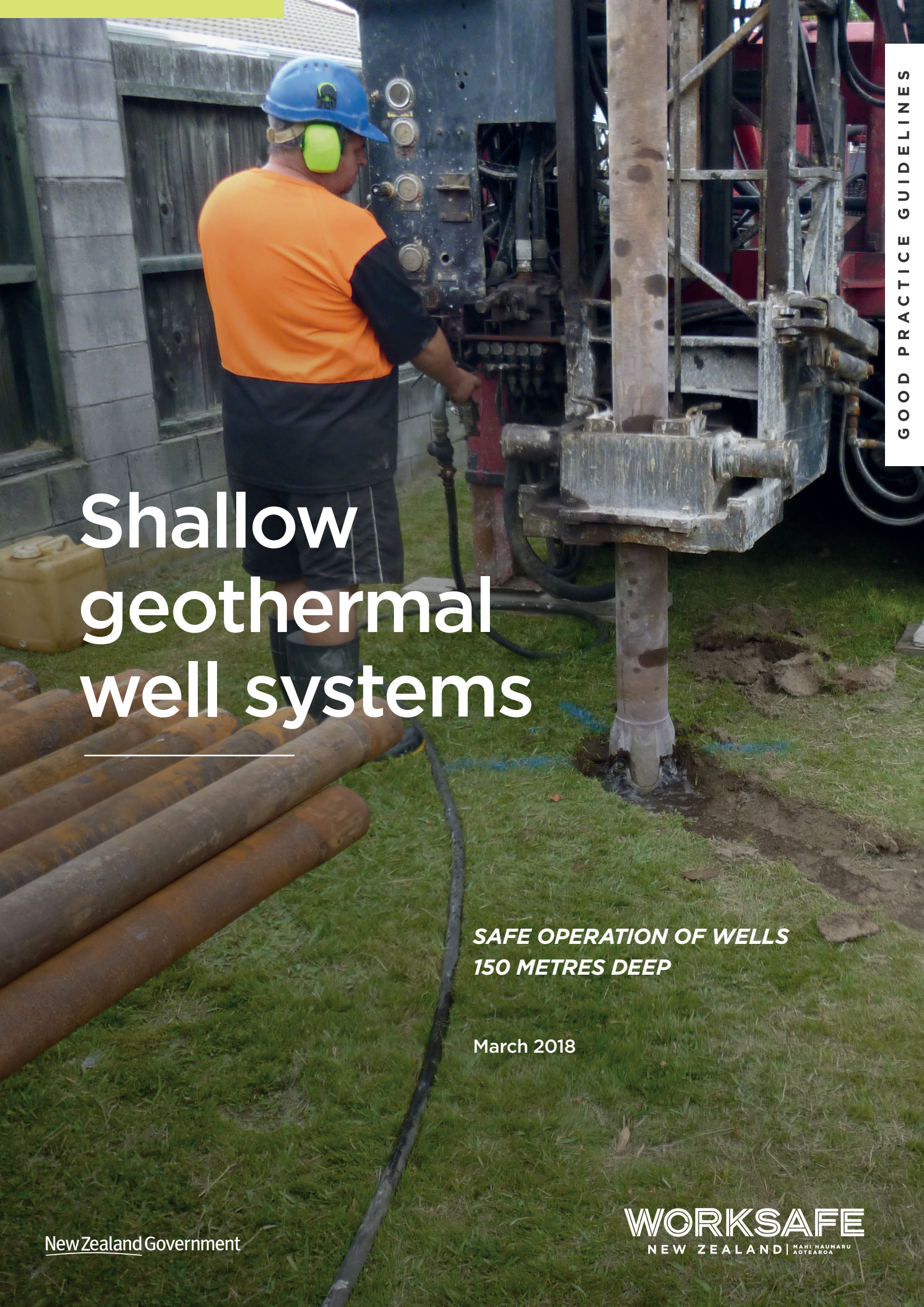

GOOD PRACTICE GUIDELINES

Shallow geothermal well systems

SAFE OPERATION OF WELLS 150 METRES DEEP

March 2018

New Zealand Government

WORKSAFE NEW ZEALAND | MAHI HAUMARU AOTEAROA

These guidelines provide practical guidance to safely drill, operate, maintain, and abandon wells 150 metres (m) deep.

Shallow geothermal well systems

KEY POINTS

- Before drilling operations begin, carry out a risk assessment to make sure risks to the health and safety of any person are eliminated so far as is reasonably practicable.
- Instruct and train all workers in well control and in the correct and safe use of all equipment and machinery they'll work with.
- Make sure workers are aware of the hazards and risks normally associated with drilling and hot geothermal fluids.

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1.0 Introduction

IN THIS SECTION:

These guidelines enable you as a manager and persons conducting a business or undertaking (PCBU) to drill shallow geothermal wells and operate them safely.

These guidelines cover:

- drilling, operation, maintenance, suspension, and abandonment of shallow geothermal wells and all subsurface work, subsurface casing, plus the wellhead components to the top flange of the master valve
- all wells down to 150 m deep, where steam or hot water exceeding 70 degrees Celsius (°C) is or is likely to be encountered.

These guidelines may apply to wells down to 250 m deep where subsurface geothermal conditions are 20°C or more below the boiling point for depth at ambient conditions, and the wellhead pressure is less than 5 barg. In acidic waters or other exceptional circumstances you may need to consider requirements beyond the scope of these guidelines.

Wells drilled in conditions more severe than those above should comply with *NZS 2403: Code of Practice for Deep Geothermal Wells* and you must construct, maintain, operate, suspend, and abandon wells 150 m or deeper according to NZS 2403.

These guidelines do not apply to equipment or operations downstream of the master valve (or wellhead isolation valves where applicable).

1.1 Your legal responsibilities

Health and Safety at Work Act 2015

The Health and Safety at Work Act 2015 (HSWA) defines the roles and responsibilities of different duty holders. These include PCBUs, officers, workers and other persons at workplaces.

For more information see WorkSafe's special guide *Introduction to the Health and Safety at Work Act 2015*, available at: worksafe.govt.nz

Geothermal Energy Regulations 1961

As well as HSWA the Geothermal Energy Regulations 1961 (the Regulations) set out duties and responsibilities for managers of geothermal well drilling operations. Under the regulations, (in particular regulation 25) you must:

- make sure the geothermal work, to which your appointment relates, complies with the Regulations
- exercise daily personal supervision of the geothermal work

- make sure that all workers on the geothermal work have:
  - been adequately instructed in the provisions of the Regulations
  - sufficient knowledge and experience of the work to be carried out
  - been adequately instructed in the potential hazards and risks of the work and any necessary precautions to take
- for drilling being carried out:
  - inspect the rigs and other installations on the work at least once every 24 hours
  - correct, as soon as reasonably practicable, any unsafe aspects of the rig and other installations
  - keep a daily log of:
    - the relevant information in section 4.6 of this guideline
    - any accident or dangerous incident which results in medical attention (ie any notifiable accident to which regulation 35A applies)
    - details of any unsafe aspects of the rig and other installations found during inspection, and of the remedial steps taken
  - prepare a summary report, within one month after completing drilling operations, containing the relevant information in WorkSafe's fact sheet Consents and Reports Required by the Geothermal Energy Regulations 1961 available at: worksafe.govt.nz

1.2 How you can use these guidelines

Use these guidelines for advice and information for eliminating and minimising risks from:

- installing and operating drilling machinery and equipment
- the well's design, operation, repair, maintenance, or abandonment.

Boxes summarise the relevant sections of the Geothermal Energy Regulations 1961.

2.0
Well design

IN THIS SECTION:

This section covers the subsurface conditions you may encounter, the type of equipment and materials to use, and casing and various wellhead designs.

Before drilling operations begin, carry out a risk assessment to make sure risks to the health and safety of any person are eliminated so far as is reasonably practicable.

Necessary steps to safely design and drill a well include:

- taking geological and reservoir engineering advice on likely subsurface conditions
- determining depths for casings and well completion
- selecting casing diameters, casing type, and cementing materials
- selecting wellhead components
- nominating the necessary equipment, tools, materials, and support facilities.

Adopt conservative assumptions on subsurface reservoir conditions and design factors.

Regulation 26 requires all wells and pipework to be constructed of suitable and sound materials and designed, constructed, operated, and maintained in accordance with safe, proper, and proficient geothermal engineering practice.

2.1 Casing

Prepare a compliant well programme that includes all casing strings and liners needed to:

- prevent hole collapse
- support drilling and permanent wellheads
- contain well fluids
- control contamination of subsurface aquifers
- counter circulation losses during drilling
- protect the well's integrity against corrosion, erosion, or fracturing.

Figure 1 shows the casing and liner configuration for a typical well.

TUBING DESIGN

Design and select tubing material considering the effects which may occur at any time or depth during the drilling or well operation from all combinations of:

- pressure
- temperature
- temperature changes
- erosion
- corrosion.

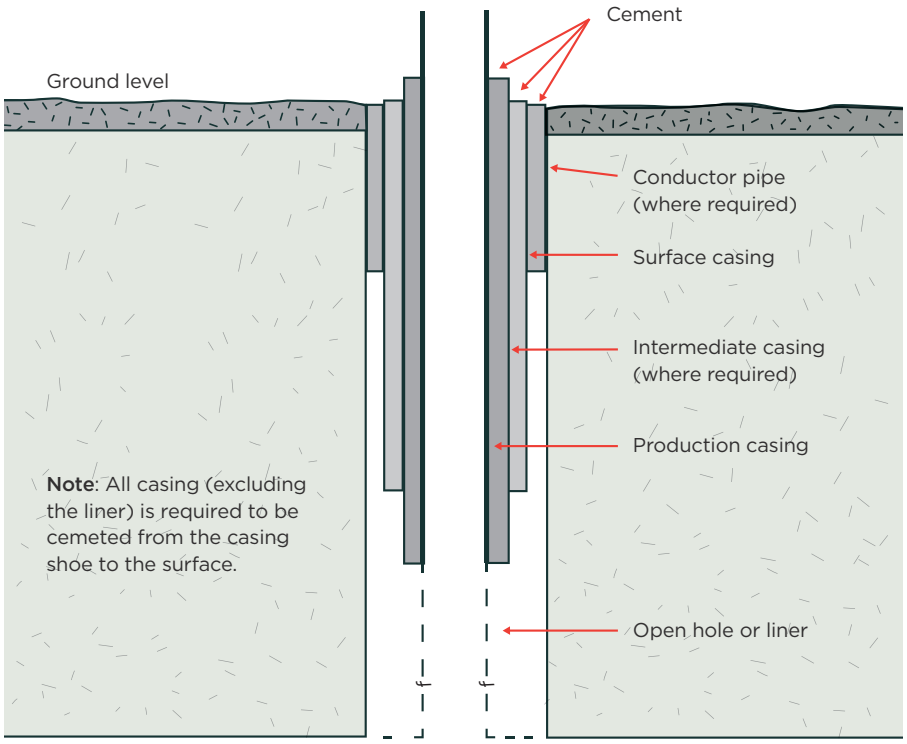

FIGURE 1:
Shallow geothermal well casing configuration

2.2 Wellhead design

This section covers the design and construction requirements for permanent wellheads, including:

- casing head flange or coupling
- well head spools
- master valve and other primary containment valves
- wellhead designs for various types of production wells
- requirements for geothermal reinjection wells.

Consider the effects which may occur at any time or depth during the drilling or well operation from all combinations of:

- pressure
- temperature
- temperature changes
- erosion
- corrosion.

Use steel materials for wellhead fittings. Cast iron is not suitable for geothermal wells. Only use plastic fittings under appropriate conditions in low temperature geothermal wells.

Regulation 33 requires wells to terminate aboveground by a short standpipe and have a wellhead master valve designed to withstand service conditions for the well's expected life and have ample additional thickness to guard against corrosion and erosion.

Self-discharging wells (except low pressure steam wells)

Wellhead parts including the well casing connection should have a factor of safety of at least 2.0 against the well's expected internal pressures. Figure 2 shows the design and valve configuration wellheads should conform to.

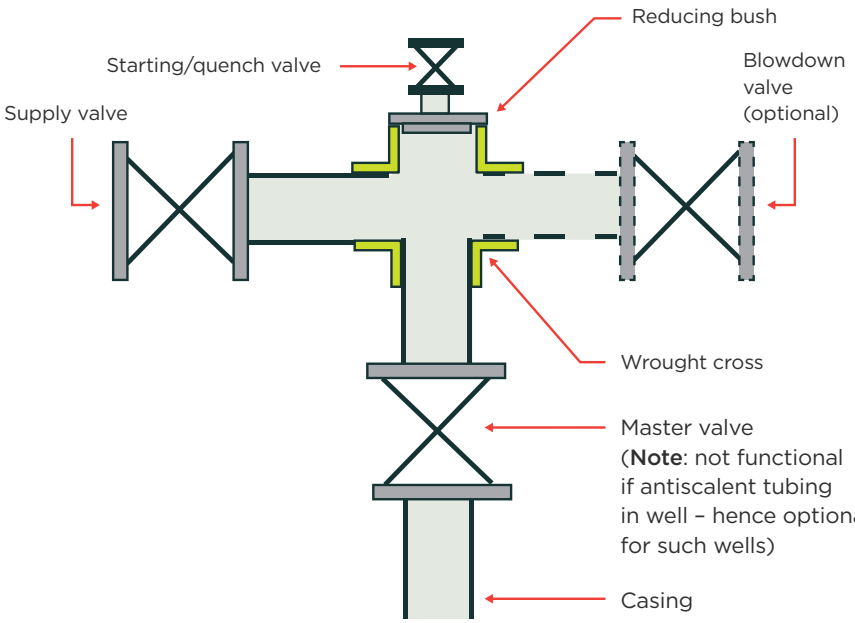

FIGURE 2: Wellhead construction details for self-discharging wells

ANSI/ASA Class 150 valves and fittings are suitable for most uses down to 150 m. ANSI/ASA Class 300 valves and fittings are suitable for uses down to 250 m.

Above the master valve install a shaped cross or tee complying with a minimum specification of, as applicable, BS EN 10241: Steel threaded pipe fitting or ASME B16.11: Forged fittings, socket-welding and threaded.

Regulation 33 requires wellheads to incorporate a suitably sized and rated valve or valves which will allow you to quench the well under all conditions and bleed off gases from a well.

The valve (or valves) will also allow vertical access for:

- indicating nominal gauge well pressure
- initiating well flow or boiling by introducing a compressed air line
- wireline instrument access.

Downhole heat exchangers

Fit wells conforming to the design and configuration of either Figure 3 or Figure 4 with a downhole heat exchanger if the maximum:

- downhole temperature is greater than 95°C or
- wellhead pressure exceeds 0.5 barg.

If necessary, design an adequate allowance for heat expansion.

Weld or screw a plain or threaded coupling connecting a flanged fitting to the production casing.

Bolt a minimum ANSI/ASA Class 150 steel plate to the casing head flange with a minimum of four 10 millimetre (mm) diameter bolts. Seal the flanges with a gasket able to withstand the temperatures and pressures encountered during the well's operation.

Connect the heat exchanger pipework either through the wellhead plate with two welded (minimum 20 mm diameter) steel barrel nipples, as in Figure 3, or, if using stainless steel pipework, through a heavy black pipe socket.

Fit steel nipples, fittings and suitably rated isolation valves to the socket connections on the wellhead plate to connect and isolate the pipework from the well.

Fit isolation valves on all pipework connecting to a downhole heat exchanger if the maximum wellhead pressure exceeds 0.5 barg.

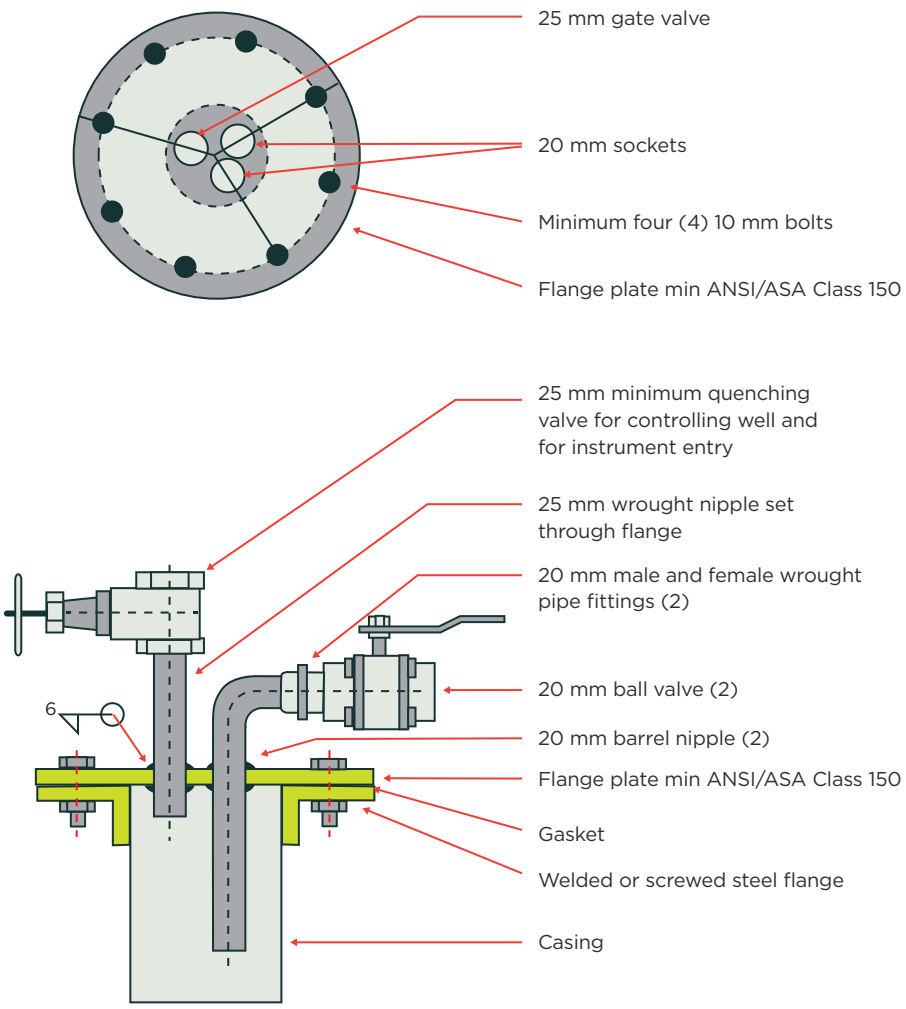

FIGURE 3: Wellhead construction details for a downhole heat exchanger using steel tube (20 mm steel tube illustrated)

For well quenching or instrument entry, weld through the plate and fit a suitably rated full opening 25 mm isolation valve in a vertical position to a 25 mm minimum diameter steel barrel nipple.

Cap and plug the quench/instrument entry valve to prevent unauthorised valve operation and to protect the valve gate from damage and corrosion.

If a geothermal well fitted with a downhole heat exchanger has, or is likely to have, a measurable wellhead pressure due to accumulating geothermal gases, open the wellhead vent to prevent pressure building up. You may extend the quench/instrument entry to use as a vent pipe in this instance.

Design the vent pipe to safely disperse the noxious gases. The height of the vent pipe should be 3 m above the nearest building ridge line, or at least 6 m above ground level.

If the wellhead will be below the surrounding ground level, make sure there is enough clearance to access flange bolts and other fittings and to inspect:

- the wellhead
- casing head flange
- production casing
- annulus cement.

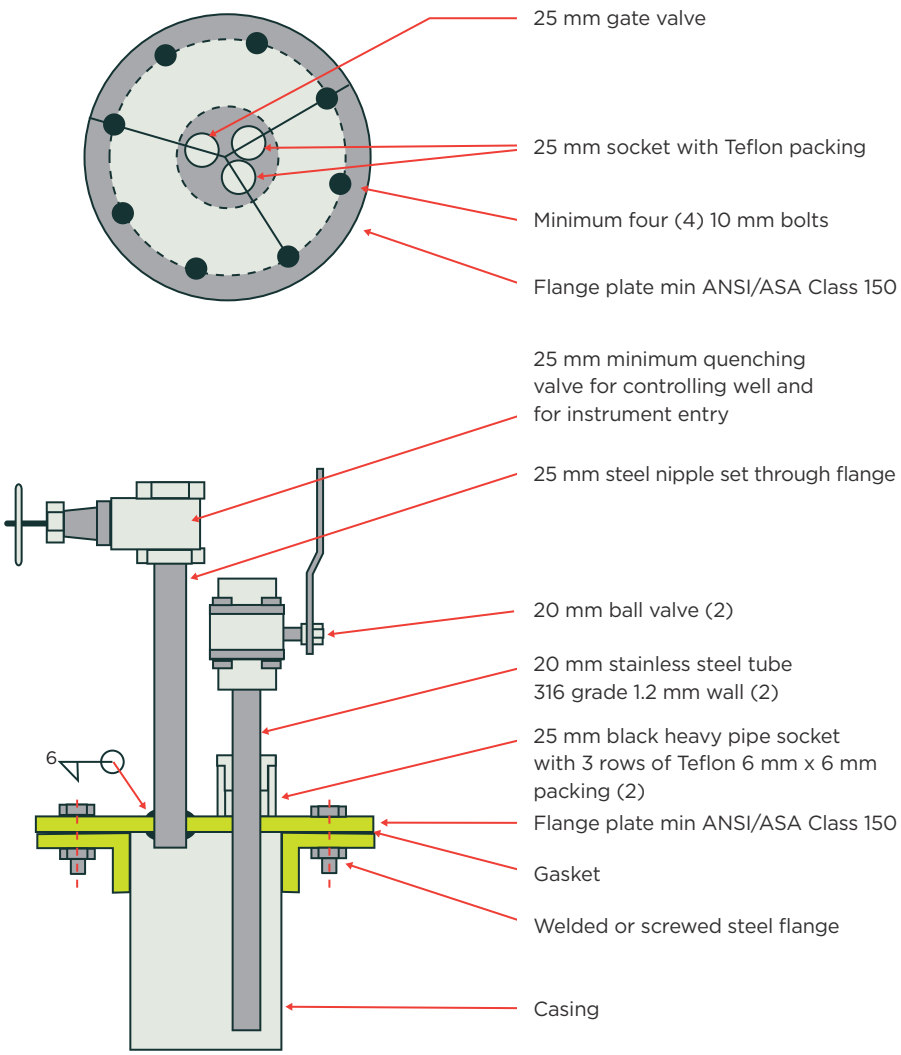

FIGURE 4: Wellhead construction details for a downhole heat exchanger using stainless steel tube (20 mm stainless steel tube illustrated)

Airlift wells

Wells which discharge only with the continual aid of an air compressor should conform to the design and valve configuration in Figure 5.

Install a shaped tee or cross complying with BS EN 10241's minimum specification on the production casing.

On one side of the tee (or cross), install a supply valve for controlling geothermal fluid and connecting to a geothermal supply pipeline.

You may install an optional blowdown valve for maintenance or emergency access on the wellhead cross.

Seal the top of the tee (or cross) with a reducer through which you can thread or weld a barrel nipple. Connect the air supply line to this nipple.

Fit a non-return valve to the air supply line connected to the wellhead.

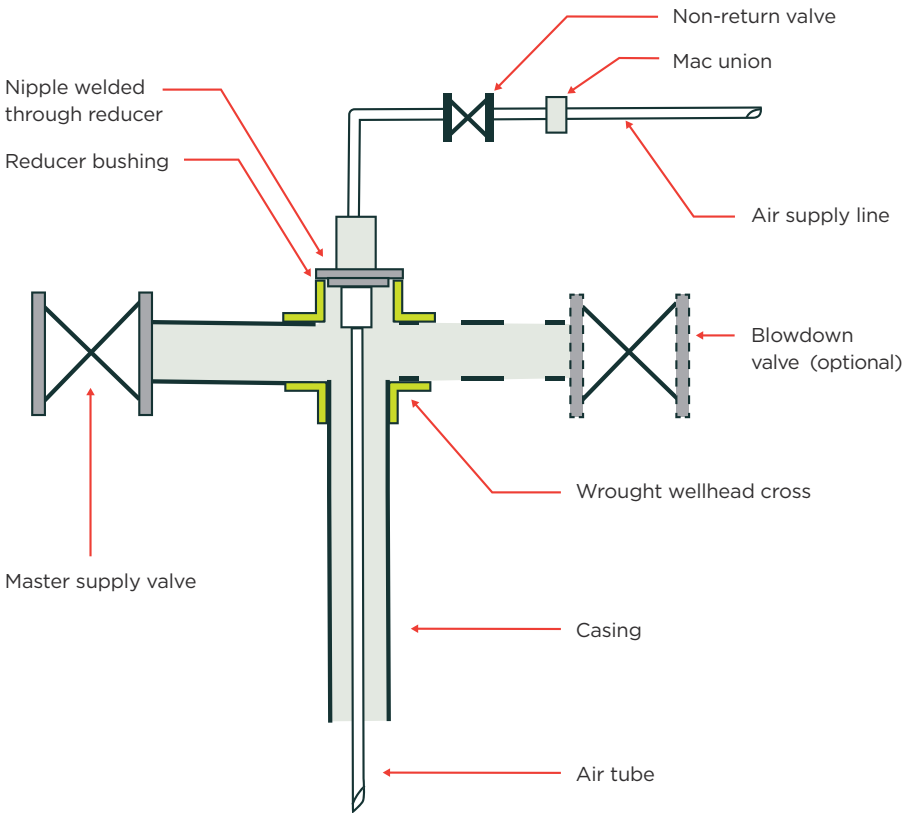

FIGURE 5:
Wellhead construction details for airlift wells

Low pressure steam wells

With a suitably designed and rated gate valve as the primary containment device you may terminate above ground level steam producing wells with a measured shut in wellhead pressure of less than 0.35 barg.

Maintain suitable access to allow operation and inspection of the valve.

Pumped wells

Design and configure wells which extract geothermal fluid by artificial lift so that the well remains under control at all times, considering all anticipated temperature and pressure conditions.

Reinjection wells

Construct reinjection wells to the same standard as production wells.

The location of a reinjection well should comply with the requirements of local authorities and public utilities where applicable.

Eliminate and minimise any possible adverse impacts and fluid reinjection interference with nearby wells.

Maintain adequate access to the well at all times for drilling rig and workover unit servicing.

The operation and maintenance of a reinjection well should include the normal procedures for a production well.

3.0
Well sites

IN THIS SECTION:

This section covers the well drilling site's location. You must maintain the site in a safe condition.

3.1 Selecting a well site

In selecting a site, consider the geological factors which could affect the site's stability and any surface thermal activity nearby.

Warm and steaming ground may present gas and scalding hazards to workers.

Well sites located over cavernous ground pose a hazard as the ground may collapse exposing hot fluids.

If near surface temperatures are close to boiling, removing overburden or lowering groundwater levels could start a localised eruption of steam and mud.

3.2 Location

Shelterbelts, solid fences, and similar barriers to moving air can create hazardous areas. Regularly inspect the condition of any hot ground, steam, or gas vents on or near the well site.

The well's location should comply with local authority and public utility requirements where applicable.

Regulation 31 requires all wells to be located more than 1.5 m from any:

- building
- permanent structure
- underground or aboveground services.

Any kind of building or structure must not enclose a well, except if ventilation prevents hazardous gas accumulating and you ensure adequate access to repair and properly abandon the well.

3.3 Cellars

Wellheads located below ground level must have a cellar. Cover the cellar with a protective plate or grill that can also provide access for people to conduct inspections.

Noxious gases can reach dangerous concentrations in deep cellars due to the lack of natural air movement. If required, adequately ventilate and minimise cellar depth.

Adequately drain cellars to minimise water collecting on the cellar floor.

For more information on excavation safety, see WorkSafe's good practice guidelines *Excavation Safety* available at: worksafe.govt.nz

3.4 Drainage

Site drainage should make sure no water can enter the cellar or pool around the well casings at ground level.

3.5 Access

Always maintain reasonable access to the well and site for workover and emergency services.

Regulation 34 requires, at all times, site access be maintained in a condition to allow adequate visual and physical access to the well. Regulation 31 includes the requirement to ensure reasonable access to the well for emergency services.

3.6 Security

Put up fences and signs around drilling sites in public areas to discourage the entry of unauthorised personnel.

Use barriers to prevent wells in public areas and those exposed to vehicle traffic from damage.

Implement controls to prevent unauthorised people from gaining access to, or operating wellhead valves. At appropriate intervals inspect these controls to ensure ongoing effectiveness.

Regulation 34 requires you to provide adequate security to prevent, as far as practicable, unauthorised operation of wellhead equipment and unauthorised access to other potentially hazardous areas.

4.0 Drilling practices

IN THIS SECTION:

This section sets out the minimum standards of drilling practice for a shallow geothermal well's drilling or workover.

4.1 Well control

Use well control equipment on all drilling and workover operations except those in areas where the known maximum well temperature is less than 90°C and there is no measurable wellhead pressure.

Select well control equipment that can safely control all expected pressures and temperatures in the well.

In certain applications you may use a diverter designed to contain and redirect all expected pressures and flows during drilling operations. Fit the diverter with a suitably sized and rated full opening valve on the discharge line to control the well's discharge.

Locate discharge lines so they discharge in a controlled and safe manner.

Controls and operating equipment for the well control devices should consist of suitably sized and rated equipment located a safe distance from the wellhead.

Before starting drilling operations, assemble the well with all its connections, materials, and, equipment for cooling and sealing the well, ready for urgent use.

Regulation 33 requires the characteristics of the drilling fluid, the equipment to handle the fluid, and the method of using the fluid to provide adequate control of the maximum subsurface pressures you expect when drilling the well.

Drilling fluids

Make sure an adequate water supply is available on the site during all drilling operations. Make sure the supply is enough for all quenching, drilling, and cementing operations.

Regulation 33 requires you to have sufficient reserves of water, drilling fluid, and supplies of drilling fluid materials available at the well site for immediate use during drilling operations.

4.2 Running casing

Safely handle and store all casings to make sure you do not damage the pipe or threads.

Tighten all casing couplings to the manufacturer's torque specifications.

4.3 Cementing casing

Try to seal severe loss zones before cementing. Use cement slurry slugs or loss circulation material additives to adequately cement the casing.

Carry out your cementing programme, and use materials, to make sure the total length of the outside casing's annulus is full of sound cement. Make sure this can withstand long-term exposure to geothermal fluids and the likely temperatures you expect to encounter in drilling the well.

Pump cement down the inside of the casing and circulate it back to the surface via the casing/drill hole or casing/casing annulus. Do not interrupt the cement's pumping and circulation.

Stop circulating cement slurry when uncontaminated cement circulates out of the drill-hole annulus at the surface.

Regulation 33 requires you to fully cement into place all casing strings, except open-hole slotted liners. Where applicable, cement casings with a uniform quality cement grout which fills the annular space between the casings and extends from the shoe to the surface.

4.4 Equipment maintenance

During drilling, carry out daily checks of well control devices and wellhead components for damage, leaks of hydraulic fluid, and anything else that could adversely affect well control.

You must make sure that adequate first-aid facilities and first-aid equipment is available on site at all times. You must post notices indicating the first-aid equipment's location(s).

4.5 Worker safety and training

Before starting work, instruct and train all workers in well control and in the correct and safe use of all personal protective equipment (PPE), equipment, and machinery they'll work with.

The Health and Safety at Work (General Risk and Workplace Management) Regulations 2016 require PCBUs either train workers to administer first aid or provide access to other trained first aiders. In the context of drilling operations, make sure that there is at least one certified first aider on site trained in resuscitation techniques.

Before starting work, make sure workers are aware of the hazards and risks normally associated with drilling and hot geothermal fluids.

Instruction should include:

- testing for CO_2 and H_2S
- well quenching
- spontaneous well discharge
- review of site-specific hazards and risks.

All workers on a well site where there is a drilling rig must wear, and use, appropriate PPE. If hazardous gases are present on site, make sure gas detectors and breathing escape apparatus is available and fully train workers to use this equipment.

PPE should include, but not be limited to:

- safety helmets
- safety boots
- goggles
- gloves
- aprons
- wet gear
- earplugs/earmuffs
- dust masks etc.

If there is any risk of a fall, or for rescue readiness, make sure workers wear fall arrest harnesses with appropriate attachment equipment and anchors appropriate to the task. Workers should be hooked on in all situations where there is a risk of a fall.

For more information see WorkSafe's good practice guidelines *Working at Height in New Zealand* available at: worksafe.govt.nz

Regulation 31 requires that after drilling starts every well must be permanently identified by a sign on or near the well clearly identifying the well's name and number by letters and numbers at least 30 mm high. The sign must be visible from ground level.

4.6 Record keeping

As the manager you should record and keep certain information for a summary report after completing drilling, and in a daily log.

The information you need to record and include in a summary report after completing drilling operations is in WorkSafe's fact sheet *Consents and Reports Required by the Geothermal Energy Regulations 1961* available at: worksafe.govt.nz

The information you should record and keep in a daily log is:

- well name, number, and location
- elevation of the kelly bushing, rotary table, or derrick-floor above mean sea level and above ground level
- for each 24-hour period:
  - date
  - drilling depths at the beginning and end
  - distance drilled
- current diameter of the hole
- current operation
- completion data on the final daily drilling log
- penetration rates or drilling breaks
- well site measurements
- cored intervals
- details of any casing operations and any subsequent modifications

- details of cementing operations, including:
  - slurry volumes used
  - measured density of the annular returns
  - setting of plugs
  - pressure tests
- downhole measurements, casing surveys, deviation and temperature surveys, and any other test or survey carried out
- record of other operations such as fishing and perforating
- circulation losses
- drilling fluid:
  - quantities
  - pumping pressures
  - periods of use
  - rate of loss
  - inflow and outflow temperatures
- changes in geothermal activity on the surface in the vicinity of the geothermal work.

5.0 Drilling practices

IN THIS SECTION:

This section covers operation and maintenance techniques and procedures to use throughout the well's life cycle.

Regulation 26 requires:

- The well, and the equipment used in the geothermal work, to be maintained to prevent damage or risk of damage to the well and the equipment, and to prevent danger to people on the site, or in the vicinity, of the geothermal work.
- All geothermal work where the heat discharged by any well is likely to exceed 20 terrajoules measured above 0°C over any period of 12 consecutive months must be carried out in accordance with *NZS 2402P Code of Practice for Geothermal Heating Equipment in Rotorua* (except Parts 2, 6, 7, and 10).

5.1 Self-discharging wells

Gradually preheat the well casings, cement sheaths, and wellhead components before discharging a well. Achieve this preheating by initially putting the well on bleed.

If you are going to open a well to discharge, particularly vertical discharge, adequately protect workers from:

- hot water
- steam
- noise
- ejecta from the discharge.

Make sure there is a clear and safe means of egress from the wellhead area for workers involved in opening valves to discharge or control the well flow.

PPE should include, but not be limited to:

- safety helmets
- ear protectors
- wet gear
- safety boots
- safety glasses
- gloves.

For discharging wells, fully open the master valve before opening the supply valve to allow the well to flow.

Immediately before discharging a well, fully close the control valve before opening the master valve. Partially open the master valve to pressurise the downstream pipework so that you can check the pressurised control valve for leakage. Fix any leaks.

Do not use a master valve to throttle a well flow and, in particular, do not use it to close in a flowing well except in an emergency situation. If the control valve does not fully seal, close it as much as possible before closing the master valve.

Following the opening of a well, inspect, for correct performance, all pressurised:

- pipes
- valves
- flanges
- fittings
- equipment.

If you observe any defects or leaks, close the well and fix the defects and leaks before reopening the well.

Following the well's opening, monitor the wellhead and associated pipework during the initial four hours. A typical inspection frequency is:

- one minute
- five minutes
- 10 minutes
- 30 minutes
- one hour
- two hours
- four hours.

Close a discharging well by fully closing the supply valve downstream of the master valve before closing the master valve. After closing the master valve, blow down the pressurised pipework downstream of the master valve and check for leaks past the gate. If there is leakage through the master valve, operate the valve to try and affect a seal.

You may install flow-reduction devices on the wellhead to restrict flow from the well. Fit an orifice plate downstream of the master valve or a pipe restriction downstream of the supply valve.

5.2 Closed or bleeding wells

Adequately secure closed and unconnected wells, or wells used for monitoring purposes. This may include:

- using chains and padlocks
- removing valve handles
- plugging valve openings.

Determine whether you should maintain the wellhead in a hot or cold condition.

Wells "on bleed" require regular inspection to make sure the control devices remain clear and that the released wet gas does not cause external corrosion of the wellhead or pose a risk to people.

Adequately design bleed discharge lines and terminate them at some distance from the wellhead to avoid:

- discharging fluids corroding the wellhead components
- hazardous gas concentrating around the wellsite.

Hazards associated with bleed lines include:

- noise
- corrosion
- toxic gas (H_2S and CO_2).

Controls may include:

- chemical injection upstream of the discharge
- installing sound absorbing apparatus at the point of discharge
- directing the discharge into a water-filled tank or waste pit.

5.3 Surface well maintenance

This section applies to:

- near-surface casings
- annulus cement

- outer cement circle
- shallow cellars
- wellhead valves, flanges, fittings and spools.

Keep the site area clear of any plant growth which could enhance corrosion or inhibit access to the well or the erection of workover equipment.

Wellhead maintenance

Inspect and make sure the wellhead and it's steel surfaces are substantially free of corrosion. Remove and assess the depth of corrosion if it has formed and carry out maintenance. Monitor outer casings, outer cement, annulus cement, and outer casings for corrosion and deterioration and any defects. Repair them as soon as practicable.

If protective paint systems require renewal, remove all defective areas by wire brushing or, if necessary, by sandblasting, before applying fresh coatings.

If severe casing corrosion is apparent or you suspect it's on the near outer casings, remove the outer casings until you can expose sound casing. Sandblast and paint the exposed casing and reinstate the outer casings, outer cement, and annular seal.

Make sure a suitably qualified and experienced person carries out any maintenance.

Inspect all valves, fittings, glands, and flanged fittings for leaks of geothermal fluid. Repair them as soon as practicable.

If possible, regularly monitor the wellhead pressure. Carry out wellhead pressure monitoring on a six-monthly basis, or more frequently if reservoir conditions are not static.

For more information about wellhead maintenance, refer to NZS 2403.

Quenching

If quenching is required, carry it out in a manner which minimises the risk of damaging the well casing.

If you are quenching a well with cold water, control initial flow rates at a level for a period of time and then gradually increase the flow until the well is off pressure. Slowly reduce any wellhead gas pressure by bleeding the gas from the well either before or during the quenching operation.

If you are using town supply water to quench a well, install two tested non-return valves on the supply line to prevent backflow of geothermal fluid in the water supply line. Consult with the local authorities to determine if you require any additional controls.

Prominently post a warning sign on the water supply valve instructing any unauthorised people not to shut off the supply of water to the well once a well is on quench and temporarily under control following a blowout or repair and is left unattended until permanent repairs can be made.

Wellhead repair

Before repairing or replacing wellhead components, gradually quench the well keep it in a totally quenched condition for twice the estimated period of time required to carry out maintenance.

Install a backup pipe if a pump supplies the water for quenching.

If, while pumping water into a well, it cannot be cooled enough to prevent well flow for twice the required time to install or change wellhead components, then plug the well with a:

- retrievable packer
- drillable plug, or
- competent, pressure-tested cement plug set inside the inner cemented casing.

If casing inspection reveals severe corrosion is on the near-surface production casing, expose the production casing until you reveal sound casing. Quench the well before cutting off the damaged casing and welding on a new section and wellhead flange.

Fit the master valve before reinstating outer casings and annulus cement.

If the well has been quenched to replace a section of casing that requires welding, then keep the well fully quenched in a way which prevents cold water coming into contact with the casing section being welded.

Welding casing or wellhead components should comply with sound and accepted welding practice. For more information see WorkSafe's booklet *Health and Safety in Welding*: worksafe.govt.nz

Avoid damaging adjacent sections of casing during any casing section cutting or removal.

Downhole maintenance and repair

Normally the well needs to be quenched to carry out any downhole maintenance and repair.

Downhole maintenance and repair may include:

- removing scale or mineral deposits from well casing or hole
- repairing damaged casing
- isolating permeable zones
- cleaning out or deepening a well.

Install well control equipment on any well which has any potential to discharge during any phase of the workover.

Workovers on low pressure quenched steam wells or wells with no measurable wellhead working pressure may include the master valve as a drill through valve. If this operation takes place, protect the master valve gate seats, gate and threads with a wear sleeve, or alternatively use a parallel face, expanding gate valve which protects the gate seats.

The output of wells may decline over time due to mineral deposits forming, including calcite in the production casing. Calcite forms when geothermal fluid, containing dissolved carbon dioxide, boils. Calcite's deposit rate depends on the chemistry of the geothermal fluid, which varies from well to well, and on the mass flow rate from the well.

Two principal methods of removing mineral deposits with a well casing or lining are:

- Mechanical reaming: carry this out using a drilling rig to drill out the mineral deposit close to the internal ID of the production casing. However, continual reaming to remove mineral deposits within a well can seriously affect the well casing's integrity.
- Chemical cleaning: this involves pumping suitably inhibited acid into the well to dissolve the mineral deposit.

Take proper precautions in both handling and using acid solutions and other hazardous products. Make sure safety data sheets are available on site for all hazardous materials you use.

Improper chemical cleaning can lead to severe casing corrosion resulting in:

- well failure
- contamination
- damage to surface pipework or mineral baths.

Preventing mineral deposits from forming

Install and use good quality equipment according to sound engineering practice to prevent mineral deposits forming.

The principal method to prevent mineral deposits forming in wells is injecting antiscalent chemicals into the well. To be effective, you must add the antiscalent chemicals below the flashpoint of the well.

5.4 Geothermal waste disposal

This section applies to disposing geothermal fluid after the useful heat has been removed.

Use suitably designed disposal equipment to take the geothermal fluid at all times, without overflow or water carry-over from the gas vent and without causing a risk to people nearby.

Maintain all disposal equipment in sound working order.

Do not dispose geothermal water to stormwater or wastewater drains. For certain testing or emergency purposes, you may dispose small quantities of geothermal fluid this way subject to local authority approval.

6.0 Well abandonment

IN THIS SECTION:

This section covers the permanent closing and sealing of wells.

6.1 Well assessment

Techniques and tools which may be used to indicate, identify, locate or qualify defects below the surface include:

- go-devil runs with cylinders of different sizes run into a well on a wireline
- temperature runs in a static or discharging state
- pressurising the well with a gas
- flow meter runs with or without fluid injection or discharge
- tools requiring the use of a drilling rig (eg lead impression blocks and retrievable packers)
- other state-of-the-art sonic, magnetic, or electrical tools.

6.2 Abandonment operations

Regulation 33 requires that you do not recover a casing if its recovery exposes any abnormal pressure or lost circulation zone. If practicable, you must completely fill wells with uniform cement grout and place it into the well using drill pipe, or other suitable pipe, so the initial placement of the grout at the pipe's bottom end starts at the deepest shoe of cemented casing.

During the abandonment, install suitable well control equipment.

If practicable:

- take wells off pressure by quenching
- ream the well to the production casing's internal diameter to the production casing shoe's depth.

After placing the cement in the well, including within the casing, treat the well as still being capable of discharging and shut it in with a valve or BOP.

After withdrawing the drill string, top the cement up to ensure there is a continuous cement plug from the production casing shoe to the surface.

Select cement with the smallest deterioration over time. Add appropriate additives such as friction reducers, and cement retarders as you require. A common cement slurry density is in the range of 1.70-1.82 kg/l.

If fluid or gas leakage is obvious from the casing annulus, attempt a grout squeeze after packing off and plugging much of the open-hole section with poorly sorted sand or gravel.

You can use bull heading to force the cement up the annulus, however, make sure to control pipe pressures to avoid hydro fracturing the open-hole section immediately below the casing shoe.

After abandoning the well, remove the wellhead and cut the casing at a minimum depth of 0.3 m below ground level.

Keep a permanent record of the:

- site
- details of the well construction and placement
- quality of cement, and any cement additives, used.

Appendices

IN THIS SECTION:

Appendix A: More information

New Zealand legislation

To access all legislation including Acts and regulations visit the New Zealand Legislation website: www.legislation.govt.nz

The Institution of Professional Engineers New Zealand (IPENZ)

A list of competent engineers can be found on the IPENZ website, under the Chartered Professional Engineers (CPEng) Register available at: www.ipenz.nz

WorkSafe New Zealand

For information and guidance about health and safety visit WorkSafe's website: worksafe.govt.nz or call 0800 030 040.

For information and guidance specifically about electrical or gas safety visit WorkSafe's website: www.energysafety.govt.nz or call 0800 030 040.

Standards

API Spec 5CT Specification for casing and tubing

API Spec 5L Specification for line pipe

ASME B16.11 Forged steel fittings, socket-welding and threaded

ASME B16.5 Pipe flanges and flanged fittings

BS EN 10216 Seamless steel tubes for pressure purposes. Technical delivery conditions. Non-alloy steel tubes with specified room temperature properties

BS EN 10241 Steel threaded pipe fittings

BS EN 10255 Non-alloy steel tubes suitable for welding and threading. Technical delivery conditions

NZS 2402P Code of practice for geothermal heating equipment in Rotorua

NZS 2403 Code of practice for deep geothermal wells

Guidance

Introduction to the Health and Safety at Work Act 2015
WorkSafe New Zealand worksafe.govt.nz

Excavation Safety
WorkSafe New Zealand worksafe.govt.nz

Health and Safety in Welding
WorkSafe New Zealand worksafe.govt.nz

Consents and Reports Required by the Geothermal Energy Regulations 1961
WorkSafe New Zealand worksafe.govt.nz

Self-Management of Shallow Geothermal Well Systems
WorkSafe New Zealand worksafe.govt.nz

Working at Height in New Zealand
WorkSafe New Zealand worksafe.govt.nz

Appendix B: Glossary

TERM	DEFINITION
Airlift wells	Wells which discharge with the continual or near continual aid of an air compressor.
Blowout	An uncontrolled flow of steam, water, gas or rock material at the ground surface either inside the well or escaping from the well at depth.
BOP	Blowout preventer.
Bore	See Well.
BPD (Boiling point for depth conditions)	Representing a column of pure water at its boiling (saturation) temperature corresponding to the pressure at every depth.
Cellar	An excavation around the top of the well to accommodate part of the wellhead.
Conductor pipe	The large diameter, very shallow pipe sometimes installed before drilling starts, used to retain surface material against collapse or washout, and to elevate returning drilling fluid to above ground level.
Diverter	A well control device consisting of sealing elements compressed in a cylindrical body mounted on a well and operated by hydraulically or air activated cylinders, with piping to direct the discharge from a well at a safe distance during drilling operations.
Downhole heat exchanger	Pipework installed in a well for the purpose of extracting heat. Circulation may be maintained by thermosiphon, mains pressure, or circulation pump.
Drilling	Includes workovers and all well site activities associated with rigging up and rigging down.
Geothermal work	Geothermal work includes: – the drilling of any well to a depth exceeding 2 m from ground level; and – any construction or maintenance work of any pipeline 150 mm or less nominal internal diameter in relation to a well which is not primarily associated with generating electricity, including associated fittings, vessels, pumps, and accessories necessary to contain and control the pipeline's pressure.
Intermediate casing	If subsurface conditions require, the casing installed to enable target depth to be reached for that stage of the well.
LCM	Lost circulation material.
Liner	A casing having openings for the production or injection of fluids, and installed in the drilled hole to prevent collapse of the formation or entry of debris into the well.
Local authority	Regional council or territorial authority.
Low pressure steam wells	Steam-producing wells with a measured shut-in wellhead pressure of less than 0.35 barg.
Master valve	The primary containment valve on the well.
NRV	Non-return valve.
Pressure	Gauge pressure (that is, pressure above ambient) unless specified otherwise. **Note**: As steam tables normally use absolute values, add atmospheric pressure to gauge pressure before using the tables.
Production casing	The deepest cemented casing extending to the surface.
Production liner	A casing string installed to protect the hole or other casings from the corrosive or erosive effects of fluid flow. Depending on its purpose, this liner may be cemented, or free to expand with increase in temperature.
Pumped wells	Wells that are fitted with artificial lift devices, which may be surface- or downhole-mounted, to enable geothermal fluid to be extracted.
Quench	The injection of cold liquid into a well to condense or prevent the formation of steam, or to reduce temperatures for other purposes.

TERM	DEFINITION
Reinjection well	A well that is drilled for the purpose of re-injecting geothermal fluids into the ground.
Self-discharging wells	Wells which discharge geothermal fluids without the aid of continued artificial lift.
Surface casing	The first casing installed in the well which supports a drilling wellhead.
Well	A fully- or partially-lined hole in the ground.
Wellhead	A set of valves and other pressure-rated components, connected to the top of the well and used to contain the well fluids.
Workover	Maintenance or repair in an existing well.

Notes

Disclaimer

WorkSafe New Zealand has made every effort to ensure the information contained in this publication is reliable, but makes no guarantee of its completeness. WorkSafe may change the contents of this guide at any time without notice.

This document is a guideline only. It should not be used as a substitute for legislation or legal advice. WorkSafe is not responsible for the results of any action taken on the basis of information in this document, or for any errors or omissions.

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