Planning Act and Regulation – This Act and Regulation provides for the planning process and, of particular relevance to this paper, the appointment and duties of Building Certifiers and the role of Referral Agencies such as the Queensland Fire and Emergency Service (QFES).

Australian Standards

Australian Standards are written at the behest of industry are written by experts from industry and other "interested parties", often from Regulatory Authorities and, in the case of Standards dealing with safety, representatives from Emergency Services.

Preparation of a Standard is managed by a committee secretary with the resultant document often being driven by the most vociferous committee member! The author has sat on many Australian Standards Committees and has observed how Standards end up as a consensus of opinion which can often be interpreted in many ways. Accordingly it is important that readers and persons applying a Code or Standard to a project do so carefully and in the *context* of the project requirements.

All parties in the project should be familiar with Australian Standards referenced in this paper.

Standards Australia has, over the last 10 to 15 years been changing key Standards to conform to International (ISO) and European Standards (EN). In most cases this has been effected by the adopting *in-toto* those Standards and renaming them with an AS/NZS prefix.

Note that unless otherwise indicated, the applicable dates of the Standards have been omitted and the intent is that persons using and / or referencing this paper should use the date of publication of this paper – November 2014.

***AS1530.4 -** Methods for fire tests on building materials, components and structures - Part 4: Fire-resistance tests of elements of building construction*

***AS1668.1-** The Use of ventilation and airconditioning in buildings – Part 1 Fire and smoke control in multi-compartment buildings: Ventilation design for indoor air contaminant control.*

***AS1668.2 -** The Use of ventilation and airconditioning in buildings – Part 2: Mechanical Ventilation*

This Standard sets out recommended practices for the ventilation of contaminants from within buildings and refers the reader to AS2676.

***AS1668.4 -** The Use of ventilation and airconditioning in buildings – Part 4: Natural Ventilation*

***AS1670.1 –** Fire detection, warning, control and intercom systems – System design, installation and commissioning. Part 1: Fire*

***AS1851 –** Routine service of fire protection systems and equipment*

***AS1905.1 –** Components for the protection of openings in fire resistant walls,* **Part 1** *– Fire resistant doorsets.*

***AS1905.2 –** Components for the protection of openings in fire resistant walls,* **Part 2** *– Fire resistant roller shutters.*

***AS2118.1 –** Automatic fire sprinkler systems. Part 1: General requirements*

***AS2359 –** Powered industrial trucks Part 1: General requirements*

***AS2380.1 –** Electrical equipment for explosive atmospheres - Explosion-protection techniques - General requirements*

***AS 2402.1.2-** Traction batteries - Lead-acid – Vented cells – Installation and usage*.

This Standard specifies requirements for the installation and usage of lead-acid batteries of the *vented type* intended for installation in electric traction vehicle, industrial trucks and the like where deep cycling is required. Although the Standard addresses battery charging and changing, it does not address storage of batteries either alone or when installed on a vehicle. "*Opportunity charging*" is also included in this Standard.

***AS 2402.2.2 -** Traction batteries - Lead-acid - Valve-regulated cells – Installation and usage.*

This Standard specifies requirements for the installation and usage of lead-acid batteries of the *valve regulated type* intended for installation in electric traction vehicle, industrial trucks and the like where deep cycling is required.

Although the Standard addresses battery charging and changing, it does not address storage 0of batteries either alone or when installed on a vehicle. "*Opportunity charging*" is also included in this Standard.

***AS 2676.1 -** Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings - Vented cells*. See **Note 1**

***AS 2676.2 -** Guide to the installation, maintenance, testing and replacement of secondary batteries in buildings - Sealed cells*. See **Note 1**

These Standards set out recommended practices for the installation. Maintenance, testing and replacement of *sealed secondary batteries* in buildings.

Both ***AS 2676.1 AS 2676.2*** limit their applications to batteries >24v and >10AH capacity as does BCA C2.12.

***AS 3000: 2007 –** Electrical Installations.*

Section 7.7 of this Standard addresses electrical installations in hazardous areas – specifically explosive gas such as Hydrogen produced in the charging of batteries.

***AS3011.1 –** Electrical Installations – Secondary batteries installed in buildings – vented cells.*

***AS3011.2 –** Electrical Installations – Secondary batteries installed in buildings – sealed cells.*

These Standards address the installation of secondary batteries and in particular the requirements for battery rooms and enclosures.

AS 4086.2 - Secondary batteries for use with stand-alone power systems, Part 2: Installation and maintenance. See **Note 1**

AS/NZS 60079.10.1 – *Explosive Atmospheres – Classification of areas – Explosive gas atmospheres*.

AS/NZS 60079.14 – *Explosive Atmospheres – Electrical installations design, selection and erection.*

Note that both the AS/NZS Standards referenced above are derived from the original EN Standards.

Note 1 - Some Standards have not been reviewed for many years and an example of this being *AS 2676.1, AS 2676.2* and AS 4086.2 which were last published in 1992.

Discussion on Australian Standards

AS 2676.1, AS 2676.2 and AS *4086.2*, all last published in 1992 use the same formula for calculation of both mechanical and natural ventilation regardless of the type of battery used, i.e. *vented* or *sealed cells.* Although this demonstrates consistency between Standards, it is counter intuitive because the hydrogen release from VRLA cell batteries is known to be significantly less than from vented call batteries.

Whilst there is a degree of correlation between AS2676 and EN50272 methodology for stationary batteries, this correlation is only evident where the safety factor of "5", inbuilt into the EN50272 methodology is applied to the AS2672 results.

It is evident that Standards Australia have not addressed to issues of Hydrogen evolution from different types of batteries since the 1992 Standards were published. As discussed in the preamble to this Section, industry generally drives the preparation and revision of Standards and where there is an inordinate time between revisions, it is usually because industry lacks the resources to commit staff to committees or is content with the current state.

Notwithstanding this correlation, industry takes the view that the methodologies for calculating ventilation rates for evolved Hydrogen do not reflect current practice. Most practitioners now use *EN 50272-2 and EN 50272-3* and FSCS considers that these **EN** Standards, having the differing calculation methods and various options of cell and charging type, are more appropriate than the *AS 2676.1* or *AS 2676.2* methodology.

European Norm (EN) Standards

EN 50272-2 - *Safety requirements for secondary batteries and battery installations. Part 2: Stationary batteries*

EN 50272-3 - *Safety Requirements For Secondary Batteries And Battery Installations - Part 3: Traction Batteries*

British Standards

BS EN 50272-3 sets out the safety requirements for secondary batteries and battery installations used in electric vehicles. These include the storage batteries and electric cells in battery powered industrial trucks – lift trucks, tow trucks, cleaning machines, locomotives and electric road vehicles, such as passenger and goods cars, golf carts and wheelchairs. The standard describes the principle safety measures to protect goods and people from hazards, including electricity, gas emission and electrolyte.

The Standard looks at the principles for the protection against electric shock, the prevention of short circuits and measures that should be taken to avoid the explosion of hazards due to ventilation. The standard also covers various battery containers and enclosures, as well as the accommodation for charging maintenance.

BS EN 50272-3 requires that battery charging installations shall be located in *areas designated for that purpose*.

Facilities shall be provided for flushing and neutralizing spilled electrolyte, for fire protection, for protecting charging apparatus from damage by trucks, and for adequate ventilation for dispersal of fumes from gassing batteries."

In general, the requirements and definitions are specified for lead-acid and nickel-cadmium batteries. For other battery systems, the requirements may be applied accordingly.

9 – International Codes and Standards

The International Fire Code (IFC) recognises the difference between stationary batteries and those in *powered industrial trucks* (forklifts).

For powered industrial trucks, the IFC Section 309.2 requires separation from combustibles of a minimum of 3 feet (915mm) and for stationary batteries the IFC requires compliance with the International Building Code (IBC).

The IBC, in Section 608, refers to legally required stand-by power systems and also mentions the type of battery, the electrolyte capacity of the battery dependant on whether or not the building is sprinkler protected and the Occupancy Group, which for a warehouse is Group S. In this instance, there is a requirement for a 1 hour separation.

Extracts from these Codes are included in **Appendix B**.

10 – International Risk Management and Insurer viewpoints

The viewpoints of Risk Managers and Insurers are often at odds with the Regulatory requirements in Codes and Standards.

Risk Managers and Insurers are primarily concerned with property and business operation losses and frequently have requirements for compliance with their own standards before insurance can be effected.

Nevertheless, these organisations generally have a greater understanding of hazards in buildings and their standards are based on documented fire and accident data.

Zurich Risk Engineering

The Zurich risk assessment considers that separation from combustibles of 2m is adequate.

FM Global

The FM Global risk assessment considers that separation of 1.5m is adequate.

Extracts from these publications are included in **Appendix C**.

11 - The Building Code of Australia

FSCS has researched the background to the requirement for the separation of battery rooms and advises that the requirement first appeared in the Queensland Building Act 1975 (1984 print) under Section 55.11, part (5) -. In that publication, the requirement was only for **batteries powering emergency lighting**.

Ensuing requirements in the BCA were only for the separation of **emergency batteries** and it was only in the 1990 edition of the BCA that the word **emergency** was dropped.

The BCA in Part C – *Fire Resistance*, Part C2 – *Compartmentation and Separation* and Part C2.12 – *Separation of Equipment*, requires battery rooms to be separated from the rest of the building by fire resistive construction. The following is an extract from the National Construction Code Series (NCC) 2014, Volume One, Building Code of Australia (BCA) – for Class 2 to Class 9 Buildings.

Performance Requirement:

CP6

A building must have elements, which will, to the degree necessary, avoid the spread of fire from service equipment having –

(a) A high ***fire hazard****; or*

(b) A potential for explosion resulting from a high ***fire hazard***

Deemed to Satisfy Requirements

(a) Equipment other than that described in (b) and (c) must be separated from the remainder of the building with construction complying with (d) if that equipment comprises –

(v) a battery or batteries installed in the building that have a voltage exceeding 24 volts and a capacity exceeding 10 ampere hours

(b) Isolation of equipment need not comply with (a) if the equipment comprises-

(iv)equipment otherwise adequately separated from the remainder of the building.

(d) *Separating construction must-*

(i) have an FRL as required by Specification C1.1*, but not less than 120/120/120; and*

(ii) have any doorway in that construction protected with a self-closing fire door having an FRL of not less than - /120/ 30.

Sub-clause (a) (v) is entered so that distributed battery systems like those powering stand-alone emergency lights, EXIT signage and batteries for Fire Indicator Panels are not caught up in the legislation.

It is interesting to note that sub clause to C2.12 (b) (iv) which in BCA 2014 reading:-

Equipment need not be separated with (a) if the equipment comprises-

(b) (iv) equipment otherwise adequately separated from the remainder of the building.

This clause will be addressed later in this section and Conclusion.

Moving on to the BCA published “Guide to the BCA”, we are advised that:-

Guide to Volume One:

C2.12 Separation of Equipment

Intent

To limit the spread of fire from service equipment having a high fire hazard or potential for explosion and to ensure emergency equipment continues to operate during a fire.

The types of equipment referred to in C2.12 (a) (iv) and (v) have a high explosive potential.

It is important that any fire in this type of equipment does not spread to other parts of the building.

Fire hazard *means the danger in terms of potential harm and degree of exposure arising from the start and spread of fire and the smoke and gasses that are thereby generated.*

Taking ***the second part of the intent*** first, the guide advises that the separation of equipment is to prevent fire spread ***from*** other parts of a building ***to*** those parts containing emergency equipment that are required or operate in the event of fire. This is readily understandable to most building designers and Building Certifiers and is supported by FSCS. Note however, that providing this separation does not relieve the building designer / owner/ operator to comply with the requirements set out in this paper in respect to WHS compliance, Hazard classification, Electrical Equipment and ventilation.

The ***first part of the intent,*** advises that certain service equipment has a *high fire hazard or potential*. This is the reason that batteries are included in the separation requirements and the impact of this are discussed herein.

As discussed in Section 2 in this paper on the types of batteries used, the BCA, in carrying over the battery separation requirements, has failed to recognise the advances in battery design and safety. There is an implicit assumption in the BCA that all battery installations are of the *stationary* type and that all batteries are of the open vented cell lead acid type that vent hydrogen gas to the atmosphere during the latter stages of charging, and indeed whilst under deep discharge conditions. This is not necessarily so.

FSCS submits that there are a number of scenarios that should be considered in any response to Part C2.12 of the BCA.

1. FSCS considers that a valid interpretation of BCA C2.12 (v) and in particular the words *"the battery or batteries installed in the building.*" relates to stationary batteries associated with building services. This is further supported by the "Guide to the BCA" advising that the separation is to ensure ongoing operation of emergency equipment in the event of a fire.

   Accordingly FSCS is of the opinion that under the BCA C2.12 requirement that the location of batteries and battery charging equipment, ***not related to emergency equipment****,* need not be fire separated from the rest of the building.

2. Batteries being <u>part of a forklift</u> that is located in a building are not "batteries installed' in a building. It could be argued that once those batteries are removed from the forklift and installed in battery charging racks; multiple batteries qualify as an installation. Although FSCS tends to agree with that scenario because the quantum of batteries so located obviously presents a greater hazard than a single forklift moving through the building, such separation by physical barriers with the BCA C3.12 FRLs are not warranted.

   The *Guide to the BCA* implies that only fire separation can protect *the other parts of the building*. However the phrase:-

   Equipment need not be separated with (a) if the equipment comprises-

   (b) (iv) equipment otherwise adequately separated from the remainder of the building.

   can be interpreted as having adequate physical separation with the design of the battery systems and equipment therein being such that any propensity for ignition and development of fire being adequately addressed.

   FSCS considers that compliance with the various requirements for WHS compliance, Hazard classification, Electrical Equipment and ventilation addressed in this paper more than adequately addresses the issue.

   Even if forklift batteries were to be charged in areas other than in a dedicated room, addressing separation from electrical equipment as discussed in Section 6 in this paper and separation from combustibles as recommended in both the FM Global and Zurich Risk Engineering publications will provde adequate fire separation. With respect to hydrogen discharge during battery charging, it should be reasonable to calculate the hydrogen discharge from multiple distributed charging stations as described in Section 7 of this paper (**Note 1**) and determine (and document) the resultant hydrogen and oxygen concentrations in the entire surrounding structure.

Note 1 - *For normal ambient temperatures of 25°C, and normal pressure of 0.1013 MPa (1 atmosphere), the amount of created gas is 0.4564 litre of hydrogen gas per overchagarged 1Ah capacity.*

3. Where battery charging is carried out in a dedicated room or service area, FSCS is of the opinion that as discussed in Section 7, the ventilation of such an area is required to comply with various Standards and Regulations and be so designed to maintain an Oxygen concentration of >18%$^{v}/_{v}$ and a Hydrogen concentration of <2% $^{v}/_{v}$.
4. The BCA implies that fire separation with an FRL of 120/120/120 will protect *the other parts of the building* in the event of an explosion in the battery room. This clearly demonstrates that the ABCB and / or its technical writers do not understand the difference between a fire and an explosion. In an explosion, especially one initiated in a hydrogen rich atmosphere flame propagation is rapid to the extent that surrounding structure is displaced to vent the rapidly developing pressures. The following definition is taken from the Ballarat School of Mines curriculum on Explosion Suppression, written by the author of this paper and referenced in the Introduction to this paper.

> An explosion is not an instantaneous occurrence but requires a definite and measurable time from the instant of ignition to the development of maximum pressure. For a single point source of ignition, say in the approximate centre of a vessel, the flame commences as a small sphere and grows as a sphere whose radius is expanding at a constant rate and follows a cube law. The pressure at any instant is thus proportional to its volume. When the flame has filled the vessel all the mixture will have been burnt and the pressure can rise no higher. It follows that the larger the vessel the longer the time taken to reach a given pressure. The final pressure depends on the initial pressure in the vessel; an ideal hexane/air mixture commencing at 100 kPa absolute develops 750 kPa gauge. However, at 200 kPa absolute the final pressure would be about 1500 kPa gauge. In turbulent conditions the rate of rise of pressure is increased although the maximum pressure is unaffected.

Bounding construction with an FRL of 120/120/120 cannot resist such a pressure development and fire doors to AS1905.1 and roller shutters to AS1905.2 if closed, will almost certainly be displaced.

Unless the separating walls, floors and roof are of reinforced concrete construction with doors having an appropriate "blast" rating, an explosion in a commercial building will breach the separating elements. Figure 16 below shows the resultant damage from an explosion in a battery room - see Case Study below (courtesy Cholamandalam MS Risk Services Ltd.)

Although the majority of the displacement and damage occurred to the roof, major displacement of the rear wall and minor displacement of the side wall can be seen.

Figure 17 – Battery Explosion Results

Case Study:

The affected building where a major explosion occurred was formerly a large computer / data centre with battery room & emergency generators. The company vacated the building, moved out computer equipment, however the battery back-up system was left behind.

This accident is a very good example of what can happen when you lose ventilation in a battery charging room. The explosion blew a 400 SF +hole in the roof, collapsed numerous walls and ceilings throughout the building, and significantly damaged a large portion of throughout the building, and significantly damaged a large portion of the 50,000 + SF building.

12 - Discussion on the available options for battery charging rooms

Central Charging

FSCS has studied the various requirements for location and ventilation of battery charging facilities and provides the following suggestions for compliance:-

1. Figure 18 below shows a configuration where the forklift is located in a dedicated room and the batteries are left “on board” whilst charging.

   This configuration would not be considered as a ‘battery room” and consequently as discussed previously, the room would not require a bounding construction of FRL 120/120/120.

   The ventilation arrangements are required to be addressed as per Section 7 in this paper with calculations as discussed in Section 7.

   Should the building be sprinkler protected and the client adopts a policy of not providing sprinklers, the bounding construction under AS2118.1 Clause 3.1.3 is required to be FRL -/120/120 with the door, in this instance shown as a roller shutter, having an appropriate FRL as discussed later.

   This door would require to be automatically closed by activation of the sprinkler system if installed and at least by a dedicated fire detection system.

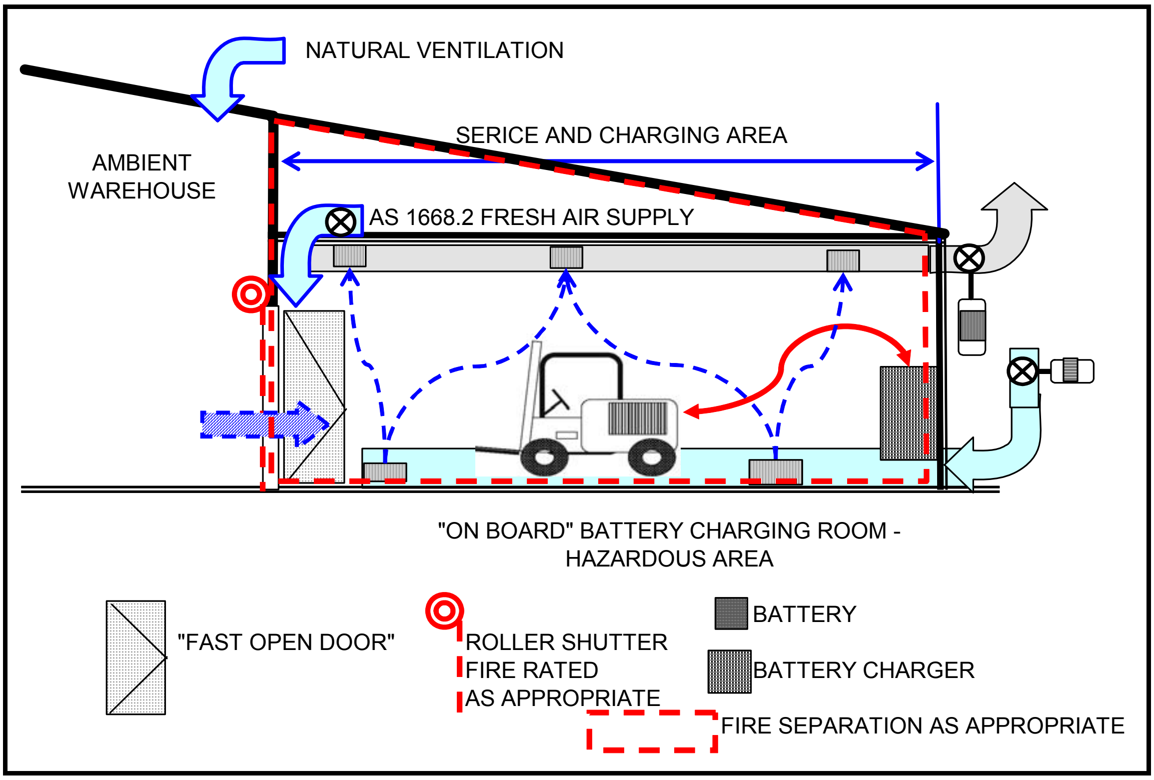


Figure 18 – On-board Battery Charging

2. Figure 19 below shows a configuration where the forklift is located in a separate room, in this case called a “service area” and dedicated room and the batteries are removed and charged in a separate room.

   In this configuration only the “charging area” would be considered as a ‘battery room” and consequently as discussed previously, the room would require a bounding construction of FRL 20/120/120, with the door, in this instance shown as a roller shutter, having an appropriate FRL as discussed later.

   The ventilation arrangements are required to be addressed as per Section 7 in this paper with calculations as discussed in Section 7.

   Should the building be sprinkler protected and the client adopts a policy of not providing sprinklers, the bounding construction under AS2118.1 Clause 3.1.3 is required to be FRL -

/120/120 with the door, in this instance shown as a roller shutter, having an appropriate FRL as discussed later.

This door would require to be automatically closed by activation of the sprinkler system if installed and at least by a dedicated fire detection system.

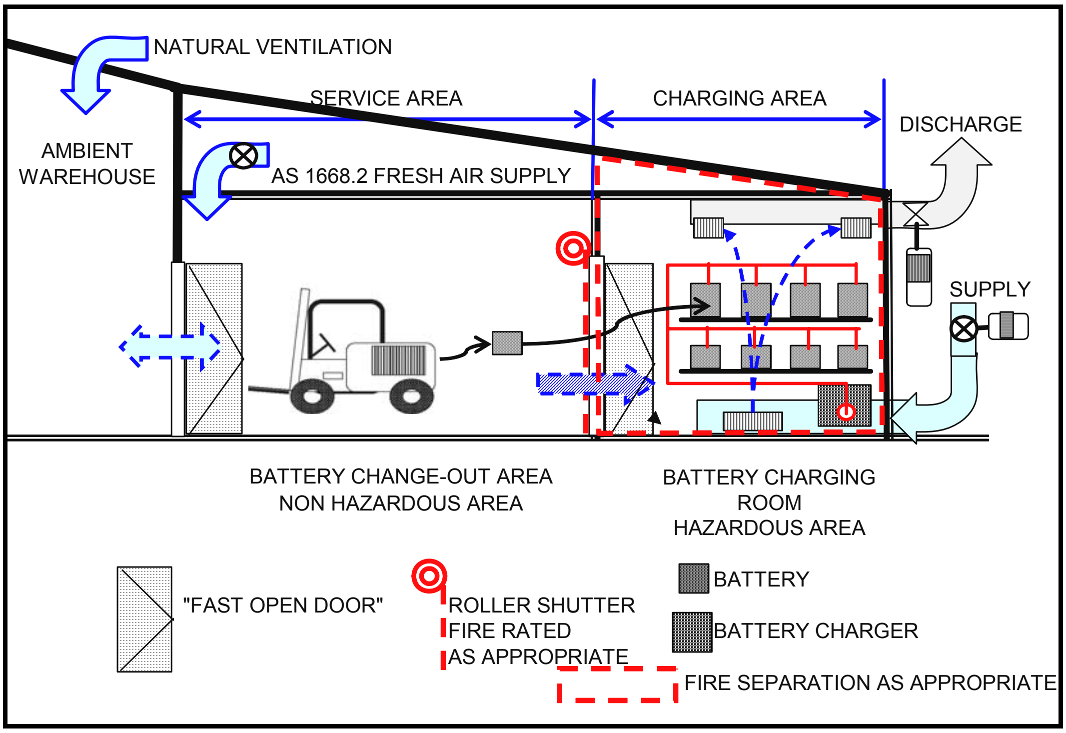


Figure 19 – Separate Battery Charging

The use of a “fast open door” activated by sensors is considered to be good practice in maintaining pressure differentials between the rooms. Figure 20 below shows a typical door. FSCS is of the opinion that the momentary opening and closing of the “fast open” door will not have any significant effect on disturbing the required negative pressure in the charging area.

Figure 20 – Typical “Fast Open Door”

Sprinkler Protection

Should an automatic sprinkler system be required under BCA C2.3 (large isolated buildings), E1.5 – large Class 6 fire compartments or Part E2 – smoke hazard management then the requirements in BCA Specification E1.5 are required to be met.

FSCS frequently has to address circumstances where the Client has a preference to omit sprinklers in electrical equipment rooms. FSCS strongly recommends that where a building is sprinkler protected that sprinkler protection be extended into battery charging rooms. There is often a misconception that water discharge from sprinklers will damage electrical equipment. The reality is that statistically, 98% of fires are controlled by three sprinklers or fewer and the water discharged is confined to the origin of the fire and the extent of fire spread. Three sprinklers will discharge approximately 150 litres per minute.

Conversely, if sprinklers are omitted, fire control and extinguishment will be in the hands of fire fighters from the local Brigade. Their response in an urban area will be in the order of 10 to 13 minutes and by the time that hose lines are set up, fire spread will be extensive and certainly engulf the entire battery charging area. On entering the compartment, the water discharge from a fire hose will be at least 300litres per minute!

Note that in a sprinkler protected building any non-sprinklered area is required under AS2118.1 Clause 3.1.3 to have a bounding construction of FRL -/120/120.

The second misconception is that sprinkler heads can fail and discharge water without fire initiation. The failure rates for sprinkler heads are extremely small (on the order of 1 in 16 million or a probability of 6.25×10^{-8}). Inadvertent discharge of sprinklers is extremely rare and usually attributed to mechanical damage or poor system design. It is so rare, in fact, that there are not enough data to be more precise. It is estimated that 1 in 2.5-million installed sprinkler systems will discharge inadvertently (probability of 4.0×10^{-7}).

Construction

AS2676 provides some useful guidance for the construction of battery charging areas and rooms including the requirement for graded impervious, electrolyte resistant, antistatic and slip resistant surface concrete floors draining to a pit with a minimum of 1% of the contents of the electrolytes or the contents of a single cell. It is interesting to note that the International Building Code provides for reduced capacity where gell type batteries are used.

The *definitions* in AS2676 differentiate between *enclosures* and *rooms* and only provide guidance for the construction of battery enclosures. Otherwise there is no guidance on the construction requirements for the room.

Except where required to have a fire rated bounding construction as detailed below, FSCS is on the opinion that where a dedicated battery charging room, including a room where service activities are conducted, the walls should be of non combustible construction such a colorbond sheet steel. However it is recommended that concrete dado panels be incorporated to minimise damage. It is also recommended that because the room is required to operate under negative pressure, joints and service openings should be sealed.

Where fire rated construction is required, Figures 15 and 16 above show, by means of dashed red lines, the extent of bounding construction required when the Insurer requires fire separation to BCA Part C2.12or when sprinklers are omitted from a building.

Now considering the requirement where the bounding construction is required to have an FRL of 120/120/120 (or -/120/120 if not loadbearing), we must address the BCA requirements and determine how the fire resistance is to be achieved and, more importantly what FRL is required for the door.

Noting that the BCA in Part C2.12 requires an FRL of 120/120/120 and AS2118,1 Clause 3.1.3 requires an FRL of -/120/120, it should be noted that the requirement is for an FRL and not for the room to be a *fire compartment*.

The customary process for determining the required FRL for the door(s) is to look to Part C3.5 in the BCA. This Part, entitled “Doorways in fire walls” provides requirements for the various types of doors and the required FRLs.

In the FSCS paper “*Fire Resistance – A Fire Engineer’s Perspective*”, the difference between a *fire wall* and a *wall with an FRL* is discussed and accordingly as the battery charging room is <u>not a fire compartment</u> and therefore not bounded by a fire wall, <u>BCA C3.5 cannot be applied</u> and the project team

With this being established, the appropriate FRL for the door needs to be determined. BCA C2.12 (d) (ii) advises that the door is required to have an FRL of -/120/30.

Where the door, either single leaf hinged, double leaf hinged or sliding, such doors are required to be self closing and comply with AS1905.1 with the appropriate FRL.

Where a roller shutter door is considered more appropriate, such doors are required to be self closing and comply with AS1905.2.

Both hinged and roller shutter doors can be held open by electro-magnetic devices designed to release upon activation of the sprinkler or fire detection system as appropriate.

Now considering that it may be proposed to use a roller shutter door, the availability of such shutters needs to be established and more importantly, the availability of a shutter with the required insulation value of “30”.

1. Gliderol Roller Shutters from Gliderol International in Adelaide can supply their “IFS 50/240” roller shutter which as an equivalent FRL of -/240/50, thus exceeding the -/120/30 requirements for the subject example. The details provided by Gliderol state:-

   The door curtain consists of 2 layers of double-walled cavity interlocking slats overall size 80mm x 20mm thick, thus forming an air gap. Located within this air gap is an additional insulation barrier of silica fabric which is rolled up into a deployable package. This barrier will be deployed by a separate fusible link in the event of a fire. The cavity of the slat is filled with insulation material consisting of a combination of Ceramic Fibre and Gypsum.

2. Roller shutters with an FRL of -/120/- are available from a variety of suppliers and where the building is sprinkler protected, the application of drenchers with an application rate of 0.2l/min/m^2 can achieve an FRL of -240/30; refer to CSIRO Test Report FCO 3803 / 3856 for Abel Doors Pty Ltd. See Figure 21 below of a typical Multiple Jet Control (MJC) actuated drencher arrangement designed by FSCS. See the FSCS paper “*Multiple Jet Controls in Fire Protection Systems*” for further details.

Figure 21 – Drenchers on Roller Shutter

Considering the CSIRO testing of a drencher protected roller shutter, FSCS does not consider the drencher arrangement to be an Alternative Solution because the BCA in Specification C3.4 clause 4(a) regards compliance with a *tested prototype* that has achieved the *required FRL* as being a DtS design. Note the requirements under 4 (a) (i) requiring size and maximum for the tested prototype as being 5.0m high and 8.0m wide.

13 - Discussion on the available options for distributed forklift charging facilities

Discussions with Toyota indicate an increased preference for distributed and opportunity charging of forklifts. Smart chargers using charge level and voltage monitoring have reduced battery damage potential and workplace productivity gains counterbalance the traditional thoughts that batteries should be fully discharged before recharging.

Companies like Fronius manufacture stand-alone charging stations with integrated watering systems as shown in Figure 22 below and separate safety stations as shown in Figure 23 below. FSCS considers that this concept has significant merit for both productivity and safety.

Figure 22 – Distributed Charging Station

Figure 22 – Safety Station

Distributed charging stations can be used in a warehouse and can be supported by:-

1. The International Fire Code in Section 309 which permits battery charging in general areas providing **a clearance of 915mm** is maintained to combustible materials; and
2. BS EN 50272-3 requires that battery charging installations shall be located in *areas designated for that purpose* and does not require designated rooms for battery charging; and
3. FM Global permits single panel charging stations providing **a clearance of 1.5m** is maintained to combustible materials; and
4. Zurich Risk Engineering permits battery charging in designated areas providing **a clearance of 2.0m** is maintained to combustible materials.

FSCS also supports the use of distributed charging stations where they are within multiple tenancies / occupancies in the same building such as a wholesale market complex as shown in Figure 23 below – Brisbane (Rocklea) Markets.

Figure 23 – Market Tenancies

Likewise where Class 6 occupancies such as the larger supermarkets "Back of house" storage areas frequently need forklifts or pallet trucks. The use of single point charging stations in these areas should be subject to satisfactorily addressing the conditions below.

Consequently FSCS recommends that the following will satisfy the requirements of the relevant Codes and Standards when using distributed charging stations and where they are within the same building / occupancy:-

1. Multiple charging stations are permissible providing a clearance of 2.0m is maintained to combustible materials and 0.5m to electrical equipment shown in Figure 10. Floor marking should be provided to reinforce this requirement; and
2. Where buildings have ventilation based on BCA F4.6 which allows ventilation openings which *can be opened*, i.e. opened when the building is occupied, battery charging should be avoided when such openings are closed, i.e. when the building is not occupied. Otherwise, ventilation provided exclusively for the battery charging stations should be provided; and
3. Ventilation calculations in accordance with Section 7 of this paper shall be effected by totaling all the distributed forklift charging stations and, where knowing the number, type and capacity of the batteries, calculate the resultant hydrogen concentration in the entire warehouse room as appropriate. This shall be shown to be $<2\%^{v}/_{v}$ and documented as such.
4. Floor markings shall show the designated charging station and the required clearance of 2.0m; and
5. Power supplies to the charging stations shall be on a separate circuit protected by an earth leakage circuit breaker; and
6. A shut down trip shall be provided such that all distributed charging stations are isolated in the event of sprinkler or fire detection activation; and
7. Where a Fire Indicator Panel (FIP) associated with an AS1670.1 detection or occupant warning system is provided, a manual shut down trip shall be provided such that all distributed charging stations are isolated.
8. Where such charging stations are located adjacent to or in egress paths, they should be configured so that the required minimum egress path width is maintained whilst the forklift is at the charging station; and
9. A rotating red beacon should be located above the charging station so that attending fire fighters can identify its location and purpose. A suitably worded sign at the main entrance should be provided advising the presence of charging stations within the building.

14 – Certification, Commissioning, Documentation and Maintenance

Certification

Critical to the acceptance and approval of the design and installation of battery charging rooms and/ or distributed charging stations is the proper documentation of the design leading to acceptable certification. The FSCS paper "*Building Certification*" is available on the FSCS web site

http://fscs-techtalk.com provides additional information on this subject.

As discussed throughout this paper, it is the responsibility of the designated designers, being Registered Professional Engineers in Queensland (RPEQ) to provide a Form 15 in accordance as required under the Queensland Building Act 1975 and the Queensland Building Regulation 2006.

The Form 15 should be accompanied with all working papers addressing the hazard classification, resultant Oxygen concentrations, electrical requirements for hazardous atmospheres, ventilation design and any design drawings and specifications that the contractors will rely on fro installation.

All contractors involved in the installation of electrical equipment and ventilation systems shall provide a Form 16 attesting that the installation conforms to the design specification and drawings.

The original and any required copies of all Form 15s and Form 16s together with copies of the documentation referenced above shall be lodged with the Certifier. Additional copies shall be retained by those preparing the documents and the project manager.

Subsequent to commissioning, a copy of all design and certification documents shall be provided to the Client.

Commissioning & Documentation

Commissioning of the systems is required to demonstrate proper operation and interfacing of the various sub-systems.

Neither AS2676.1 nor AS2676 .2 provides any guidance commissioning the integrated ventilation and control systems and accordingly the Mechanical and Electrical engineers are required to develop the procedure. The development of a "Cause and Effect" matrix which addresses all the systems design parameters and how they interface will be of assistance in this process. This matrix will be indispensable in the commissioning phase where every function will need to be tested and documented. This matrix will also be invaluable for troubleshooting in the maintenance phase of the project and is recommended in Sections 1.8 and 1.12 in AS1851.

A typical fire services matrix (**not complete herein**) can be based on the example in Figure 24 below.

Further guidance is available in the various Australian Standards for some the various sub-systems which have particular commissioning procedures and documentation requirements.

- For sprinkler systems, provision of all the documents referenced in AS2118.10. – "Approval Documentation". This includes Appendix A - "Standard System Completion Certificate".
- For fire detection systems – provision of all the documents referenced in AS1670.1 – Appendix E – "Commissioning Test Report" and Appendix F – "Standard Form of Installer's Statement for Fire Alarm System".
- For fire doors– provision of all the documents referenced in AS1905.1 Section 6.3.3 "Records and Required Information".
- For fire rated roller shutters – provision of all the documents referenced in AS1905.2 Section 7 "Evidence".
- For service penetrations (fire collars, control joints and the like) – provision of all the documents referenced in AS4072.1 Appendix B "Documentation". For fire dampers – provision of all the documents referenced in AS1682.2 "Commissioning" and a list of the dampers, type, rating and location.

A dedicated Systems Operation and Commissioning manual should be developed for the project which includes the documentation of all the design parameters discussed in this paper. This should be effected by the appropriate Mechanical or Electrical Engineer and, together with copies of the above, and kept for review by a Peer Review Engineer and / or Building Certifier as appropriate.

ALERT (yellow)

EVACUATE (red)

X FUNCTION

OUTPUT / INPUT	25% H_2 GAS DETECTION	50% H_2 GAS DETECTION	EXTRACT FAN AIR FLOW FAILURE																SPRINKLER SYSTEM ZONE FLOW SWITCH	SMOKE DETECTION SYSTEM OFFICES	SMOKE DETECTION SYSTEM BATTERY CHARGE ROOM	HEAT DETECTION SYSTEM BATTERY CHARGE ROOM
SHUT DOWN BATTERY CHARGERS		X	X																X		X	X
AS1668.2 SUPPLY VSD STAGE 2																					X	
BMS ALARM	X	X	X																			
FIP ALARM																						
FIRE BRIGADE ALARM																						

FIRE AND SECURITY CONSULTING SERVICES

FIRE SAFETY ENGINEERS

PREPARED BY RICK FOSTER RPEQ 7753

SHEET 1 OF 1

FOODLAND CALOUNDRA - FORKLIFT SERVICE & BATTERY CHARGING ROOM

CAUSE AND EFFECT MATRIX

Figure 24 – Typical "Cause and Effect" Matrix

Maintenance

AS2676 Section 6.2.3.1 requires monthly inspections of "Condition of ventilation equipment". FSCS considers that this is insufficient and accordingly advises the following should be addressed in

Maintenance is required to be effected in accordance with AS1851 – *Maintenance of fire protection systems and equipment* as appropriate.

AS1851 addresses the various sub-systems as discussed under Commissioning" which include sprinkler and fire detection systems.

Note that the maintenance frequency in Australian Standard 1851 for *Passive and Smoke Containment Systems* (i.e. fire doors fire rated roller shutters and service penetrations) is amended under QDC MP6.1 under Schedule 1 to 6 monthly for Class 5, 6, 9a and 9c buildings and yearly for Class 2, 3, 4, 7 and 8 buildings.

FSCS advises that whilst there are no specific maintenance schedules for the exhaust fan system and it interfaces, there is sufficient similarity with the maintenance requirements in AS1851 for "*Fire and Smoke Control Features of HVAC Systems*". Accordingly FSCS recommends that the Mechanical and Electrical Engineer develops a dedicated maintenance schedule for the combined systems.

15 - Conclusions

FSCS concludes that:-

1. Distributed charging stations are not prohibited under the BCA and in the opinion of FSCS, are permitted subject to the requirements in Section 13 in this paper being addressed; and
2. For battery rooms, this paper substantiates the reasoning that BCA C2.12 should NOT apply to traction batteries (forklifts and the like) because these batteries are NOT emergency equipment and that the hazards are adequately addressed in the recommendations.
3. Notwithstanding that this paper substantiates the omission of protection under BCA C2.12, fire rated bounding separation of non sprinkler protected areas from sprinkler protected areas is required.
4. As discussed in Section 11 in this paper, fire separation with an FRL of 120/120/120 as required under BCA C2.12 and defined in the "Guide to the BCA", will not protect *the other parts of the building* in the event of an explosion in the battery room.
5. FSCS advises that meeting the Legislated requirements in terms of Workplace Health and safety, Electrical safety and compliance with the ventilation and safety requirements therein will provide a degree of protection in excess of what would be achieved if BCA C2.12 was complied with, e.g. a wall with an FRL which would certainly fail. The resulting risk to occupants from an explosion and subsequent structural failure are greater than from fire spread.
6. FSCS is of the opinion that meeting the applicable Codes and Standards referenced in this paper in respect to eliminating fire and ignition hazards, reduces the fire hazards in a battery charging room to a level which requires no fire separation from the rest of the building.

Now noting the phrase in BCA clause to C2.12 (b) (iv) which reads:-

Equipment need not be separated with (a) if the equipment comprises-

(iv) Equipment otherwise adequately separated from the remainder of the building.

FSCS contends that "**adequate separation" of hazards** is provided and therefore is a DtS design.

----------- End of Document---------

Richard A Foster

Dip Mech Eng; Dip Mar Eng; MSFPE

Fire Safety Engineer

RPEQ Mechanical – 7753: Accredited by Board of Professional Engineers as a Fire Safety Engineer

Principal – Fire and Security Consulting Services

References

1. References to Codes and Standards should be taken as those in force at the date of this paper.
2. FSCS papers referenced can be downloaded from the FSCS web site at

   http://fscs-techtalk.com

I trust that this paper provides useful information for Architects, Design Consultants and Builders in the design and construction of warehouses, and Certifiers and QFES Building Approval Officers in their assessment of buildings containing battery charging facilities.

Version 2 – August 2015

Version 2 addresses some minor typographical errors. I have also qualified some sections and these are marked with a revision bar in the margin.

FSCS would like to offer its thanks and appreciation to Guy Beazley of Toyota Forklifts, Ray Milner of Century / Yausa Batteries and James Chien of Century / Yausa batteries for technical assistance regarding market size and battery types.

FSCS advises that it has no commercial interest in products referenced. These references are solely to demonstrate equipment that may be appropriate.

APPENDIX A

WORKPLACE HEALTH AND SAFETY

Work Health and Safety Act 2011

Work Health and Safety Regulation 2011

Current as at 1 July 2014

The Work Health and Safety Regulation 2011 defines a confined space as:-

confined space means an enclosed or partially enclosed space that—

(a) is not designed or intended primarily to be occupied by a person; and

(b) is, or is designed or intended to be, at normal atmospheric pressure while any person is in the space; and

(c) is or is likely to be a risk to health and safety from—

(i) an atmosphere that does not have a safe oxygen level; or

(ii) contaminants, including airborne gases, vapours and dusts, that may cause injury from fire or explosion; or

(iii) harmful concentrations of any airborne contaminants; or

(iv) engulfment;

but does not include a mine shaft or the workings of a mine.

Exposure standards for airborne contaminants in the atmosphere in the workplace are addressed in the National Occupational Health and Safety Commission (NOHSC) "*Adopted National Exposure Standards for Atmospheric Contaminants in the Occupational Environment*". This document, an extract of which is below, does not consider Hydrogen as a toxic substance but as an asphyxiant.

EXPOSURE STANDARDS FOR ATMOSPHERIC CONTAMINANTS IN THE OCCUPATIONAL ENVIRONMENT (continued)

(1) SUBSTANCE	(2) [CAS #]	(3) TWA ppm	(3) TWA mg/m^3	(4) STEL ppm	(4) STEL mg/m^3	(5) CARCINOGEN CATEGORY	(6) NOTICES	(7) REF
Hydrogen	[1333-74-0]	Asphyxiant	(see Chapter 10)			-	-	-

The paper – "Guidance on The Interpretation of workplace Exposure Standards For Airborne Contaminants – April 2012, published by WorkSafe Australia has superseded the Regulation cited above, Section 5.8 reproduced below advises that a minimum of 18% by volume is required to be maintained in a workplace where an asphyxiant may be present.

5.8 Simple asphyxiants

Simple asphyxiants are non-toxic gases which, when present in an atmosphere in high concentrations, lead to a reduction of oxygen concentration by displacement or dilution. It is not appropriate to recommend an exposure standard for simple asphyxiants but it is essential that a sufficient oxygen concentration is maintained.

The minimum oxygen content in air should be 18 per cent by volume under normal pressure. This is equivalent to a partial pressure of oxygen (PO_2) of 18.2 kPa (137 mm Hg). At pressures significantly higher or lower than the normal pressure, expert guidance should be sought.

APPENDIX B

INTERNATIONAL CODES & STANDARDS

British Standards BS EN 50272-3 sets out the safety requirements for secondary batteries and battery installations used in electric vehicles. These include the storage batteries and electric cells in battery powered industrial trucks – lift trucks, tow trucks, cleaning machines, locomotives and electric road vehicles, such as passenger and goods cars, golf carts and wheelchairs. The standard describes the principle safety measures to protect goods and people from hazards, including electricity, gas emission and electrolyte.

The Standard looks at the principles for the protection against electric shock, the prevention of short circuits and measures that should be taken to avoid the explosion of hazards due to ventilation. The standard also covers various battery containers and enclosures, as well as the accommodation for charging maintenance.

BS EN 50272-3 requires that battery charging installations shall be located in *areas designated for that purpose*.

Facilities shall be provided for flushing and neutralizing spilled electrolyte, for fire protection, for protecting charging apparatus from damage by trucks, and for adequate ventilation for dispersal of fumes from gassing batteries."

In general, the requirements and definitions are specified for lead-acid and nickel-cadmium batteries. For other battery systems, the requirements may be applied accordingly.

The International Fire Code (IFC) recognises the difference between powered industrial truck batteries and charging and stationary batteries providing a power supply for the building.

The following is an extract from the Code freely available at:-

http://publicecodes.cyberregs.com/icod/ifc/2000/icod_ifc_2000_6_sec008.htm

SECTION 309
POWERED INDUSTRIAL TRUCKS

309.1 General: Powered industrial trucks shall be operated and maintained in accordance with this section.

309.2 Battery chargers. Battery chargers shall be of an approved type. Combustible storage shall be kept a minimum of 3 feet (915 mm) from battery chargers. Battery charging shall not be conducted in areas accessible to the public.

309.3 Ventilation. Ventilation shall be provided in an approved manner in battery-charging areas to prevent a dangerous accumulation of flammable gases.

309.4 Fire extinguishers. Battery-charging areas shall be provided with a fire extinguisher complying with Section 906 having a minimum 4-A:20-B:C rating within 20 feet (6096 mm) of the battery charger.

309.5 Refueling. Powered industrial trucks using liquid fuel or LP-gas shall be refueled outside of buildings or in areas specifically approved for that purpose and in accordance with Chapter 34 or 38.

309.6 Repairs. Repairs to fuel systems, electrical systems and repairs utilizing open flame or welding shall be done in approved locations outside of buildings or in areas specifically approved for that purpose.

APPENDIX C

FM Global & Zurich Risk Engineering

FM Global – formally Factory Mutual Insurance is a US based International risk group which has its own large fire test facilities and is the premier approval agency for the approval of fire related equipment and products.

FM Global has published in excess of 300 publications covering everything from the design of sprinkle systems to the assessment of risks in various occupancies.

All their publications can be freely downloaded from download from **www.fmglobaldatasheets.com**

Their publication "Data sheet 7-39 – Lift Trucks" addresses the operation this equipment and the following is reproduced form that publication regarding battery charging.

2.1.1 All Lift Trucks

2.1.1.1 Provide a designated location for parking trucks during idle periods separated from manufacturing and storage areas by one of the following:

- a minimum space separation of 5 ft (1.5 m) between the garaged trucks and combustibles, or
- a one-hour fire-rated barrier between the garaging area and combustibles

2.1.1.2 Provide a designated location for service and repair of trucks away from manufacturing and storage areas by one of the following:

- a minimum space separation of 35 ft (11 m) between the service and repair area and combustibles, or
- a one-hour fire-rated barrier between the service and repair area and combustibles

2.1.2 Battery Powered Trucks

2.1.2.1 Locate single-panel charging installations serving one or two trucks so readily ignited material are not located closer than 5 ft (1.5 m) from the truck or the charging equipment. Do not place electrical chargers within storage racking.

2.1.2.2 Locate multiple-panel battery-charging installations serving more than two trucks in a separate area along an exterior wall (a cut off room is preferred). Include the following features:

A. Maintain a minimum space separation of 5 ft (1.5 m) between any combustibles and the battery chargers, if they are not located in a cut off room, or locate the battery charges within a cut-off room with fire-rated walls.

B. Provide automatic sprinklers designed to deliver a density of 0.2 gpm (8 mm/min) over the most remote 2500 ft^2 (230 m^2) with a hose stream demand of 250 gpm (950 L/min) for a duration of 60 minutes. Use FM Approved sprinklers with a temperature rating of 160°F (70°C).

C. Provide natural ventilation at high points in the exterior walls or roof.

3.2 Battery Powered Trucks

Insulation, battery boxes, and accumulated grease deposits on a battery-powered truck are combustible material that could be ignited and involve the truck in a fire.

The principal source of ignition is short circuits in wiring. Fires have also resulted from current being left on, ignitable liquid being unsafely carried, and collision.

Small quantities of hydrogen evolve from a battery on charge and can introduce a potential fire and explosion hazard. An electrical disturbance may cause a fire in grease and dirt on the truck, insulation, or charging equipment.

3.2.1 Ventilations Rates for Battery-Charging Rooms

During the recharging process, a lead battery releases hydrogen and oxygen through the electrolysis of sulfuric acid. The beginning of gassing is determined by the battery voltage. The amount of gas created depends on the current that isn't absorbed by the battery, and can be used in the electrolysis process.

As the battery reaches its full state of charge, the acceptance of current becomes less, and more hydrogen is liberated.

If ventilation is required it needs to maintain the concentration of hydrogen vapor at or below 25% of the lower explosive limit (LEL). The LEL for hydrogen in air is 4%, so maintaining the hydrogen vapor concentration in a room at or below 25% LEL equates to 1% hydrogen concentration.

The ventilation requirements are dependant on the rate of hydrogen being released. The equation below can be used to determine the amount of hydrogen being liberated from the batteries.

Zurich Risk Engineering – is a UK based Risk Management group which provides insurance advice to building owners in the UK context. Note that their focus is on property protection and naturally have a very high standard of compliance.

In their "Risk Topics" publication "*Fork Lift Trucks – Fire and Property Related Guidance*" dated January 2012, the following guidance was provided:-

Ideally, the charging of batteries should be carried out in a separate building of non-combustible construction, reserved for this purpose, or in a specially designed charging area comprising a separate compartment of 120 minutes fire resistance. If this is impractical, charging can be confined to a designated area of a building which is devoid of combustible materials. A clearance of at least 2 metres should be achieved between the charging unit and any adjacent combustible materials. This clear area can be defined with barrier rails or, at the very least, demarcation lines.

Battery chargers should be installed on a concrete floor or securely wall mounted against a non-combustible structure. They should not be installed within storage racking, as any sparks given off by the charger could ignite combustible packaging. Where, due to space restrictions, a battery charger has to be sited immediately adjacent to racking, 10mm thick plasterboard (or similar 30 minute fire rated material) should be fixed to the side of the racking, in order to separate the charger from any combustible stock or packaging materials contained within the racking.

Note the term "ideally" for the 120 minute separation and the acceptable alternative of a 2 metre separation.