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Managing seismic risk across process and manufacturing facilities

D.B. Saunders & C.J. Chapman
Beca Ltd, Wellington.

K. Shekaran,
Beca Ltd, Auckland.

J.C. Mogarajah
Fonterra, New Zealand.

ABSTRACT

To manage seismic risk at large Process and Manufacturing Facilities requires a PCBU to understand the compliance requirements from legislation. However, this is not an easy task as there are multiple Acts, Regulations, Standards and Guidelines that will apply to the various existing and new assets at the site. These have differing requirements for Certification and Building Consent. They also allow differing degrees of compliance below 100% of Current Standard or the application of generally accepted design practice. Throw in the need to comply with the Major Hazard Facilities Act and all of the "what if's" and it makes for a challenging situation. For example, in assessing the risk for a pipe bridge that carries hazardous substances under pressure across from storage tanks through and near buildings to processing areas one needs to apply the whole suite of compliance requirements from legislation. Fonterra and Beca have had to cross this bridge and it has certainly not been easy. What has helped is breaking down this complex linkage of legislative documents and their specific requirements into a simplified and understandable step by step process.

1 INTRODUCTION

Generally structures in New Zealand fall under the New Zealand Building Act 2004 (NZBA), however all places of work (for which these structures are constructed) also need to adhere to the Health and Safety at Work Act 2015 (HSW). In the case of a process and manufacturing facility there are specific pieces of legislation within the HSW Act, that come into play and may impose more onerous requirements on a structure than the NZBA requirements. These include:

- Health and Safety at Work (Major Hazard Facilities) Regulations 2016 (MHFR),
- Health and Safety in Employment (Pressure Equipment, Cranes, and Passenger Ropeways) Regulations 1999 (PECPR), and
- Health and Safety at Work (Hazardous Substances) Regulations 2017 (HSR).

These imposed requirements include the magnitude of loading from natural hazards (seismic risk), timeframes to complete works on non-compliant components or permissible geometrical limitations.

The numerous Regulations and separate pieces of legislation make compliance pathways difficult to determine. Engineers and Person's Conducting a Business or Undertaking (PCBU) need to consider all the legislation to understand the method and level of compliance required for each different structure on the site. Different requirements are set out depending on the type of structure, as well as whether the structure is existing or new. There are also behaviours or knowledge that has become ingrained into the industry that is no longer compliant as the legislation has been updated removing or altering requirements in new revisions.

This paper, in the majority, only discusses navigating the compliance pathways in the overarching New Zealand legislation. *A PCBU needs to also delve into the different accepted/cited Standards within the overarching legislation where further complications, contradictions, and limitations arise.* Figure 1 depicts how a PCBU of a process and manufacturing facility could work through the compliance requirements for their site. This understanding and clarity has come from Beca assisting Fonterra to meet their obligations of operating sites that are considered Major Hazard Facilities.

The following sections each look at a specific piece of the compliance pathway where particular structure types have been identified on site and a discussion of their requirements.

2 STORAGE OR PROCESS VESSELS

Storage or process vessels fall under three main categories based on their contents and operating conditions. The three categories listed below all follow different pathways to show compliance.

- Pressure Vessels
- Vessels containing Hazardous Substances
- Vessels not containing Hazardous Substances or operated at Pressure

2.1 Pressure vessels and pipework

In New Zealand, a pressure vessel and/or pipework is defined as any vessel or pipework, and all associated fittings, containing a gas or liquid that operates at a pressure exceeding 50kPag. It also includes vessels that contain steam at any pressure.

These vessels and pipework shall comply with the Health and Safety in Employment (Pressure Equipment, Cranes and Passenger Ropeways) Regulations 1999 (PECPR).

The PECPR require that pressure vessels and pipework are designed (including repairs or alterations), so far as reasonably practicable, in accordance with standards of generally accepted design practice. In 2001, the Department of Labour issued an Approved Code of Practice for Pressure Equipment that included a list of recognised standards for this type of vessel or pipework.

When considering what is 'reasonably practicable' in the context of pressure equipment, the PCBU shall refer back to the overarching HSW. This requires the PCBU to assess the extent of the risk against the costs associated with eliminating or minimising it and undertake all steps where 'the cost is not grossly disproportionate to the risk'. Therefore, the level of seismic strengthening required for existing vessels and pipework under pressure may vary depending on how the PCBU assesses the risk. IPENZ Practice Note 19 (PN19) provides guidance to PCBU on seismic strengthening levels based on the risks associated with different types of equipment and structures. It is reasonable to expect that the minimum level of 'reasonably practicable' for a new design is full compliance with current Acts and Regulations.

The PECPR requires certificates of design verification and inspection for pressure vessels. A new certificate of design verification is required following any alteration or repair to the vessel and there are specified organisations that can do this activity. The certificates shall only be issued if the vessel complies with the PECPR.

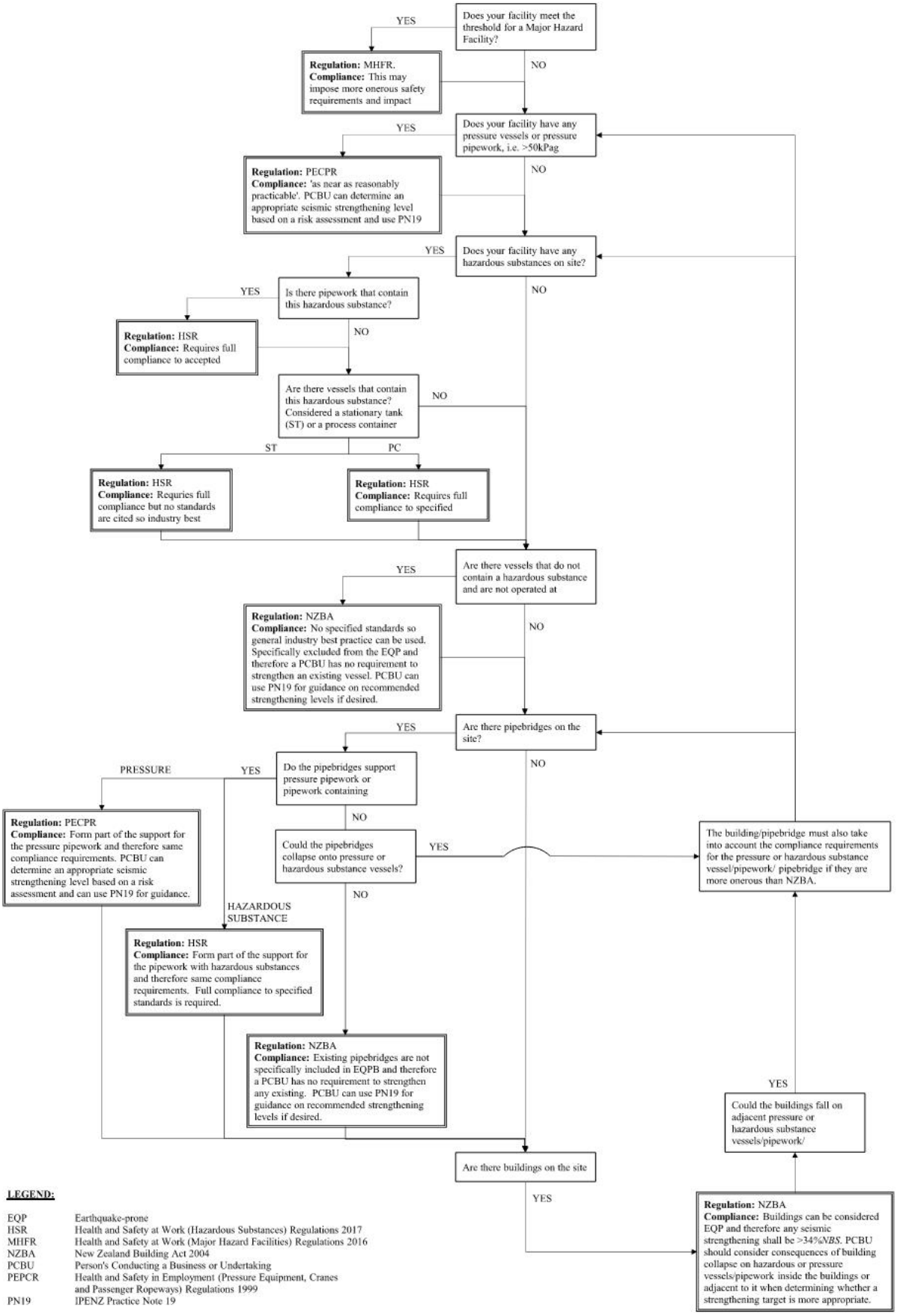

Figure 1: Process and manufacturing facility compliance pathways

Vessels and pipework under pressure that do not contain hazardous substances, plus their foundations and their supporting structure are required to have Building Consent.

2.2 Vessels containing hazardous substances

Vessels containing hazardous substances are excluded from the NZBA and shall instead comply with the HSR. In particular, they shall comply with Section 17 of the HSR, unless they meet the minimum thresholds requiring the use of the PECPR which then govern. Some aspects of the HSR will still apply in regard to the stored substance itself. While all vessels containing hazardous substances shall comply with Section 17 of the HSR, the compliance pathway within the HSR depends on the type of vessel being assessed – pipework, process container or stationary tank.

Pipework, process containers and stationary tanks make up a stationary container system. In accordance with Clause 17.3, the stationary container system needs to comply in a way that is reasonably practicable and consistent with accepted engineering principles and practices. However, each part of the stationary container system has additional particular requirements.

With vessels being excluded from the NZBA, they do not require Building Consent. However, there is a general practice that new foundations for vessels are submitted for Building Consent and this is a requirement when the foundations support multiple structures even if only some of which are covered by the NZBA.

2.2.1 Pipework

Pipework that moves hazardous substances between storage or process vessels shall comply with Subpart 13 of the HSR. In this Subpart is the requirement that the PCBU shall ensure the pipework 'is suitable for all reasonably foreseeable working pressures, temperatures, and structural stresses' throughout the operational life cycle. The PCBU must ensure it complies with one of the standards and Regulations defined in this Subpart. This governs over the more general requirement of Clause 17.3. In accordance with these requirements, the PCBU would be required to undertake seismic strengthening to any existing pipework so that it is fully compliant to at least one of the specified standards in the HSR, prior to being issued a compliance certificate.

However, one of the options for a PCBU to show compliance for pipework under the HSR is in accordance with the PECPR, which as already described, can comply as 'reasonably practicable'. Therefore, depending on the standard chosen by the PCBU, the requirements to show compliance may vary.

There are other requirements for pipework to comply with, including the Health and Safety in Employment (Pipelines) Regulations 1999 and the Gas (Safety and Measurement) Regulations 2010, however these have not been considered here.

2.2.2 Stationary tanks

Stationary tanks shall comply with Clause 17.6 of the HSR. This clause states that a stationary tank containing a hazardous substance shall be designed and constructed in accordance with one of the listed standards. This requires full compliance with the chosen standard. There is no reduced acceptable level for existing stationary tanks.

Under the HSR, stationary tanks require a valid compliance certificate which needs renewal at set time intervals. This can only be issued if the stationary tank complies with the requirements of the HSR for design, construction and installation. Therefore, any repairs, alterations or maintenance shall be designed and constructed such that the tank still fully complies with the chosen standard.

Unlike the pipework, a stationary tank that contains hazardous substances, cannot use the PECPR as a means of compliance with the HSR, unless it is operated at pressure and therefore falls under those Regulations.

Clause 17.6.3 sets out what standards a PCBU needs to use to show compliance for stationary containers for seismic and wind loading. The four standards listed are on an 'or' basis such that to comply, you need to use one of them only for each loading type. The third standard listed is AS/NZS 1170.2 which is for wind loading leaving three options of seismic loading. One is NZS 1170.5 however this cannot be used by itself to determine all requirements for seismic loading of tanks on the basis that it notes tanks containing liquids are outside of its scope. Beca Ltd structural engineers have interpreted that the intent of NZS 1170.5 is for the regional seismic hazard and soil properties to be derived using this standard and these parameters applied, where possible, to one of the other standards. BS EN 14015:2004's seismic section is based off API 650:1998 so is no different to the remaining standard except it has an onerous requirement for a Safe Shutdown Earthquake with a return period of 1/5,000 years. The remaining standard is NZS/API 650:1998 being the Standards New Zealand approved version of API 650. Thus, more modern versions of API 650 would be strictly non-compliant when applying the requirements of HSR and should not be used.

What is also an issue is that API 650 seismic design provisions are only for flat bottomed cylindrical tanks with a uniformly supported base. This leaves no clear requirements for the seismic checks of above ground stationary tanks that are not flat bottomed and cylindrical or are supported on legs or other frames.

2.2.3 Process containers

A process container, defined as a stationary container that contains a hazardous substance in the course of manufacture or use of the substance, i.e. not used for storage, falls under Subpart 8 of Section 17 of the HSR.

This Subpart has no specific design requirements, and therefore the general requirements of Clause 17.3 apply. This allows the process container to comply as near as reasonably practicable with generally accepted engineering practices and standards. There are no listed standards for process containers, and therefore, the designer can choose any standard or guidelines that are generally accepted within the industry. These do not have to be cited standards and can be industry best practice guidelines. This may or may not have been the intention of the regulators that prepared the HSR but has not to date been amended.

As for the stationary tank, a process vessel requires a compliance certificate which can be issued if the container is suitable for service for all reasonably foreseeable operating pressures, temperatures, stresses, and loadings. These also need renewal at set time intervals. Again, this requires repairs, alterations and maintenance to be designed and constructed such that the container still fully complies with the chosen standard.

Therefore, the main difference between compliance for a process container versus a stationary tank is that there are no specified standards which a process container must comply and the choice of standard is left to the designer/checker. However, a reasonable expectation here would be the need to apply the current revision/edition of the standard selected by the designer/checker.

2.2.4 Below ground stationary tanks

Further complicating these regulations for PCBU is that for an existing below ground stationary tank, repairs or alterations to the tank can be undertaken to a level that continues to meet the standards and codes to which the tank was designed and constructed, Clause 17.84. This suggests that the standard and revision used from the original design can be used regardless of the age of the tank and changes in those standards over time.

Under Clause 17.30 the design and construction of new below ground stationary tanks containing a hazardous substance shall be in accordance with one of the listed standards.

2.2.5 Knowledge that has been ingrained into the industry

The predecessor of the HSR, the HSNO Act:1996, allowed what is now restricted to existing below ground stationary tanks for all existing stationary containers. That being tank repairs or alterations can be undertaken to a level that continues to meet the standards and codes to which the tank was designed and constructed. As such sometimes PCBU's, and certifiers not looking into the details of an engineering calculation, may

assume that a set of calculations held on file from a previous compliance certificate remain as an illustration of current compliance where in fact the methods used within those calculations are no longer compliant.

2.3 Vessels not containing hazardous substances and not operated at pressure

If a vessel, be it pipework or a tank, does not contain hazardous substances and is not operated at pressure greater then 50kPag, then compliance reverts to a much simpler pathway. The vessel shall now comply with the NZBA.

New vessels will require a Building Consent unless they are listed in the exempt tanks in Schedule 1 Part 1 Clause 23 of the NZBA. Territorial Authorities may provide further exemptions as allowed by the NZBA provided that compliance will be maintained without the building consent process and associated inspections. This is of particular importance for Food and Beverage facilities.

Producer statements by design engineers to confirm design compliance cannot be issued using B1/VM1 as loads are not determined in full compliance of AS/NZS 1170 and as such should be Alternative Solutions with sufficient explanation setting out the selected design standard or guideline used.

Tanks are specifically excluded from the special provisions for Earthquake-prone Buildings in the NZBA. As a result, in the case of an existing vessel, there is no requirement to improve the level of compliance when undertaking an alteration, repair or maintenance. The NZBA only states that the alteration shall not make the structure any worse.

While the NZBA does not require any improvement to an existing vessel, a PCBU may opt to do so. For recommended levels of seismic strengthening, PN19 provides guidance to PCBU based on the risks associated with each structure.

3 PIPEBRIDGES AND ACCESS WALKWAYS

Pipebridges and access walkways fall under the NZBA and therefore, any existing structure shall not be made worse by an alteration or repair and there is no requirement to strengthen it. PN19 can again be used for guidance on recommended strengthening levels. Also, it appears that pipebridges and walkways are not specifically excluded from the special provisions for Earthquake-prone Buildings in the NZBA and would be thus subject to its requirements. It is also unclear that if pipework and access walkways are directly supported off stationary containers whether the stationary container also is now subject to the Earthquake-prone Building provisions. These matters have been tested to varying degrees in recent insurance claims for seismic damage without any clear consensus.

However, if the pipebridge is supporting pipework that contains a hazardous substance or operates at pressure, it is classified as part of the pipework and therefore it shall comply with the relevant regulations associated with that type of pipework, i.e. PECPR or HSR.

For a pipebridge supporting pressure pipework, this would require the pipebridge to comply as near as reasonably practicable with the standards. An appropriate strengthening level would therefore need to be determined by the PCBU based on the risks associated and the costs to mitigate them.

If the pipework contains a hazardous substance, then there is no longer an option to choose a level of strengthening as the HSR requires full compliance.

Where existing access walkways are part of the means of escape from fire and are removed to facilitate repairs or alterations of adjacent vessels or other structures Clause 112 of the NZBA applies. This means they should be reinstated to comply as nearly as is reasonably practicable including both geometry and strength requirements. Seismic loading requirements need not be greater than existing or the Earthquake-prone threshold, whichever is the higher.

New pipebridges and access walkways including their foundations would require Building Consent.

4 BUILDINGS

Various types of buildings will be found across the facility e.g. process buildings, storage warehouses, administration buildings etc. Each of these shall comply with the NZBA which allows for existing structures to be assessed a given a Percentage of New Building Standard, *%NBS*, rating. Where the buildings differ from other structures on the site is that they shall meet the requirements under Subpart 6A of the NZBA. This Subpart requires a PCBU to strengthen the building when undertaking a significant alteration, to greater than 34%*NBS*. If a building is found to be Earthquake-prone by the Territorial Authority, this also sets a time frame in which the building must be strengthened or demolished.

While 34*%NBS* is the required minimum, a PCBU, when determining the level of strengthening, should consider:

- The impact that the loss of use of the building due to earthquake damage would have on the overall facilities operations. Depending on the size of the building this could extend to the impact on adjacent buildings.
- The number of people in the building.
- The value of equipment housed in the building or adjacent to it.
- Insurance premiums for buildings with lower %NBS ratings.
- The relative rating to other buildings on the site.

What further complicates the compliance management of buildings is when the building has a structure within or adjacent to it that contains hazardous substances or pressure equipment. In this case the HSR and PECPR regulations may dictate higher compliance requirements for the building to achieve the required compliance for the structure. While not explicitly stated in either the HSR or PECPR if a building is integral with the storage/process structure or is of a type and form that would adversely affect the storage/process structure within it, the level of compliance should match that of the HSR or PECPR. If the structure is of a form, for example a light weight steel clad portal warehouse, such that it's collapse would not have an adverse effect on the storage/process structure within it then the building compliance could be treated separately to the storage/process structure.

Under the NZBA the *%NBS* rating of a building need not consider unconnected adjacent buildings however in applying the MHFR the scenario of an adjacent building collapsing onto a structure containing a hazardous substance or at pressure needs to be considered. The required compliance level for the building is based on the assessed risk and if a reasonably practical approach in accordance with standards of generally accepted design practice is permissible for compliance under the HSR or PECPR.

It is reasonable to expect that Building Consent would be required for new buildings even if their structure is integral with vessels containing hazardous substances and thus linked into the compliance documentation required by the HSR.

5 MAJOR HAZARD FACILITIES

Facilities may be designated by WorkSafe as a Major Hazard Facility, MHF, under the MHFR if it has more than set quantities of specific hazardous substances. This is based on the potential to generate catastrophic events that could cause harm to people, the environment and the wider community.

PCBU that operate a MHF must, among other requirements:

- Carry out a safety assessment to identify potential major incidents and major incident hazards.
- Have and test an emergency plan.
- Put in controls to manage risks
- If an Upper Tier MHF, have a safety case that demonstrates that the operator has the ability and means to control major incident hazards effectively.

- If a Lower Tier MHF, have a Major Accident Prevention Policy.

The above obligations require consideration of earthquakes as a hazard and the resulting impacts that may cause incidents or create further hazards. This can be described as a collection of "what if" scenarios that is supported by engineering assessment of the structures at the MHF that have the potential to affect the structures that contain the hazardous substances. It is within this activity that the various compliance pathways need to be understood such that appropriate mitigations and controls be put in place that meet the legislative requirements.

The MHFR do not define the Importance Levels, (IL), required in the assessments as this has been left to the various standards that define the loads to be applied under the hazard scenario.

6 IMPORTANCE LEVELS

In general, there is some consensus from regulators and engineering professionals that the applicable Importance Levels to apply across the various standards under the suite of Acts and Regulations to show compliance come from AS/NZS 1170 or are at least well aligned. However, there is one significant deviation from this in the HSR.

AS/NZS 1170 places buildings that contain hazardous materials into two Importance Levels. First, Importance Level 3, IL3, where the building is not designated as post-disaster and contains hazardous materials capable of causing hazardous conditions that do not extend beyond the property boundaries. Second, Importance Level 4, IL4, where the building is either designated an essential facility, with a special post-disaster function or contains hazardous materials capable of causing hazardous conditions that extend beyond the property boundaries. For seismic loading these require a 30% and 80% premium respectively on buildings considered as having normal use.

AS 1210 links the hazard level of pressure vessels to the importance levels of AS/NZS 1170 and notes that any pressure vessel located within or adjacent to a hazardous facility, which on failure could initiate a further event shall be allocated an Importance Level 4 unless a detailed risk assessment determines that a lower Importance Level can safely be allocated.

Under the HSR and use of NZS/API 650:1998 the Importance Levels are defined as an Importance Factor but the requirements differ quite significantly from AS/NZS 1170 values. All tanks shall have a value of 1 (equivalent to normal buildings in AS/NZS 1170) unless a larger factor is specified by the purchaser. The Importance Factor should not exceed 1.25 and this maximum should be applied only to tanks that must provide emergency post-earthquake service or to tanks that store toxic or explosive substances in areas where an accidental release of product would be considered to be dangerous to the safety of the general public. As the wind loading falls under AS/NZS1170.2 this can result in two different Importance Levels for the same structure.

In applying an Importance Level to buildings consideration of their impact on adjacent structures containing hazardous substances is required and may result in a higher Importance Level than for the building alone.

7 DESIGN LIFE

In the past many industrial structures have been designed with a design life of 25 years and this was considered acceptable previously as the environmental loading exposure period. However, this is not the case now and this industry ingrained expectation on design life needs updating. Following the basis set out in AS/NZS 1170 for a permanent structure, a design life of 50 years is required, which is defined as the minimum exposure period for an indefinite design life. Any design life less than 50 years implies a temporary structure that must be demolished or have its life extended if it is to be retained at the end of the 25 years. To extend a structure's life, the design life must be increased with the life to date included in the new extended life. This means a 25 year design life tank that needs replacement after 25 years cannot be replaced by a new 25 year design life tank to perform the same function. This also applies to foundations

where the construction works are likely to be more difficult to have their design life extended. Section 5.1 of PN19 clarifies this change in philosophy and explains how the mechanical and NZBA compliance design lives may be different for the same structure.

AS 1210 allows a design life of 25 years for all pressure vessels in Australia but PN19 modifies this for pressure vessels in New Zealand to have any vessels operating for greater than 25 years to have a design life of 50 years.

8 FONTERRA'S PROCESS

Fonterra are advancing their requirements as PCBU/operators of a MHF and vessels containing hazardous substances. One of the initial steps here was to understand, with depth, what the requirements of the MHFR meant for their current sites. This has been a complex activity to define the interactions of individual structures and their potential impacts on critical structures falling under the HSR and PECPR.

Applying that knowledge, the pipebridges have proven to be one of the more challenging structures to test with the MHFR 'what if' scenarios. This is due to their interconnections with many other structures on site which fall under all of the possible regulations. This then sets the criteria to assess the structures, including seismic assessments of buildings, that other than their proximity to the pipebridges would be considered normal buildings now needs to consider the impacts of their failure on the pipebridges. This presents options where assessment as is requires certain Importance Levels and compliance thresholds, which can be addressed directly or these could be lowered by implementing other mitigation measures to reduce the risk. One mitigation that has been considered in this area is active valve control on the pipebridges that in the event of an earthquake shut the flows off limiting the total volume of hazardous product that could potentially be released.

9 CONCLUSION

The compliance pathway for structures on a process and manufacturing facility is not straightforward for a PCBU. Each type of structure must show compliance to a different legislation and even within the types of structure, sub-types use different methods of compliance. This can become overwhelming for PCBU but the use of a flow chart that steps them through each type of structure has been found to simplify the process and provide them with more clarity. It also allows practical approaches to mitigate the risks based on knowledge of what triggers the non-compliances.

Engineers operating in this area of the profession also need to remain knowledgeable about changes in the legislation and where approaches of the past are now no longer considered appropriate.

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