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THE DESIGN OF FIRE PUMP ROOMS – V2

Fire and Security Consulting Services (FSCS) is frequently consulted on the design requirements for fire pump rooms. FCSC considers that the current expertise from both services Consultants and Contractors leaves a lot to be desired compared with times past.

Accordingly this paper is structured to provide the necessary design requirements including attention to Workplace Health and Safety, ventilation, power supplies, safety etc to ensure that the fire pump room is a safe working environment for persons carrying out testing, commissioning and general maintenance.

Previously the design requirements together with information on water supplies was published as "*Water Supplies for Fire Services – V3*" This is now published separately as Version V4 with the fire pump section deleted and now published in this paper.

1 - BUILDING CODE OF AUSTRALIA

The BCA forms the prescriptive and performance requirements for fire services in a building and advises that if a design meets the Performance Requirements, then the prescriptive or "Deemed to Satisfy" (DtS) requirements are met.

The BCA references a number of Australian Standards, the relevant ones for this paper are listed below. The design of the fire pump rooms and the provision for space and facilities therein is based on these Standards with the Hydraulic, Mechanical and Electrical Consultants being responsible for the relevant design features.

Where there are no design consultants, such as for a Design and Construct project, then the main contractor has the responsibility to meet the legislated Codes and Standards.

This paper, based on many years' of observations, is formulated to provide advice to Clients, Developers, Architects, Certifiers, Consulting Engineers, QFES Building Approval Officers and Builders so that at the building approval stage, time delays, cost overruns and subsequent "finger pointing" is avoided. A building design that does not address the system requirements can result in significant cost and time overruns.

2 - AUSTRALIAN STANDARDS

The Australian Standards related to the fire services design include the following. These Standards contain critical design data that the Architect or Consultant must make provision for. :-

- *AS2118.1 – Automatic fire sprinkler systems. Part 1: General requirements*.
- *AS2419.1 – Fire hydrant installations. Part 1: System design, installation and commissioning.*
- *AS 2941 – Fixed fire protection installations – Pumpset systems.*

3 – THE PUMP ROOM

AS2419.1 (Fire hydrant installations) and AS2941 (Fixed fire protection pumpset systems) provide details on the requirements for pump rooms. AS2419.1 also has a mandatory requirement for a weatherproof pump room.

FSCS is of the opinion that these should be seen as guidelines only and that the appropriate designers and Consultants should apply the necessary Codes and Standards in terms of the environmental conditions considering that the pump room is a working environment and Occupational Safety and Health Regulations apply.

In addition to the AS2419.1 and AS2941 requirements referenced above, QFES have published additional guidelines for fire service pump enclosures which and tanks at:-

https://www.fire.qld.gov.au/buildingsafety/guidelines.asp

Access and Spatial Requirements

There are a number of critical spatial and access requirements for pump room as below and the following should be achieved:-

- Where fire pump rooms are located at grade outside the building being serviced, they are required to be located a minimum 10m from the building ,otherwise, if closer, they are required to be of fire resistant construction in respect to fire spread from the building.
- Where fire pump rooms are located at grade outside the building being serviced, they are required to provide access by maintenance staff and fire fighters who will operate the pumps in a fire situation. Internal services and features as described below for internal pump rooms are required with the exception that natural ventilation may be used if properly designed.
- Independent access for the Fire Brigade directly from the outside of the building is required. Should independent access not be feasible, access from a basement car park via the required egress stair may be acceptable subject to an Alternative Solution being formulated. In that case a stair lobby would be required in the basement typically as shown in Figure 2 below from a recent FSCS design accommodating hydrant and sprinkler pumps and sprinkler tanks. Note that Figure 2 also shows the following features that are required.
- The required FRLs bounding the pump room are required to be addressed in respect to compliance with the Building Code if Australia.
- Where fire pump rooms are constructed as part of an overall building, they are usually located in basement car parks; accordingly a construction access door from the car park is required. FSCS has frequently seen pump rooms constructed where the only way to install the fire pumps is to dismantle them, take each part down the stairs and then reassemble. This process is very costly because after reassembly the factory test certificate may be void and an on site test carried out. Later, if and when pump replacement is contemplated, the reverse has to be carried out.
- Space for the fire pumps. Typical fire pump sets are approximately 2.0m long x 1.0m wide (including pump starter panels). Space for the access door opening in at 1.0m x 1.0m and space for ancillary equipment is also required. Atypical pump room with two sprinkler and one hydrant booster pumps, the minimum dimensions would be in the order of ~4.0m x ~3.5m x 2.5m in height. This will provide for the required clearance around the pump and the 2.1m headroom.

  QFES have published guidelines for fire service pump enclosures as follows:-

  Fire pump enclosures require a minimum of:

  - *2.1 metres head clearance.*
  - *1 metre wide, clear path of travel to the fire pump controller.*
  - *1 metre wide, clear path of travel to the manual shut-down for diesel drivers.*
  - *1 metre wide, clear path of travel to all other required control valves.*

  These minimum requirements are supported by:

  - *Building Code of Australia 2009 (Part E1).*
  - *Australian Standard 2941-2008 (Section 11, Clause 11.3).*
- *Australian Standard 2419.1-2005 (Clause 6.4; Sub-Clause 6.4.1)*
- A preferred separate space for the tank(s). It is important to understand that the fire pumps and water tanks are on the same level. In one building that FSCS was asked to investigate, the tank had been constructed beneath the fire pump room, ***in this case the pumps would not function***.
- Space for a jockey (pressure maintenance) pump of approximately 1.0m long x 0.75m deep for each of the sprinkler and hydrant systems.

General design considerations

- Fire pumps cannot be stopped automatically. Only the stop functions on the starters, or in the case of a diesel pump, the governor shut off.
- Each pumpset shall be fitted with a circulation relief valve to prevent overheating from churning at low or no flow.
- Restrictions in the pump suction piping such as butterfly valves are *not permitted*. This is consistent with NFPA20 and FM Global requirements.
- Flow testing arrangement so that each sprinkler pump (not hydrant pumps) can be tested to 140% of their design flow. The arrangement may be separate for each pump or combined, with suitable valving, shared between two or more pumps.

  FSCS recommends that a permanent installation of flow testing be incorporated with the initial installation. The preferred equipment is the "Rosemount Eagle Eye" annubar and meter as shown in Figure 1 below.

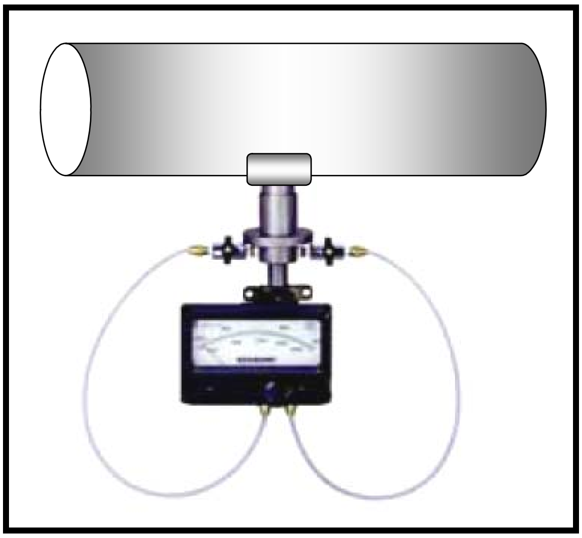

Figure 1 – 'Eagle Eye" flow measurement fitted to tank return pipe

  Three types of meters are available: - (a) directly mounted to the Annubar Primary, (b) fixed for pipe or (c) wall mounting and the self-contained portable unit, including hoses, carrying case and bleed valves.
  The meter is calibrated directly in litres/minute so that readings can be verified by QFES, building managers and Certifiers without having to rely on testing contractors carrying out calculations based on differential readings from complex equipment and charts.

- Diesel exhaust lagged to 2.1m height and routed to outside the building with the outlet not closer than 6m to a building ventilation inlet. This may require the exhaust pipe being run in the fire isolated shaft housing the car park exhaust ducting.
- The pump room should be provided with a 100mm drain suitable for accommodating the discharge from the 50/25mm waste and test valve on the sprinkler alarm valve, discharge from the fire pump circulation relief valve(s) and general spillage. It is estimated that the capacity should be ~10.0l/s.
- General floor drainage is also required with the grade being sloping towards the drain. This also applies to external pump rooms.
- The QFES requirement for painting pipework to AS1345 as noted in AS2941 has presented approval problems in the past. AS1345 comprises three elements for the identification of pipes, conduits and ducts and include the base identification colour, pipe marker and supplementary colours.

  AS1345 determines the location and the form of the three elements. This includes the general requirements and form of marking.

The base identification colour is a single colour that is intended to provide immediate information on the contents of the pipe. When applying the base identification colour the pipe can be completely painted with the identifying colour, or regularly banded with the identifying colour or identified with proprietary markers with the following characteristics:-

- background colour is the same as the base identification colour;
- lettering in either white or black;
- lettering that is large enough to be read by normal eyesight;
- contrasting border around the label in white or yellow;
- chevron within the border indicating the direction of flow within the pipe.

Accordingly FSCS considers that pipe identification can be by any of the above and pipe does not have to be completely painted.

Pump Room & Tank Layout

Figure 2 below is the same as in the companion paper on water supplies and is included here to further reinforce the design requirements.

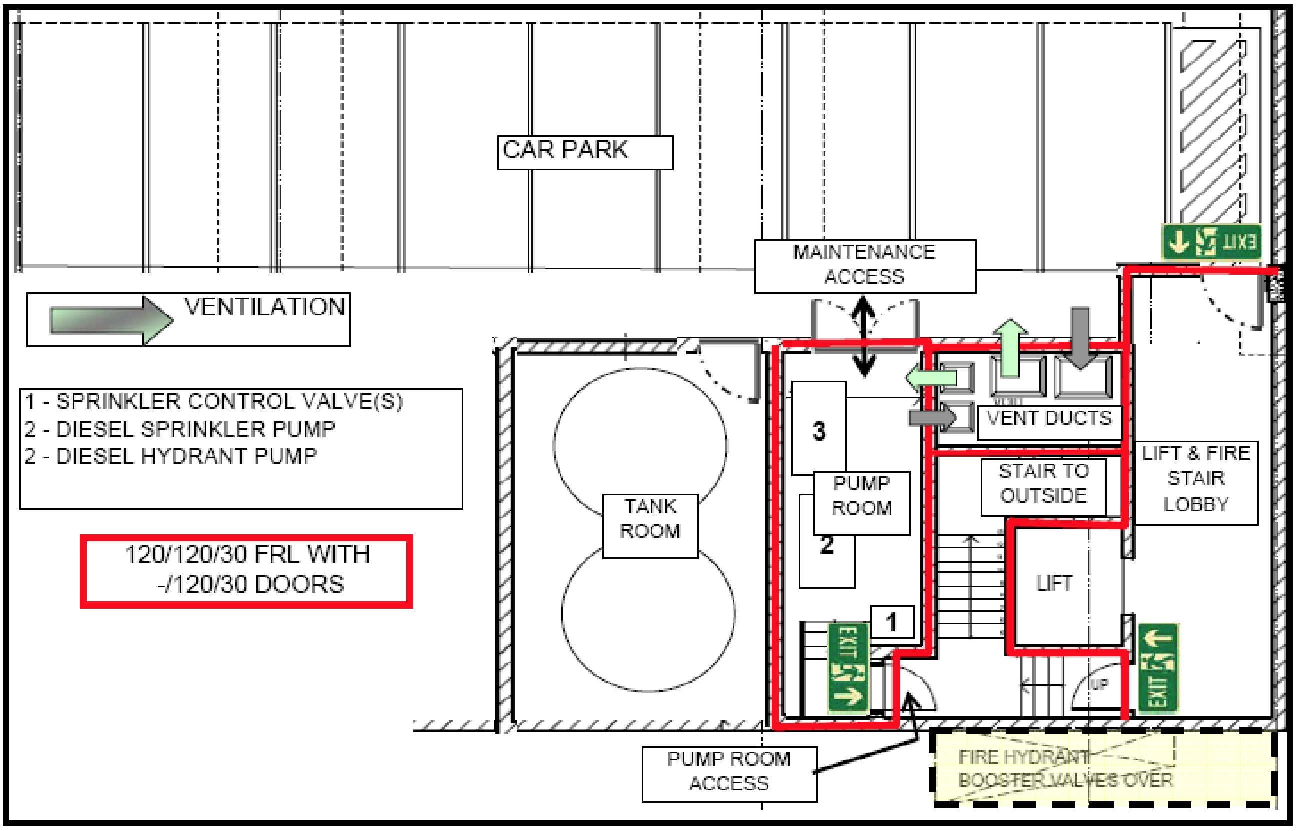

Figure 2 – Fire Pump Room & Tanks

The tanks shown in Figure 1 are circular steel tanks complying with *AS2304 2011 – Water Storage Tanks for Fire protection Systems.* These tanks are delivered in modular form with the components being able to be transported through normal doorways and subsequently assembled on site. This has been found to be the most cost effective solution because these tanks are common in the fire protection industry. Figure 3 below shows the system schematic for the arrangement in Figure 1

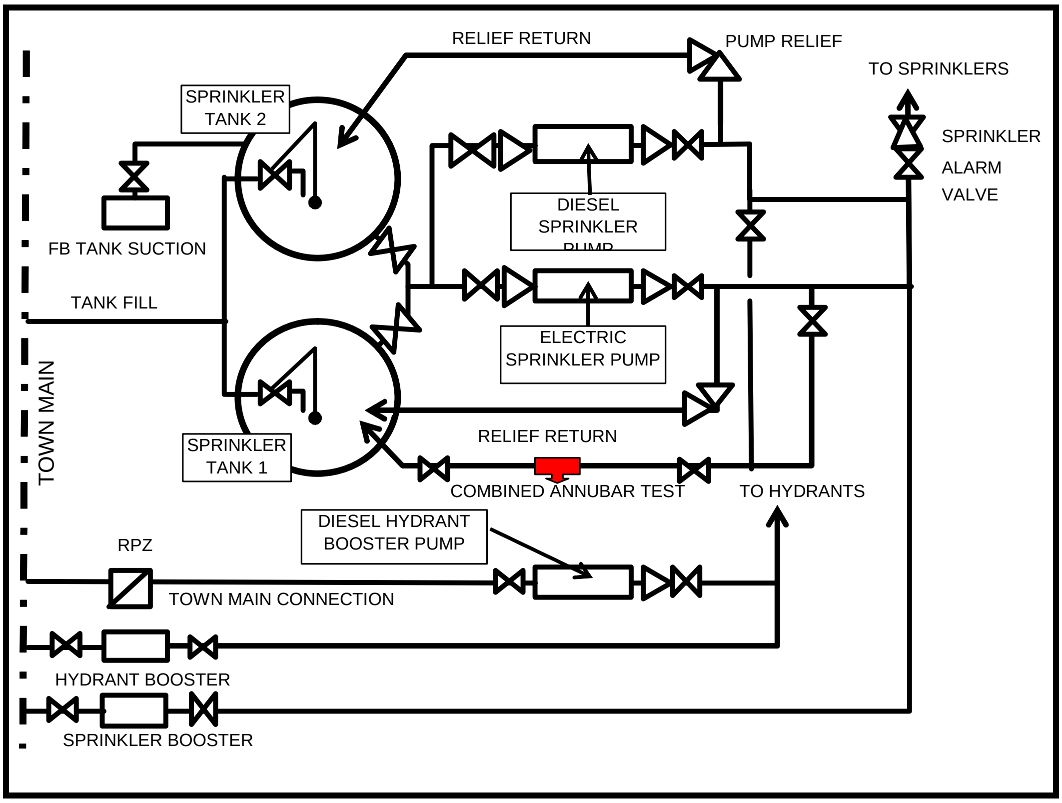

Figure 3 – System Schematic

4 - PUMP ROOM SERVICES

Non Slip Flooring

Pump rooms frequently have water leaks present on the floor which present a significant hazard to occupants. This is especially serious when hot and / or moving machinery parts are present. FSCS has seen pump room floors with polished concrete finishes; they look good but can be deadly.

Accordingly FSCS recommends that the floor surface be treated with a non slip application.

Such treatments can be a simple as a coarse brush finish to the concrete after pouring to durable two pack epoxy paints containing a coarse granular substance or coatings such as from Roxset (www.roxset.com.au) which are typically used in the food processing industry.

Mechanical Ventilation

The pumproom requires ventilation for the ventilation associated with diesel engines as follows:-

- Cooling the diesel engines.
- For combustion air.

Being a workplace where maintenance personnel as well as fire fighters are likely to be in attendance, ventilation is required for eenvironmental air.

Ventilation ducts (supply and exhaust) for the pump room shall have dampers at each transition of walls and floors required to have an FRL.

Accessible metal hinged flap or metal concertina fire dampers should be installed in both supply and exhaust air ducts on the pump room side of the wall. They should be fitted with fusible links rated two levels above that for the sprinklers in the pump room. Pump room sprinklers should be 79^{o}C and therefore the damper links should be 141^{o}C or higher with an associated higher RTI. The intent of this is that under normal conditions the air supply and exhaust will be maintained. Under fire conditions the damper will not operate unless the sprinkler system fails.

The calculations below are for a pump room located within the building and provided with mechanical ventilation. Figure 4 below shows a typical system and with a supply air (outside air) temperature of 30°Cand a <u>maximum </u>room temperature of 40°C.

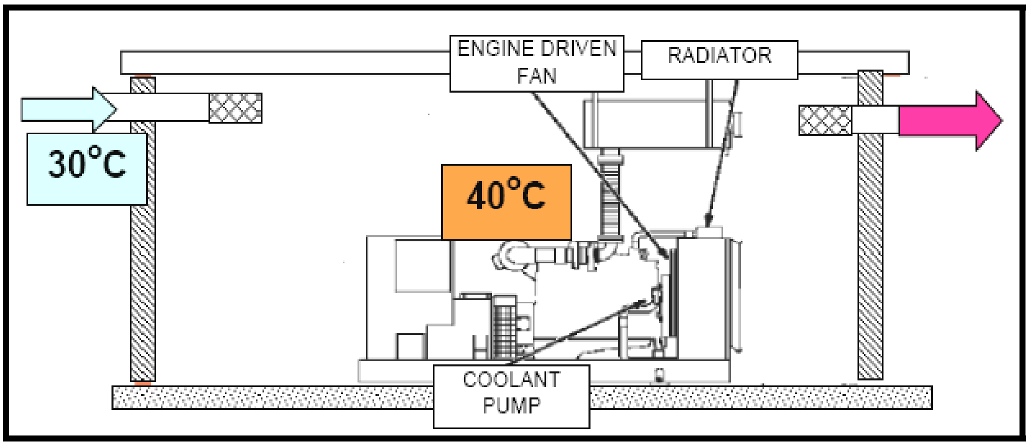

Figure 4 – Pump Room Temperature

The Cummins Engineering Standard 027 for Engine Room ventilation calculations provides detailed methodology for precise calculations. This is available for download at

http://cumminsfirepower.com/documents/ES027ventilation.pdf

Where pump rooms are located outside the building in a separate "shed", natural ventilation such as from the engine radiator fan is usually sufficient. Figure 4 below shows a typical installation.

Regardless of location, all external pump rooms are to be provided with the services and features with the exception of Mechanical ventilation where natural ventilation is acceptable as shown in Figure 5.

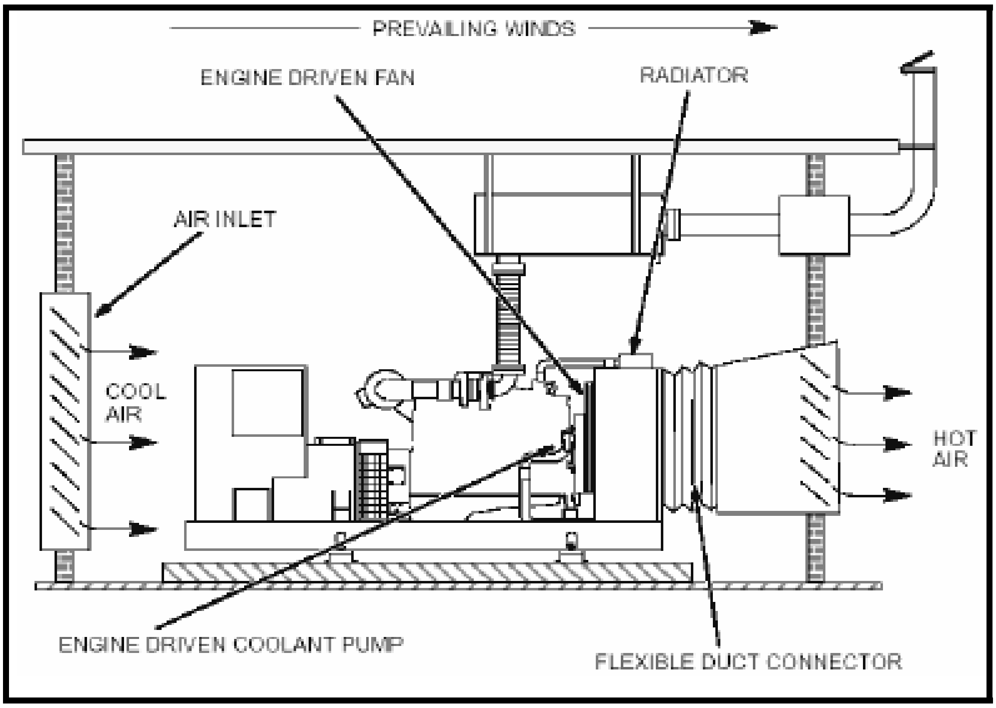

Figure 5 – Natural Ventilation

Typical mechanical ventilation calculations are shown below:-

- Cooling the diesel engines. The heat generated from typical fire pump engines is discussed below. Generally for pump rooms in ambient conditions an air flow of ~30 litres/second/kW is required. Therefore for a typical 30kW engine, a cooling air flow into the pump room is 900/s.

- For combustion air. A typical diesel engine requires approximately 1.5litres/second /kW. Therefore, for a typical 30kW engine, combustion air flow into the pump room is 45/s.
- Environmental air, this is to be a minimum 6 air changes per hour which for a pump room with a single diesel engine having dimensions of 3.5m x 3.0m x 2.5m, is 43.75l/s.

The total mechanical ventilation requirements therefore for a single diesel engine in a pump room will be 989 l/s with an equivalent exhaust capacity. This can be rounded off to 1,000litres or 1m^3 per second.

Because of the consumption of the combustion air supply, the pump room will be at slightly negative pressure which will ensure that contaminated air does not leak out of the room.

Where there are two or more engines, the calculations should include for cooling and combustion air, e.g. sprinkler and hydrant pumps operating simultaneously as required by the Standards.

The operation of the ventilation system may be arranged by a relay trip on the pump starters so that both exhaust and supply fans start when the pumps start. Environmental air however, should be operating at all times when personnel are present. This can be interlocked with the lighting.

This variable demand can be met with fan motors having variable speed drives (VSD).

Ideally, the pump room should be provided with ventilation continuously to address humidity issues, one elegant and cost effective way is to install a split system air conditioner, have the condenser unit in the car park and run it on “dehumidify” mode.

Figure 6 below shows a pump room with obvious leakage problem which leads to high humidity and consequent corrosion, Corrosion on the copper pipe at top left is clearly seen.

Figure 6 – Pump Room Leakage

Lighting

Being a workplace where maintenance personnel as well as attending fire fighters are likely to be in attendance, lighting in accordance with AS/NZS1680.2.2 – *Interior and workplace lighting* should be provided

The objective and purpose of a lighting system should be considered at the design and installation phases. This is especially significant for workplaces where construction work is performed as the lighting system must be able to accommodate changes in work activities and the progression of construction.

The lighting system should ensure the safety of people to the extent that the lighting makes hazards visible. The facilitation of visible tasks and the creation of an appropriately illuminated environment must also be considered.

The lighting system should, therefore, be designed and installed, so as to illuminate the task area and provide a safe and comfortable visual environment.

The following workplace issues must be considered for compliance with the *Workplace Health and Safety Act 1995* and the *Workplace Health and Safety Regulation 2008.*

- Task lighting
- Access and stair lighting
- Emergency lighting.

Lighting of at least 240lux is required and where available, the lighting shall be supplied from the Essential Services section of the main switchboard. If no such equipment is available, the lighting shall be "maintained" emergency lighting accordance with AS2293.1. Such lighting is energised at all times when normal or emergency lighting is required.

Fluorescent lighting should be avoided because rotating parts, dependant on the rotational speed, may appear to be stopped.

Noise

Workplace Health and Safety Queensland Code of Practice 2011 for Managing noise and preventing hearing loss at work provides standards that must be met.

Exposure standard for noise is defined in the WHS Regulations as an $LA_{eq,8h}$ of 85 dB(A) or an $LC_{peak\ of\ 140}$ dB(C). There are two parts to the exposure standard for noise because noise can either cause gradual hearing loss over a period of time or be so loud that it causes immediate hearing loss.

$LA_{eq,8h}$ means the eight hour equivalent continuous A-weighted sound pressure level in decibels, determined in accordance with AS/NZS 1269.1. This is related to the total amount of noise energy a person is exposed to in the course of their working day.

It takes account of both the noise level and the length of time the person is exposed to it. An unacceptable risk of hearing loss occurs at $L_{Aeq,8h}$ values above 85 dB(A).

LC_{peak} means the C-weighted peak sound pressure level in decibels, referenced to 20 u-pascals,. It usually relates to loud, sudden noises such as a gunshot or hammering. LC_{peak} values above 140 dB(C) can cause immediate damage to hearing.

Research data confirmed by the author of this paper indicates that noise levels in concrete walled and floored pump rooms with a ~30kW diesel engine running can exceed 110dBa,

The Equivalent Noise Exposures based on the LAeq,8h = 85 dB(A) for any given exposure time are shown in the table below showing that the length of time a worker could be exposed to the noise is reduced by half for every 3 dB increase in noise level.

Noise Level - dBa	Exposure time
80	16 hours
82	12 hours
85	8 hours
88	4 hours
91	2 hours
94	1 hour
97	30 minutes
100	15 minutes
103	7.5 minutes

Noise Level - dBa	Exposure time
106	3.8 minutes
109	1.9 minutes
112	57 seconds
115	28.8 seconds
118	14.4 seconds
121	7.2 seconds
124	3.6 seconds
127	1.8 seconds
130	0.9 seconds

Accordingly as it is likely that the 1.9 minute permitted exposure time of 110 dBa will be exceeded during testing, maintenance and inspection, hearing protection shall be provided with either personal ear muffs or, for incidental occupants, a dispenser of sanitised ear plugs at the entrance.

Companies like Seaton at http://www.seton.net.au/work-wear-ppe-first-aid/personal-protection/ear-muffs.html can supply hearing protection devices with the ear plug dispenser shown at Figure 7, and should be consulted as to the appropriate level of hearing protection when the incident background noise is ~110dBa.

Additionally, an appropriate warning sign as shown in Figure 8 should be posted at the door.

Figure 7 - Ear Plug Dispenser

Figure 8 - Caution Sign

Emergency Evacuation

The emergency evacuation occupant warning system shall be extended into the pump room and, considering the noise levels discussed above, it shall include appropriate visual indicators.

Pump Power

For those that are interested in calculating the size of a fire pump driver, the following formula may be of interest.

$P_{kW} = Q_{l/s} \times H_{kPa} / 650$

For a pump to provide a flow of 20l/s at a residual pressure of 350 kPa at the top of a 7 storey building where the static and friction losses are 450kPa the following are the inputs:-

$Q_{l/s}$ = 20l/s, H_{kPa} = 350 + 450 = 800kPa. Therefore P_{kW} = 20 x 800 / 650 = **24.6kW**

Electrical

For general use, the pump room should be provided with electrical services as follows:-

- Normal and emergency lighting as described above; and
- Current carrying parts of any electric motor and all wiring shall be located at least 300mm above the floor and installed on galvanized cable trays.
- Overhead wiring shall be installed on galvanized cable trays at least 2.1m above the floor.
- All electrical equipment including pump starters, light fittings, general power outlets and fuse / breaker enclosures.
- A 240v 50Hz 15A power supply to a dedicated board to cater for the jacking pump, pump starters and a 240v 50Hz 15A double weatherproof socket.
- Building power supply, switchboard and cable sizes suitable for a DOL (Direct on Line) starter which draw between 6 and 7 times the full load current of the pump. As an example, a 30kW 4 pole electric motor running at 1,500 rpm draws a full load current (FLC) of ~54A. the DOL current, although only momentary, is ~350A. A high rupture capacity (HRS) is at least going to be required.
- Where it is desired to use a single electric pump for a sprinkler system in a building <25m ***effective height***, the following should be noted:-
- Power from the "Essential Services" section of the main switchboard shall be used. **§**
- Fire rated supply cables shall be used for electric fire pumps. **§**

Note **§** Where two pumps are required such as in a sprinkler system in a building >25m ***effective height***, the electric pump need not have fire rated cabling nor be supplied from the Essential Services power supply. The requirement for cable and power supplies being suitable for DOL starting still remains.

This concession is because the diesel pump can be considered as a “stand-by” in case there is a failure in the electric pump or its power supply.

Note the use of 4 pole electric motors (1,500rpm) will allow matching of pump duties where two pumps are required such as in a sprinkler system in a building >25m effective height. The diesel pump will be selected to run at a similar speed. This ensures that identical pumps can be used making calculations much easier.

If it is desired to use an electric pump for the sprinkler system, a connection from the town main connection of suitable size for the sprinkler demand should be routed to the pump adjacent to the sprinkler control valve(s).

Drainage

The pump room should be provided with a large capacity drain suitable for accommodating the discharge from the 2” (50mm) waste valve on the sprinkler alarm valve. It is estimated that the capacity should be ~1.0l/s and at least 100mm diameter.

A 150mm fire hydrant test drain is required to be provided at the hydraulically most disadvantaged (remote / highest) hydrant. This is usually in the fire isolated stair.

6 – ACCEPTANCE TESTING & BUILDING CERTIFICATION

Acceptance testing of the installed systems is likely to proceed in a more orderly fashion if the systems installers cooperate to ensure that all necessary interfaces

Whilst acceptance testing procedures for sprinkler and hydrant systems are addressed in the relevant Australian Standards, there are a number of critical details in the pump room that warrant attention. Figure 9 shows the range of test instruments listed below:-

1. Air Speed meter (showing a speed of 1.6m/s). This measures the air speed at either the supply or return air register so that the design ventilation can be measured. The FSCS paper “*Miscellaneous Mechanical Ventilation Systems in Buildings – V1*” on the FSCS web site provides families of graphs for either rectangular or circular registers. Applying the air speed reading against the appropriate curve will determine if the ventilation system complies.
2. Light meter (showing 587 Lux). The measures the lighting level(s) in the pump room.
3. Sound Level meter (showing 66.7dB (A). This measures the sound level when the pump(s) are running to determine if the selected hearing protection is appropriate.

Figure 9 – Test Instruments

There are a number of issues that need particular attention whilst testing fire hydrant and sprinkler systems. The first is the proper use of testing equipment and the second is the FSCS recommendation that the discharge of water from hydrant testing should be recouped for other uses.

For hydrants, the testing of flow(s) for internal hydrants is usually conducted by QFES using their own McCrometer device(s) discharging into the 150mm drain in the fire isolated stair as discussed earlier. It is imperative that this test be conducted by the contractor prior to QFES attendance. In both cases observe the correct use of the McCrometer and residual pressure gauge as discussed earlier and detailed in the FSCS paper "**Fire Hydrant Flow Testing**".

FSCS recommends that the 150mm hydrant test drain in the fire isolated stair be connected to the property "rainwater harvest" tank to save water. Likewise, when testing external hydrants, the discharge should be directed to the rainwater harvest tank or if not provided into a road tanker of appropriate size. Such tankers can be hired from rural water providers.

Note that the current standards for sprinkler system testing contemplate discharge back into the storage tank(s).

The FSCS paper entitled "***Building Certification***" on the FSCS web site provides guidance on the required Form 15 (design) and Form 16 (installation) certification that designers and installers are required to provide.

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

I trust that this paper provides useful information for Architects, Design Consultants and Builders in the design of fire pump rooms.

QFES Building Approval Officers and Building Certifiers may also fine the information contained herein useful.

Richard A Foster

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

Principal – Fire and Security Consulting Services

Version 2 corrects some typographical errors in Version 1a and also references pump rooms located outside the protected building. Version 2 also clarifies the issue of fire pump selection.

Version 2 – July 14th 2016