HEALTH AND SAFETY BY DESIGN

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PURPOSE

The purpose of this Practice Note is to raise awareness of a design engineers' obligations in the context of other parties' obligations under the Health and Safety at Work Act (2015) (hereby known as 'the Act') for Health and Safety by Design, including:

- an introduction to the concepts of Health and Safety by Design
- an overview of the duties imposed by the Act
- responsibilities of practitioners, including engineers in their various roles as worker and Person Conducting a Business or Undertaking (PCBU), and as designer and consultant. The Act imposes duties on these parties as well as on principals.

Other stakeholders, including regulators (at national and regional levels), will have needs and expectations. WorkSafe and Waka Kotahi (among others) publish strategies alongside guidance which provides insight into performance issues. The engineer should understand the industry context when carrying out a design.

This document is not a source of legal advice or a comprehensive guide to the obligations of the Act or Health and Safety by Design. Engineers should always apply professional judgment and seek legal advice if they have questions or concerns about their obligations.

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Note: this Practice Note is not a definitive guide to the Health and Safety at Work Act 2015. For details of the Act and supporting guidance go to **https://worksafe.govt.nz/**

HEALTH AND SAFETY BY DESIGN

WHAT IS HEALTH AND SAFETY BY DESIGN?

The term Health and Safety by Design describes the consideration for health and safety and the prevention of harm, including chronic illness, during the early phases of a project or system lifecycle to improve safety at all future stages of the project or system lifecycle. Safety in Design activities need to consider the technical, human, and ergonomic factors associated with the hazard of the project's construction and the operating life cycle.

Indicators that design activities are achieving their purpose will be evident in the fabrication, construction, operator safety, ease of maintenance, efficiency, productivity, and comfort, as well as the safety of the public.

TIMING

Consideration for health and safety at the design stage of a project is a powerful tool that can drive fundamental design changes. Eliminating and minimising safety risks as early as possible in the project lifecycle is more effective, cheaper and easier than doing so retrospectively.

Health and Safety by Design uses foresight and knowledge of foreseeable events, including operations, activities and situations that can arise during the project or system lifecycle.

The engineer[1] uses that knowledge to identify the potential hazards and safety risks, and modify the design or development of preventions to reduce the risk to the overall facility hazards; for example, by using safety-critical elements (SCEs).

The engineer addresses each hazard and provides mitigation measures to render the overall facility hazards to a level “as low as is reasonably practical” (ALARP).

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[1] For the purposes of this document, the phrase engineer refers to the engineer responsible for designing the project.

EFFECTIVE USE OF HEALTH AND SAFETY BY DESIGN

To do this effectively, practitioners, designers, and engineers need to consult with those who best understand the nature of the operations, activities, and situations and work together to identify the hazards and determine how they can be eliminated and minimised in the design.

Examples of elimination or complete prevention of risk could include:

Leak minimisation
Depressurisation
Collision avoidance
Automation
Closed systems
Fail-safe design
Dropped object protection
Isolation

Examples of minimisation or mitigation of risk could include:

Ignition prevention
Fire and gas detection
Emergency shutdown (ESD)
Bunding
Explosion protection
Hazardous areas
Blowdown
Firefighting systems
Passive fire protection
Escape routes

CHARACTERISTICS OF HEALTH AND SAFETY BY DESIGN

Health and Safety by Design characteristically:

- **obtains** the correct technical inputs such as a Basis of Design (BOD), and ensures the team has the right skills and competencies for the project area
- **modifies** the design to eliminate and minimise hazards and safety risks across the lifecycle by addressing them early in the design when it is cheaper and easier to do so
- **communicates those remaining hazards and safety risks** not addressed early in the design to later design stages, such as construction, operation, use, maintenance, and possibly demolition
- **documents** design decisions for assurance and recording purposes to meet the requirements of the Act. These include but are not limited to assurance reviews such as:
    - Project risk review
    - Hazard and operability studies (HAZOP)
    - Layers of protection analysis (LOPA)
    - Hazard identification (HAZID)
    - 3D model review
    - Constructability (buildability), operability and maintainability reviews
- **implements** the agreed processes and management plans such as the Project Execution Plan (PEP).

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COMMUNICATION

Interested parties (stakeholders) need to be considered and consulted during the design process. The engineer needs to understand the client's relationships as a PCBU and support the flow of information.

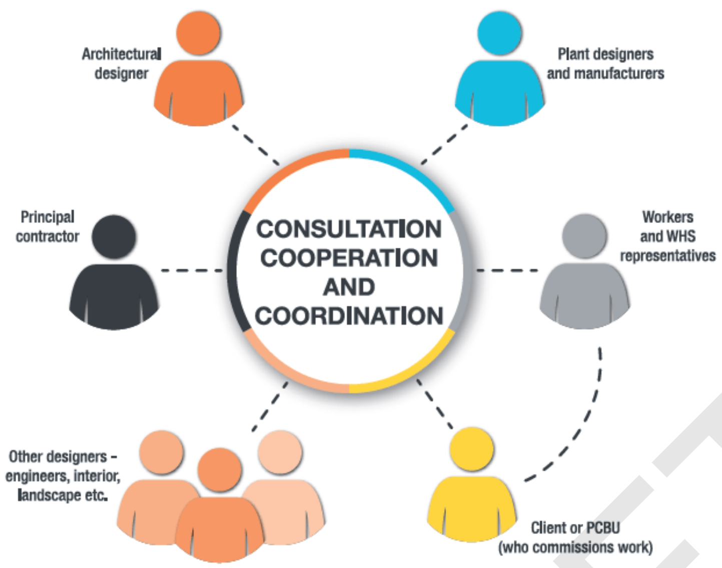

Figure 1: Consultation and co-operation (Safe Design Australia, 2018)

Construction, pre-commissioning, and commissioning are high-risk phases of project work. However, work should not compromise the public's safety, construction personnel, adjacent property and equipment.

CONSTRUCTION SAFETY PLAN

The alignment of all stakeholders to understand, eliminate, and mitigate the risks during construction are crucial goals of the safety in the design process. To communicate and document such risks and mitigations, an engineer can consult with stakeholders to complete a Construction Safety Plan.

It may be a component of an integrated construction safety system, a construction safety case (where the regulatory jurisdiction requires this), or a project or activity-specific safety plan. Supporting documents would include approved standard operating procedures (SOPs) and simultaneous operations procedures (SIMOPS), as well as other supporting health and safety in employment (HSE) documents, forms, and guidelines.

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HEALTH AND SAFETY AT WORK ACT 2015

The Act has far-reaching obligations for engineers. The obligations apply to sole practitioners, small practices, and large organisations.

All stakeholders– including client, engineer, manufacturer/constructor and supplier – have specific obligations under the Act. Engineers may have a direct or indirect relationship with any of these parties and should be proactive in working with them to manage health and safety risks.

PCBU

The Act uses ‘PCBU’ (Person Conducting a Business or Undertaking) to describe all forms of modern working arrangements, which we commonly refer to as ‘businesses’.

The Act imposes specific duties on PCBUs who design, manufacture, import, supply, or install any plant, substance, or structure. The duties place an obligation on the PCBU to eliminate risks to health and safety so far as is reasonably practicable. Risks that cannot be eliminated must be minimised so far as is reasonably practicable.[2]

A PCBU must ensure the health and safety of workers and others. The PCBUs responsibilities include the design of structures, plant, or substances to be used, or could reasonably be expected to be used, at work.

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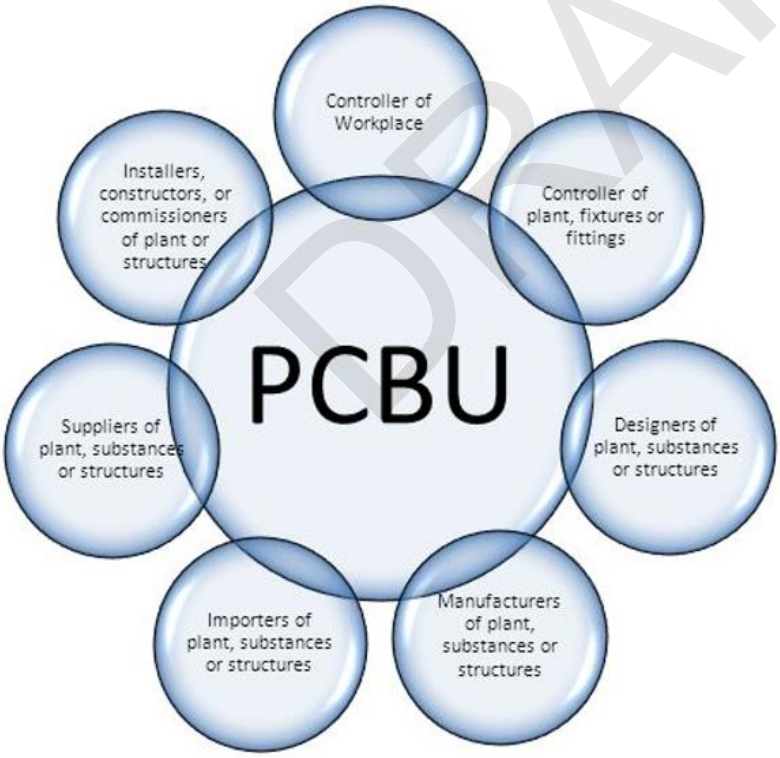

Figure 2: PCBU interactions (Swenson & Associates)

[2] Refer to Sections 39-43 of the Health and Safety at Work Act (2015)

WORKER ENGAGEMENT

Part 3 of the Act, supported by regulations and WorkSafe guidance, outlines worker engagement, participation, and representation requirements. A meaningful, structured process is required to share appropriate information to allow workers to provide their input.

Workers' input will assist in addressing the divide between the 'real' and the 'imaginary' – how the contractor will complete the work in practice. While an engineer [3] may not have much influence and control over the client's organisation and their workers, they may need to access an organisation's information and workforce to fulfil their obligations in design.

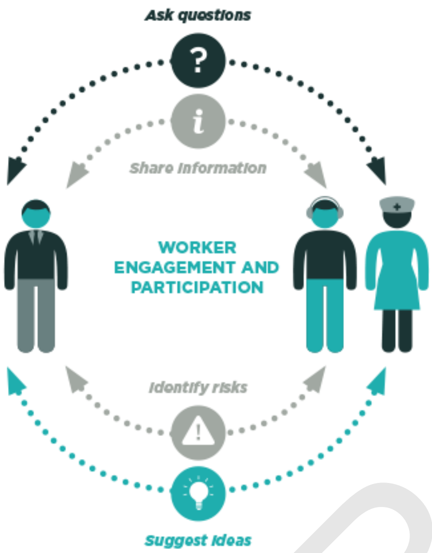

Figure 3: Worker engagement (WorkSafe, 2017))

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[3] While the Act typically refers to the 'designer', for the purposes of this document we refer to the engineer as the designer.

WHAT IS 'REASONABLY PRACTICABLE'?

'Reasonably Practicable' defined by the Act means "that which is, or was, at a particular time, reasonably able to be done concerning ensuring health and safety, taking into account and weighing up all relevant matters, including—

(a) the likelihood of the hazard or the risk concerned occurring; and
(b) the degree of harm that might result from the hazard or risk; and
(c) what the person concerned knows, or ought reasonably to know:
    a. (i) the hazard or risk; and
    b. (ii) ways of eliminating or minimising the risk; and
(d) the availability and suitability of ways to eliminate or minimise the risk; and
(e) after assessing the extent of the risk and the available ways of eliminating or minimising the risk, the cost associated with available ways of eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk."

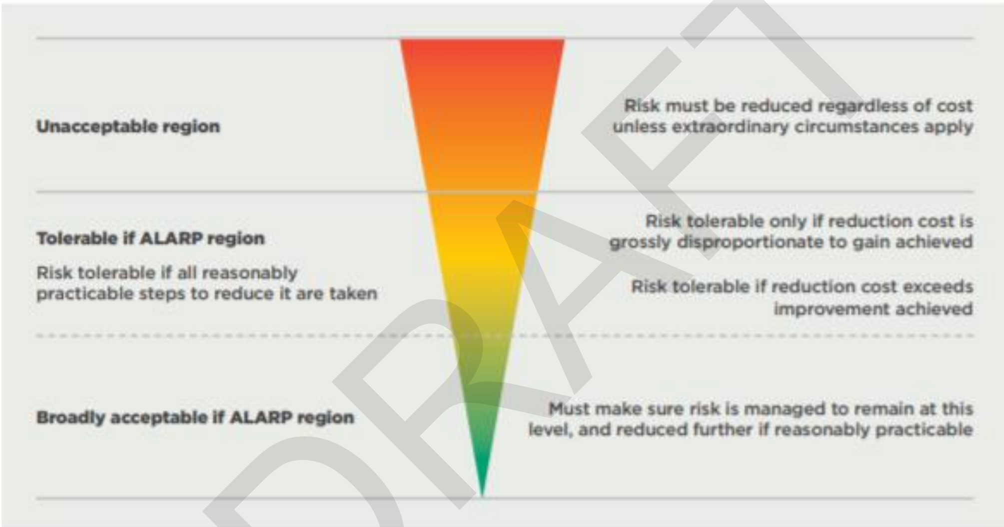

Figure 4: As Low as Reasonably Practicable (WorkSafe, 2016)

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OUR TIPS TO MEET OBLIGATIONS UNDER THE ACT

The following points aim to assist engineers to meet their legal obligations under the Act, using the principles of Health and Safety by Design:

(a) Doing Health and Safety by Design well can be complex. The future is uncertain, and operations can be complicated. Take the time to understand the complexity of the operations, situations, and events that can arise. Don't jump straight into the design. Visiting existing sites and talking to workers to understand their perspectives and issues will vastly improve early decision making to improve safety and the overall design.
(b) The Act requires the engineer to contemplate 'that which is, or was, at a particular time reasonably able to be done'. It means that engineers should prioritise those things that they

can address early in the design process and document decision-making as the project progresses.

(c) Consideration for health and safety includes the prevention of chronic illness. So concern for materials, fibres, liquids, and substances used in the construction, manufacture, use, maintenance, refurbishment, cleaning, and disposal must be considered. The best way to eliminate these is to select materials and substances early in the design process carefully.

(d) The engineer should contemplate what should be known about operations and the associated hazards and risks, and how to minimise them in the design. Talk to others, look at industry data about accidents' nature, and consider how associated risks are eliminated and minimised in similar contexts.

(e) The requirement for the engineer to demonstrate they have reduced risk so far as is reasonably practicable requires that the engineer step through each element of the design and only consider the cost once the other factors are understood. The engineer must document what they know about the availability and suitability of potential controls.

(f) The engineer must demonstrate they have reduced risks so far as reasonably practicable and then engage with the end-user, owner or client and communicate remaining hazards or safety risks that they have identified but did not eliminate in the design. Recording what they know at each stage of design helps with the requirements of the Act.

Tools such as the Construction Hazard Assessment Implication Review (CHAIR[4]) can help engineers identify and mitigate risk when engaging stakeholders. There are significant time and cost savings by engaging with stakeholders early.

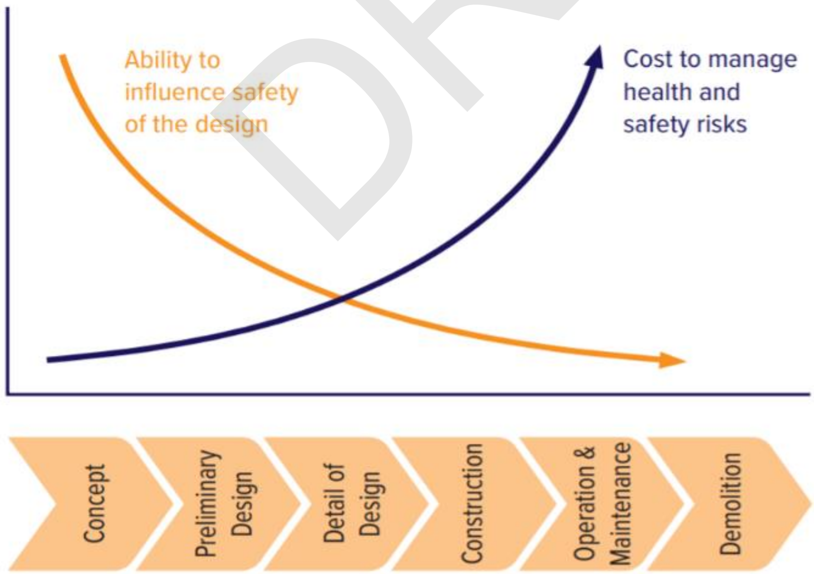

Figure 5: Symberski chart of influence for construction safety planning (SiteSafe, 2019)

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[4] https://www.safedesignaustralia.com.au/wp-content/uploads/2018/10/CHAIR_Safety_in_Design_Tool_WorkCoverNSW.pdf

ETHICAL OBLIGATIONS OF THE ENGINEER

CODE OF ETHICAL CONDUCT (2016)

The Engineering New Zealand Code of Ethical Conduct (2016) identifies the duty of engineers to "Take reasonable steps to safeguard health and safety: *You must, in the course of your engineering activities, take reasonable steps to safeguard the health and safety of people*".

PRACTICAL CONSIDERATIONS

The following points offer practical considerations when assessing the hazard or risk.

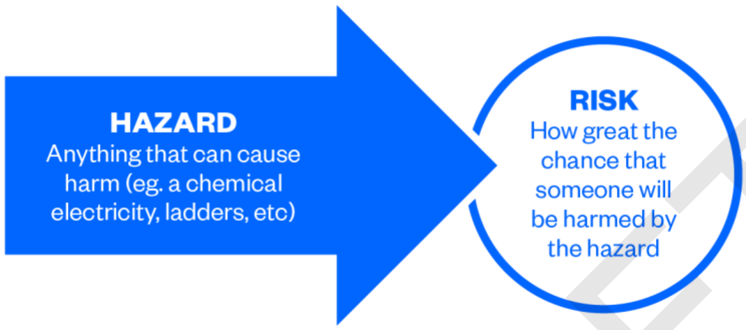

Figure 6: Hazard vs Risk

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1. A design should ensure that they have contained a hazard. If the engineer judges a control to be reasonably practicable, they must implement it regardless of the level of risk. Remember, it is cheaper and easier to control the safety risks early in the design process.
2. While an unusual or rare hazard may not be considered credible, related hazards of a lesser degree are still plausible, and the design must control those hazards sufficiently. Disagreement on which hazards are credible may arise and industry accident data may resolve uncertainty.
3. Controls used for similar hazards or risks elsewhere in similar applications are considered reasonably practicable – that is, unless the engineer can demonstrate they are unavailable, unsuitable, or would introduce new hazards or risks with more severe consequences.
4. The time required to implement controls is not sufficient justification for not applying controls. The engineer, contractor or client, should seek additional time.
5. The capacity or willingness to fund controls is not justifiable for avoiding suitable and available safety controls. Unless the engineer can demonstrate that the cost is grossly disproportionate to the benefit provided, the engineer should seek additional funding or resources. The request typically needs to get escalated to the officers[5] of the client organisation, and potential consequences of non-compliance should be made clear to all

[5] An 'Officer' includes any person who can exercise significant influence over the management of the business or the undertaking. Refer to the Act for a full definition.

concerned. The engineers must make the client aware of hazards and risks identified and additional controls needed.

6. The Act requires elimination and then minimisation. When controlling a hazard and the associated risk, use the hierarchy of controls (Figure 7). Choose controls from as high on the hierarchy as possible, then assess residual risk. If the residual risk is still too high, the engineer should apply additional controls regarding the hierarchy until they have reduced the risk as far as reasonably practicable.
7. Avoid risk shuffling, where one hazard or risk is eliminated or minimised in one part of the project or system lifecycle, only to create a new hazard or risk in another part of the system life cycle. An example is eliminating a safety risk for construction while creating a new safety risk for users or maintainers.
8. Communicate the remaining residual risks to the client or end-user in their own language and framework. Ask them about their risk assessment of the risk and how they want those remaining hazards and risks communicated.
9. Controls that are part of normal processes or fall outside the hierarchy of controls should be captured as assumptions (e.g. ‘meets code requirements, competent engineer, competent builder’).

In addition to the final design, the engineer should provide the following to later project lifecycle phases by:

(a) **Communication** of hazards and risks the engineer did not eliminate (i.e. residual risks)

(b) **Assurance documentation** regarding knowledge of the nature of operations, hazards and risks

(c) how those have been eliminated or minimised by design.

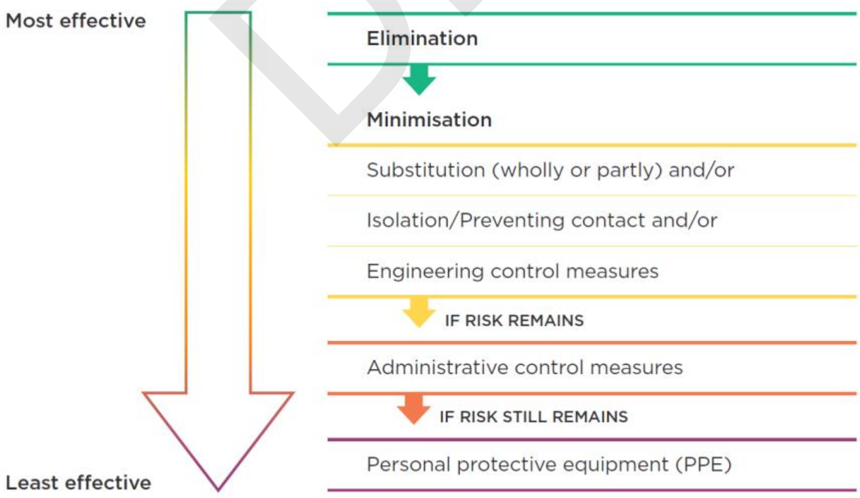

Figure 7: Hierarchy of controls (WorkSafe, 2017)

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EXAMPLES OF HEALTH AND SAFETY BY DESIGN

EXAMPLE 1 – PARAPETS AND WORKING AT HEIGHTS

A client is building a large warehouse for use as a storage depot. The architect designs a small parapet to run around the building, with the design of the parapet ranging from 50mm - 500mm above roof level.

However, this height does not meet any requirements for edge protection. Those that need to access this area and maintain the gutters will face a significant challenge and an increased safety risk of a fall resulting in injury or fatality.

The client will incur additional maintenance costs and risks when accessing the roof. Safety measures are required for workers to access the roof, including:

- anchor points and permanent lines installed to the roof structure
- formal annual inspection on anchor points to confirm they are still sufficient
- 'Warning' notices on the access door to the roof advising of the pitch and associated risks
- training required for staff working in harnesses.

By collaborating with the contractor and identifying the issue at the design stage, the parapet could be increased to at least 1,100mm. This increased height could reduce the need for any of the above measures during the life of the building. The increase may not be possible due to height to boundary issues, but the Health and Safety by Design process allows the engineer to recognise possibilities early.

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Example 1 Control hierarchy table

	Hazard control hierarchy	Preventative method/treatment
1	**Eliminate** the risk.	It is unlikely that the engineer can eliminate the falling hazard.
2	**Minimise** risk by isolating the source.	Erect a permanent physical barrier around the edge (the hazard) to protect all people, including the public.
3	**Minimise** the risk by engineering controls**.**	If a 1,100mm high parapet is not possible, design permanent attachment points early in the process.
4	**Minimise** the risk further by devising standard operating procedures.	Train all people to follow procedures, including site visitors and sub-contractors, and check they are actively using them.
5	**Minimise** risk further by ensuring all workers use PPE.	Help ensure contractors are aware of the hazard and use fall restraint systems or similar.
6	Have **recovery mechanisms** in place for residual risk in case an incident or accident occurs (e.g. emergency response procedures and readiness).	Practice recovery activities if an incident or accident occurs.

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EXAMPLE 2 – MAJOR HAZARD FACILITY FIRE RISK

A client is building a separation loop for a petroleum facility. The separation loop uses a reboiler to reheat condensate, allowing it to be further separated into its different component fluids and gases. A conventional design burns natural gas to heat the tubes containing the flammable condensate fluid.

However, conventional design introduces an ignition source near the flammable condensate, potentially causing extensive damage or injury during a tube failure. If the bundle is damaged during maintenance, the tubes can be weakened and fail. Deterioration of the fire tubes from exposure to high temperatures could also cause failure. The engineer must select materials to meet the specific operating conditions and specify regular inspections to ensure integrity.

The client will incur additional infrastructure costs in fire and explosive protection when operating the plant. Other safety measures required for the site could include:

- additional firefighting/firewater infrastructure
- additional fire barrier or explosive barrier construction
- larger exclusion zones
- training required for staff working
- additional emergency shutdown functionality

Removing the ignition source could reduce the need for many of the above control measures. By collaborating with the client and identifying the issue at the design stage, the engineer could identify an alternative reboiler – for example, a steam-heated boiler. This may not be possible due to a lack of steam services on-site for tie-in and/or restrictions on implementing a completely new system. Still, the Health and Safety by Design process allows the engineer to recognise possibilities early.

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Example 2 Control hierarchy table

	Hazard control hierarchy	Preventative method/treatment
1	**Eliminate** the risk.	Change the reboiler heating method from natural gas to steam.
2	**Minimise** risk by isolating the source.	Position the reboiler away from other equipment and personal work areas with a significant exclusion zone.
3	**Minimise** the risk by engineering controls**.**	Have fire detection systems and design the vessel shell for a fire scenario.
4	**Minimise** the risk further by devising standard operating procedures.	Train all people to follow the procedures, such as operations, maintenance teams, sub-contractors, and check they are actively using them.
5	**Minimise** risk further by ensuring all workers use PPE.	Help ensure contractors are aware of the hazard, wear fire-retardant overalls and know the locations of respirators.
6	Have **recovery mechanisms** in place for residual risk in case an incident or accident occurs (eg emergency response procedures and readiness).	Practice recovery activities if an incident or accident occurs. Use of fire barriers and foam firefighting systems.

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EXAMPLE 3 – ACID LOAD OUT FACILITY

A client sells concentrated acid to customers throughout the country. The product is stored in large tanks and loaded into trucks, with the driver required to stand on the top of the truck during the filling operation.

During an internal safety review, the client identified that truck drivers could potentially be exposed to the acid. Although the driver always wears an appropriate PPE, the review clearly identified the need to institute further risk control measures. The driver also has an assistant who could be at risk.

The client engaged a consultant to redesign the loading system to address the safety concerns. After undertaking a thorough risk assessment involving the client, the trucking company, and the consultant engineers, it was concluded the acid risk is likely to stem either from:

- the tanker being overfilled
- the bursting of a process pipe/hose.

The driver falling into the tanker was deemed highly improbable as the filling hatch was small.

Several engineering and administrative safety controls are required to protect the driver and the assistant, including:

- removing the operators (ie the driver and the assistant) from harm's way
- interlocking the loading system with the safety systems
- proper operating procedures and training.

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Example 3 Control hierarchy table

	Hazard control hierarchy	Preventative method/treatment
1	**Eliminate** the risk.	Although the equipment is specifically engineered for the task, it is unlikely that the possibility of a bursting hose/pipe can be eliminated entirely. Similarly, it is unlikely that overfilling the truck can be eliminated (overfill protection level sensors exist but can be unreliable in corrosive environments).
2	**Minimise** risk by isolating the source.	• The truck driver and assistant are locked in the safety (operator) booth. • Booth doors are interlocked with the loading system, and the system shuts down if the doors open. • The system requires two people to start, thereby ensuring the system does not start unless both driver and assistant are in the booth.
3	**Minimise** the risk by engineering controls**.**	• Process loading is authorised via control panel starting procedure (including confirming correct hose designation, the capacity of the tanker being filled, and the quantity to be loaded). • Loading hoses are interlocked with the storage hoop (ie if a hose is in the storage hoop, loading out will not commence). • A flowmeter is installed so that only the desired amount of acid is delivered (thereby reducing the risk of an overflow). • Warning lights flash when the system is running.
4	**Minimise** the risk further by devising standard operating procedures.	• Standard operating procedures are produced. • Operators are trained in the standard operating procedures. • Standard operating procedures are reviewed annually, and operators are given an annual refresher. • Operators always were proper PPE.
5	**Minimise** risk further with proper signage	The area is signposted to make sure pedestrians are aware of the risks (this is an additional control to the fencing and flashing lights).

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EXAMPLE 4 – LOW AND EXTRA-LOW VOLTAGE

A client is installing new temperature transmitters on their site. Due to their site location, the cables are to run from the PLC (programmable control circuit) cabinet “CJB-1” through two intermediate cabinets “CJB-2” and “CJB-3” to the instrument in the field. The client standard temperature transmitter uses a 230V AC signal, which is considered ‘low voltage’.

230V AC signals are more dangerous to work on and require more safety controls when compared to ‘extra low voltage’ 24V DC signals. Most modern temperature transmitters will have 24V DC counterparts. Choosing a lower voltage instrument during the design phase will lower the risk exposure of workers and may save time and money for operations in the long run.

- Having 230V signals present in a cabinet makes that cabinet ‘Low-Voltage’ (compared to ‘Extra-Low Voltage’ 24V signals)
- Further additional engineering controls are usually required for ‘low-voltage’ cabinets compared to ‘extra-low voltage’ cabinets.
- It is best practice always to have two people present when opening a 230V cabinet.
- Higher voltage cabinets have a chance of arc flash resulting in burns.

Another way to reduce risk would be to install relays in CJB-1 and CJB-3 to switch most of the cable to a 24V DC signal. Installing the relays would prevent the need for 230V AC precautions in the intermediate CJB-2.

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Example 4 Control hierarchy table

	Hazard control hierarchy	Preventative method/treatment
1	**Eliminate** the risk.	Unlikely to be practicable in this case.
2	**Minimise** risk by isolating the source.	Use relays to change the cable length to a 24V signal. Reduce the number of 230V cabinets on site.
3	**Minimise** the risk by engineering controls**.**	Separate the 230V and 24V cabinets in the same switch rooms to limit the number of times contractors need to work on the 230V cabinets.
4	**Minimise** the risk further by devising standard operating procedures.	Train all people to follow the procedures, such as operations, maintenance teams, sub-contractors, and check they are actively using them. Best practice may include having two people present whenever opening a 230V cabinet.
5	**Minimise** risk further by ensuring all workers use PPE.	Help ensure contractors are aware of the hazard and wear appropriate PPE. Gloves and safety glasses may protect against burns from arc flash.
6	Have **recovery mechanisms** in place for residual risk in case an incident or accident occurs (eg emergency response procedures and readiness).	Practice recovery activities if an incident or accident occurs. All electricians trained in first aid.

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EXAMPLE 5 – DRESSING OF VERTICAL VESSEL

A client is building a separation loop for a petroleum facility. The separation loop uses a 30m vertical stabiliser column to separate condensate into different components of fluids and gases. Platforms and ladders must be added to the stabiliser column to access a series of process nozzles, valves and inspection points.

To dress the stabiliser column, the contractor would traditionally erect it and add the platforms and ladders afterwards. In this case, the engineers identified the opportunity to dress the stabilizer column while it’s horizontal in the fabrication shop before being transported to the site. This sequence reduces the cost of site-based works and eliminates the risk of working at heights.

By approaching the design with constructability in mind and identifying the issue at the design stage, an alternative plan for dressing the stabiliser column is possible.

Example 5 Control hierarchy table

	Hazard control hierarchy	Preventative method/treatment
1	**Eliminate** the risk.	Dress the stabilizer while horizontal and below 1.8m high.
3	**Minimise** the risk by engineering controls**.**	Use of scaffolding with handrails, kick plates and harnesses.
4	**Minimise** the risk further by devising standard operating procedures.	Train all people to follow the procedures, such as operations, maintenance teams, sub-contractors, and check they are actively using them.
5	**Minimise** associated risk further by ensuring all workers use PPE.	All construction staff use helmets to protect from falling objects.
6	Have **recovery mechanisms** in place for residual risk in case an incident or accident occurs (e.g. emergency response procedures and readiness).	Have rescue plans in place for construction personnel using harnesses.

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ADDITIONAL RESOURCES

This practice note provides an overview of Health and Safety by Design. The list below contains some of the resources that can be sourced free of charge for further knowledge.

1. Health and Safety by Design: an introduction – WorkSafe New Zealand
   https://www.worksafe.govt.nz/topic-and-industry/health-and-safety-by-design/health-and-safety-by-design-gpg/#lf-doc-48060
2. Worker Engagement and participation – WorkSafe New Zealand
   https://www.worksafe.govt.nz/managing-health-and-safety/businesses/worker-engagement-and-participation/
3. Temporary Works Procedural Control – Temporary Works Forum
   https://secure.chasnz.org/downloads/resources/TemporaryWorksProceduralControl_GPG_.pdf
4. Construction Health and Safety New Zealand (CHASNZ)
   https://www.chasnz.org/
5. Safe Design of Structures: Code of Practice – Safe Work Australia
   https://www.safeworkaustralia.gov.au/system/files/documents/1702/safe_design_of_structures2.pdf
6. Getting Started – the basics – Health and Safety Authority Ireland
   https://www.hsa.ie/eng/supports_for_business/getting_started/the_basics/

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