A BRIEF REVIEW OF GEOTHERMAL HEALTH AND SAFETY REGULATIONS FOLLOWING THE "PIKE RIVER INQUIRY"

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ABSTRACT

New Zealand is on the brink of major structural change to its health and safety regime following the Pike River Royal Commission and an Independent Taskforce on Workplace Health and Safety. Changes include a new stand-alone regulator, and greater emphasis on a tripartite regime in which the regulator, workers and companies all have responsibilities for appropriate outcomes, including regulation.

Improved health and safety regulation of many sectors, including geothermal, will be implemented. The geothermal industry is currently reviewing both the Geothermal Energy Regulations 1961 which gives effect to the now-repealed Geothermal Energy Act 1953, and NZS 2403:1991 Code of Practice for Deep Geothermal Wells to bring this in to line with current technology and regulatory environment. However, to reflect industry best practice in managing hazards associated with geothermal development, the suite of regulations ultimately required may be wider than the current work stream.

Regulators have a special focus on high-hazard industries, including the geothermal industry. This paper briefly examines why the geothermal industry currently has this "high hazard" classification, and whether or not this is appropriate.

Ultimately the question will be what form of health and safety regulation is appropriate.

1. PIKE RIVER INQUIRY AND ITS RELEVANCE TO GEOTHERMAL DEVELOPMENT

On 19 November 2010, 31 men entered the Pike River coal mine undertaking normal duties. Following an initial explosion, two men working in the stone access tunnel staggered out. Further explosions followed in later days. There was initial talk of rescue – then of recovery – but the remaining 29 bodies are still in the mine.

On 14 December 2010 a Royal Commission on the Pike River Coal Mine Tragedy was called under the Honourable Justice Graham Panckhurst. In the commission's final report dated 30 October 2012 they noted that this was the 12th commission of inquiry into coal mining disasters in New Zealand over a period of 130 years of disasters. "This suggests as a country we fail to learn from the past."

"It is the commission's view that even though the company [Pike River Coal Ltd] was operating in a known high-hazard industry, the board of directors did not ensure that health and safety was being properly managed and the executive managers did not properly assess the health and safety risks that the workers were facing."

The Commission searched for contributing factors within the company, then at wider systemic issues including the overall regulatory and legislative environment. There are several references to high-hazard industries specifically including the geothermal industry. It is in these higher views that there are direct implications for geothermal development.

At the end of this paper observations on which specific recommendations from the Commission's report may be relevant to the geothermal situation are presented (and adapted). Key recommendations (here condensed from a list of 16) were:

1. Establish a new "Crown agent" regulator focusing solely on health and safety in employment (HSE), to improve New Zealand's poor record of health and safety. It was thought that HSE aspects had been lost in the list of priorities being managed by the Department of Labour.

2. Develop a tripartite HSE regime involving health and safety regulators at an early stage of projects, underlining the responsibilities of company directors and managers and giving guidance to them through codes of practice then requiring their review and monitoring of compliance, then drawing in worker participation.

3. Urgently review management systems for emergencies for the high-hazard mining industry (and, by implication, others).

4. Urgently establish an effective regulatory framework for underground coal mining (and, by implication, others).

2. OTHER HSE REVIEWS AND REFORMS

2.1 Recent Reforms

The Health and Safety in Employment (HSE) Act 1992 triggered a step change in health and safety thinking. Subsequently, evolution in occupational health culture has probably reduced high-frequency low-consequence accidents (typical individual safety and occupational health issues). However, it was a low-frequency high-consequence "process safety" event that triggered the Pike River Mine disaster, and there is evidence that these events are not adequately covered by current regulation. This in turn has led to a further review of the effectiveness of the health and safety framework.

Government departments face ongoing reform, and this is also so for health and safety personnel and systems. HSE reforms were underway prior to the Pike River tragedy. The effect of the tragedy was to accelerate some of these initiatives, while some major new initiatives have followed.

Mid-way through the Royal Commission inquiry, the Government set up a High Hazards Unit within the Department of Labour (now within the Ministry of Business Innovation and Employment (MBIE)). While mining clearly sits under this unit, other activities covered by this unit include quarries, upstream petroleum industry and geothermal drilling. These are industries viewed as having the potential for catastrophic (multiple fatality) consequences to design, construction or operational failures. Whether or not it is justified to categorise geothermal drilling and operations as a high hazard industry will be discussed later in this paper.

2.2 Independent Taskforce on Workplace Health and Safety

An Independent Taskforce on Workplace Health and Safety was formed to review health and safety more generally across industry. Within their report of April 2013 they stated "We need a new, stand-alone, well-resourced health and safety agency that is effective in its enforcement and its provision of advice, but this on its own will not be sufficient to ensure the level of change needed across the system. There needs to be a broad-based approach involving change on a number of fronts to help workplaces do the right thing yet hold outliers to account for evading their responsibilities. We need better law, a stronger regulatory toolkit, a lift in leadership, greater commitment and participation from everyone in the workplace, more robust research and data, more effective incentives, and information and guidance material that are fit for purpose. We also require working New Zealanders to shift their mind-sets and lift their game."

A brief comparison between the Royal Commission report and the Independent Taskforce report shows agreement on the need for a new and better funded regulator set up as a Government agency, and the need for greater leadership and for greater worker participation in the HSE process. A tripartite approach is required to bring in the regulator, employer and workers. Stronger regulation is required. The Taskforce was of a view that new legislation was required though still based on the "Robens[1]" health and safety model that formed the basis for the HSE Act 1992. The Taskforce wrote of a "profound unease" at the quality of data from which improvement in performance could be gauged. There were concerns that catastrophic harm risk extends from the extractive industries to chemical storage and processing facilities, and there is a need to "map the risk landscape" around potential catastrophic failure, then to ensure robust regulatory requirements apply to all priority facilities. Criteria for inclusion within the major hazards regulatory framework were required. The Taskforce made special mention of our risk-tolerant culture and the need for re-education on this.

[1] The "Robens" model is discussed in detail in both the Royal Commission and the Independent Taskforce reports. It was based on the work of a United Kingdom health and safety committee established in 1969 under the chairmanship of Alfred Robens, with their report finalised in 1972. "Robens" legislation addresses attitudes, capacities and performance of people and organisations, rather than specific hazards. Under this system "employers and workers would consult and achieve a high degree of "self-regulation", supported by general legislative requirements and voluntary codes and standards."

2.3 Recent Reform Announcements

In August 2013 the Government announced its next health and safety reforms, largely based on the recommendations of both the Pike River Inquiry and the Independent Taskforce. The independent regulator, WorkSafe New Zealand will be operational by the end of 2013 with significant funding, although policy aspects and legislation of health and safety will remain with MBIE. New HSE legislation will be introduced based on the Australian Model Work Health and Safety Act (a modern "Robens"-based law) to replace the HSE Act 1992, and to tidy links to the Hazardous Substances and New Organisms Act 1996. The new Bill will be before Parliament by the end of 2013, but may take almost a year to finalise and enact. Major hazard facilities that store or process large quantities of hazardous substances will be targeted for risk assessment and regulation from now through 2014. These facilities (and by implication high hazard facilities) will be required to produce safety cases and emergency management plans, and report incidents or near misses.

2.4 Sequence of Regulatory Reform for High Hazard Industries

Of the four areas listed under the High Hazards Unit, the first to be addressed for regulatory reform was the petroleum sector. The new Health and Safety in Employment (Petroleum Exploration and Extraction) Regulations (HSE(PEE) Regulations) were released in June 2013. The details of these will be discussed at the end of this paper, but there is a strong emphasis on detailed safety cases to ensure all risks are managed.

Mining industry regulation is currently being addressed. While the Pike River Royal Commission recommendations have largely been accepted, there is still a need to work through the detail of new regulation for the mining industry. As with the petroleum industry, this also involves revision of the Crown Minerals Act, so is reasonably tied in with those reforms. These form part of a first tranche of work including new legislation and major hazard facility regulations which MBIE aim to have live in early 2015.

Geothermal regulations will form part of a second tranche of work. Existing regulations may initially be rolled over with minor modifications to tie these in to the new legislation. From discussions, MBIE had a strong aversion to simple clause deletions and tweaks of the current Geothermal Energy Regulations 1961. Cabinet papers associated with the recent reform announcements explicitly state that geothermal regulations will eventually be written "from scratch." MBIE will review these carefully following the roll-over in 2015, such that new geothermal regulations will be in place before 2017. Requirements from the Model Law, and the precedent from the HSE(PEE) Regulations make it clear that safety cases and emergency management plans will be essential elements of these new geothermal regulations.

After geothermal regulation is dealt with, the next industry for review will be that of quarries.

3. BACKGROUND ON RELEVANT LEGISLATION

Legislative and regulatory frameworks are needed for the establishment and development of an industry in a country. Primary or "governing" legislation will outline agreed government policy around specific rights, duties or responsibilities. Secondary legislation (which includes

regulations) creates or limits a right, creates or limits a duty, or allocates a responsibility with reference to the governing legislation. Regulations can be thought of as the child of the parent legislation, and would normally be of a similar nature.

Earlier generations of New Zealand geothermal developers recognised the need for an appropriate framework. Both the Geothermal Energy Act 1953 and the associated Geothermal Energy Regulations 1961 were founding documents on which geothermal development was based, and, in turn, have been used as legislative and regulatory models for development in other countries. However subsequent amendment and the introduction of the Resource Management Act 1991 and the Health and Safety in Employment Act 1992 have fully repealed this Act, and gutted and orphaned the Regulations.

3.1 Geothermal Energy Act 1953

The Geothermal Energy Act 1953, while silent on resource ownership, initially vested the Crown with the sole right to tap and use geothermal energy, while setting up a system of licencing to enable controlled development by others. The Minister had the power to authorise access to any land for the purpose of survey or drilling, and the Governor-General had the power to take land under the Public Works Act for electricity generation or certain industrial purposes (but focussed on Kawerau though not stated explicitly). Provision was made in the Act for establishment of Regulations, which followed in 1961.

3.2 Resource Management Act 1991

A large number of laws governed protection of the environment and allocation of resources. These were pulled together under the Resource Management Act (RMA) 1991 which has the purpose "to promote the sustainable management of natural and physical resources". It uses a devolved regulatory model, with local government being responsible for its implementation. It is still silent on ownership but allocates resource and controls resource use. The focus is on managing the actual and potential effects of an activity on the environment. The passing of this Act led to the repeal of many of the clauses of the Geothermal Energy Act 1953 and Geothermal Energy Regulations 1961.

3.3 Health and Safety in Employment Act 1992

Similarly, many laws were pulled together under the Health and Safety in Employment (HSE) Act 1992 (and it was this Act that fully repealed the Geothermal Energy Act for which remaining clauses covered health and safety aspects). This HSE Act promotes the prevention of harm to all employees, placing obligations on the employers to achieve this through a duty to "take all practicable steps". Duties extend through regulations to those who control workplaces, or design, manufacture or supply plant or equipment. MBIE 'assists' employers in their duties through determining compliance (or likely compliance) and taking enforcement action if needed.

Passing of the HSE Act 1992 and consequent revocation of the Geothermal Energy Act 1953 meant that remaining clauses in the Geothermal Energy Regulations 1961 lost much of their context. The HSE Act 1992 is performance-based legislation, but it was originally intended that it be underlain by comprehensive, and possibly prescriptive regulation for all industries. The undermining of the Geothermal Energy Regulations was an unintended consequence.

3.4 Crown Minerals Act 1991

The petroleum and coal mining industries are both covered by the Crown Minerals Act 1991 which covers both resource allocation and health and safety. Geothermal energy by contrast was regarded as an attribute of water rather than something to be mined. Consequently it has not been covered by the Crown Minerals Act, but all allocation is covered under the RMA 1991.

3.5 Hazardous Substances and New Organisms Act 1996

The purpose of the Hazardous Substances and New Organisms (HSNO) Act 1996 is to protect the environment, and health and safety of people and communities, by preventing or managing the adverse effects of hazardous substances and new organisms. This covers hydrocarbon refrigerants that would be used in binary cycle plant.

4. 'REGULATIONS' AFFECTING GEOTHERMAL DEVELOPMENT

4.1 General Background

For some Acts, there are a range of specific 'regulations' that give effect to the Act. In fact, there is a hierarchy of documentation that may apply.

While some people may regard regulation as a form of control, regulations may also be thought of as a form of professional indemnity insurance. Regulations set out acceptable practice such that compliance gives a measure of legal cover.

For health and safety legislation, 'Regulations' are developed to control particular hazards. These should reduce compliance costs by giving people a clear understanding of the general provisions of the Act, set minimum criteria for the management of particular hazards, and cover matters contemplated by but not specifically addressed in the Act. Regulations are enforceable and breaches may result in prosecution and fines.

'Approved Codes of Practice' are at a lower level, are more detailed statements of preferred work practice approved by the Minister of Labour, and are often referred to in the regulations. Their requirements are not mandatory or enforceable, but their observance is accepted in Court as evidence of good practice. The language used in Codes of Practice does not always provide the degree of certainty required by enforceable regulations.

Beneath these are 'Guidelines' which are self-explanatory in nature. They are developed by or with the Occupational Safety and Health Service but may not have gone through a formal approval process. At a similar level are standards, industry publications and best practice documents, and manufacturers' information/MSDSs/manuals, etc. These may be accepted by courts as evidence of good practice.

Many industries have been allowed a measure of self-regulation, an underlying principal of "Robens"-style health and safety frameworks. Industry will then create guidelines or standards. An example of an industry guideline is the recently issued "Good Governance Practices Guideline for Managing Health and Safety Risks" published jointly by the Institute of Directors in New Zealand and MBIE (May

2013) and is a direct consequence of a recommendation in the Pike River Royal Commission report targeted at company directors. An example of an industry standard is NZS 2403:1991 Code of Practice for Deep Geothermal Wells which was developed by the New Zealand geothermal industry and subsequently referenced in the Geothermal Energy Regulations.

Generically, a requirement (whether a section of an Act, or a regulation, or a code of practice or a guideline) is referred to as a standard.

4.2 Specific Regulations/Standards

A number of key geothermal standards have been developed. Among these are:

- Geothermal Energy Regulations 1961 – detailed in the next section.
- Health and Safety in Employment (Pressure Equipment, Cranes and Passenger Ropeways) Regulations 1999 (more commonly known as the PECPR Regulations) – general regulations that from a geothermal perspective covers pipes, valves and pressure vessels. These also cover use of refrigerants such as the hydrocarbon refrigerants used in binary cycle plant[2]. One effect of these regulations is to tie design done to international codes back to legislation.
- NZS 2403:1991 Code of Practice for Deep Geothermal Wells – which covers the deep wells typically associated with geothermal power or industrial heat projects. Industry representatives are currently reviewing this Code of Practice.
- Health and Safety Guidelines for Shallow Geothermal Wells 1996 – this covers shallow wells typical of domestic applications. The guidelines set techniques but do not preclude the use of alternative techniques based on sound data and engineering, but documented justification should be retained.

Note that in this list of regulatory standards, the "Code of Practice" for deep geothermal wells was developed at the time when the Ministry of Works and Development was disestablished (Leaver et al, 1990). That meant that most geothermal drilling expertise was no longer resident in government agencies. Thus the Code was developed by industry to capture the knowledge and experience available at the time. This is an industry code of practice rather than an "approved code of practice" as defined in the HSE Act. As such, it sits at the same legal level as the guidelines for shallow wells, even though it is specifically referenced in clause 32 of the amended Geothermal Energy Regulations 1961.

4.3 Current Content of Geothermal Energy Regulations 1961

The original Geothermal Energy Regulations 1961 were of a prescriptive form typical of regulations before the "Robens" regulatory model was established. Over time, eleven of the 36 clauses (plus various sub-clauses) of the Geothermal Energy Regulations have been revoked as provisions of the Geothermal Energy Act were covered by other Acts. However, the remainder are listed below.

2. Interpretation. An important definition relates to "geothermal work" which includes "a) the drilling of any bore to a depth exceeding 2 metres from ground level; and b) any work in the construction or maintenance of any pipeline of 150 mm or less nominal internal diameter in relation to a bore which is not primarily associated with the generation of electricity, including associated fittings, vessels, pumps, and appurtenances necessary for the containment and control of pressure in the pipeline". On this definition, geothermal works would apply to small-scale direct use equipment, could arguably apply to any shallow groundwater application as there is no reference to temperature, and would not apply to electricity generation projects.

There is no definition of geothermal energy in the regulations. This was originally defined in the Geothermal Energy Act. The only current definition in New Zealand law is that found in the Resource Management Act 1991 which has a lower temperature limit than the Geothermal Energy Act.

3. Geothermal Inspectors. There is provision for the appointment of Geothermal Inspectors under a Chief Geothermal Inspector. Significant powers are available.

4. Authorities and Licences. Individuals can apply for authorities or licences for geothermal drilling or works.

9-13. Authorities. The holder of an authority shall promptly set about the work. There are some clauses giving access to the Secretary, relevant government employees and members of the Department of Scientific and Industrial Research (DSIR) to inspect the works, check records and give direction. Discharge of bores is prohibited until at least 3 successive temperature logs to full depth are substantially static. If an authority expires or is revoked then the holder of the authority shall cease all work, leave all equipment in a permanently safe condition and restore the site as directed. If the holder fails to do necessary work, the Minister can cause needed work to be done and recover the costs from the holder.

14A, 14B, 16, 19 Licences. A system of class A and class B licences is established. The class A licence authorises the licensee to drill, tap and use geothermal energy directly while the class B licence allows a downstream user to use geothermal energy. A rental (clause 14B) is payable in arrears for users of geothermal energy. In practice, all of these clauses should have been revoked when the Resource Management Act 1991 was passed.

21. Taking of Land and Compensation. Unless agreed with a landowner beforehand, at the time a licence or authority finishes, no compensation shall be due to the landowner for any improvements and the land shall be restored to original condition as far as is reasonable or practicable.

24-25. Appointment of Managers/Duties/Responsibilities. Managers shall be appointed before a geothermal work is started, and suitable substitutes shall be available when managers cannot be present. The managers are responsible for compliance with these regulations, based on daily personal supervision.

[2] Binary cycle plant is also covered by various other standards (DOL July 2008).

26-29. Safety. All bores, pipework and related equipment shall be of suitable and sound material, designed/ constructed/ operated in line with good practice, and shall be maintained to prevent risk of damage to equipment or danger to persons on site. The manager shall ensure the site is kept in a safe condition and specific safety equipment is supplied, training is given and equipment is used. A person trained in resuscitation shall be available on site for any rig work. Clause 28 is around hazardous gases, and avoiding design of works in which they could accumulate, and safety provisions around managing potential situations. Clause 29 is similar and relates to explosives.

30. Consents. Consent shall be sought from the Chief Geothermal Inspector before the start or suspension of drilling, bore abandonment, use of explosives or atmospheric discharge of a well, based on certain information requirements.

31-36. Particular Provisions for Bores and Drilling. There are some specific clauses around bore identification and location (31), bores greater than 150 m deep (32), bores less than 150 m deep (33), access to and security of bores (34), downhole surveys focussed on casing condition (35) and notification of accidents (35A). Finally in clause 36, fines are imposed for anyone who commits an offence under these regulations up to £50 and £5 per day or part day subsequently.

Schedules 1 and 2 outline information requirements during and after drilling, and prior to a consent being given.

5. CURRENT PRACTICE: HEALTH AND SAFETY ON GEOTHERMAL SITES

5.1 Safety Management Systems and Culture

All project owners have their own health and safety programmes. Any visitor to a geothermal site will be immediately aware of the health and safety culture. Prior to arrival they will be alerted to appropriate clothing. Safety equipment will be issued at the time of an initial safety briefing. Guides will take visitors through in a controlled manner. Visitors will know where to assemble in the event that an alarm sounds. For construction sites, contractors must report to the site office for a similar briefing, and there will be notices about where all significant hazards will be on that day. Warning signs will be present beside hazards. For some people there will be toolbox safety sessions. This is all appropriate culture and practice for geothermal sites – and it was the culture and practice at Pike River Coal Mine too.

Where specific "near miss" incidents have occurred, companies will develop internal procedures to avoid these in future, possibly in association with some other companies.

Construction companies will have a health and safety programme in place and a review of this to ensure satisfaction by the project owner is part of the tender assessment process.

5.2 Safety Engineering

Safety starts at the design phase of a project (and some of the direct causes of the Pike River tragedy lay in inadequate preparation at the design phase then subsequent construction phase e.g. the inadequate second egress option). Equipment is designed to accepted codes using sound engineering practice by competent engineers.

HAZOP analysis is often used as a method for identifying potential hazards in a system and identifying operability problems. In fact HAZOP is one of a number of systems approaches to safety engineering including hazard analysis, design, safety in operations, and management of safety-critical systems (Levesen 2011).

5.3 Regulatory Overview

All aspects of development are subject to regulatory overview through the HSE Act 1992.

The current Geothermal Energy Regulations enables regulator verification and supervision of geothermal drilling and works, but there appears to be consistent misapplication of the Regulations. While the definition of geothermal works seems to target direct use application and exclude power station applications, the Regulations, in respect to "works", are applied in the opposite manner. Designers of plant for direct use will design for compliance with the PECPR rather than Geothermal Regulations, while designers of power stations will draw in the Chief Geothermal Inspector. In practice, if a failure happened, the Chief Geothermal Inspector would be responsible for all aspects of the investigation.

Shallow geothermal wells are covered by the Guidelines for shallow wells, deep wells are covered by the Code of Practice (NZS2403), and supervision of all of these comes under the Chief Geothermal Inspector's ambit.

The regulator and duty holders are faced with a number of difficult choices as they try to interpret the Geothermal Energy Regulations, as many clauses have lost their context now that the Geothermal Energy Act no longer applies. Licencing and rental clauses are not applied. The Chief Geothermal Inspector's effort is directed at making sure directors and senior managers are aware of their health and safety obligations, rather than ensuring that each well and geothermal work is fit for purpose. Inspectors have distilled rigorous information requirements set out in the regulations into Details of Works Notices (or DOWNs forms) and these are enforced.

5.4 Emergency Management

In addition, for geothermal developments in the Waikato and now Bay of Plenty, System Management Plans (SMPs) must be developed as a requirement of the Regional Plans under the RMA 1991.

These SMPs cover a wide range of issues, but examples that have been seen include co-ordinated incident management systems. Unfortunately, while these set out response in a range of emergencies (tsunami, earthquake, volcanic eruption, etc.) they do not cover such specific geothermal risks as well blowouts, hydrothermal eruptions, or dangerous gas clouds.

6. IS GEOTHERMAL A HIGH HAZARD INDUSTRY AND WHAT IS THE RISK 'LANDSCAPE' LIKE?

It appears that the geothermal industry has ended up under the High Hazards Unit (HHU) by association, but is geothermal a high hazard industry i.e. is there a risk of catastrophic loss of multiple lives from a failure?

6.1 Drilling

In practice, almost all of the regulator's drilling experience is now resident in the HHU, so geothermal drilling has been brought under this along with oil and gas drilling. Both petroleum and geothermal industries required drilling inspectors and, recently, the Chief Petroleum and Chief Geothermal Inspector positions became a single position under one person. Both industries use drilling rigs and require well development, so in many ways are similar. However the risks associated with the two industries are not similar because of the different fluids. While any drilling operation is hazardous because of the heavy machinery and sometimes height involved, it can easily be argued that it is not the presence of a drilling rig that exposes an industry to catastrophe – rather it is the fluid.

Consider a continuum of drilling operations from offshore deep-water drilling for petroleum (with 100 people trapped on the rig and a risk of fire or explosion), to a small water-well driller in the Hauraki Plains drilling a 50m well to intercept 40^{o}C fluid for a hot pool. Clearly the hazards are not comparable, but both operations currently fall under the High Hazards Unit (HHU), so are labelled "high hazard".

There is the intermediate position of deep onshore drilling for either petroleum or geothermal purposes. The petroleum industry has agreed to an extension of the offshore regulatory position to onshore drilling, though clearly risks are reduced. Fewer people are located on a drill site and the option to flee exists in the event of fire or explosion. Geothermal drilling can use the same on-shore rigs and services drilling to similar depths, but risks are further reduced because of the fluid being handled.

One of the initial prompts for the Geothermal Energy Regulations 1961 was hurried drilling at Kawerau by private drillers without adequate site work or numbers of casing. A blowout occurred during the drilling of KA9 in 1956 in which the drilling rig collapsed into the resultant hole and a crew member was scalded. The Ministry of Works had their own blowouts including WK201 in 1958, WK26 in 1960 and WK204 (which became known as the Rogue Bore) in the same year, but without loss of life or injury to individuals, or loss of equipment, as lessons had already been learnt about the need for site consolidation grouting (Bolton et al. 2009). There have been other incidents both nationally and internationally, but across the thousands of geothermal wells drilled globally over a sixty year period, there are no known incidents involving multiple loss of life. In addition, New Zealand geothermal drilling experts have international reputations and have been involved with blowout recovery in these situations which threatened project progress, the environment and local communities.

Photo 1: The crater left by the Rogue Bore. Note the person standing on the right.

Well and drilling lessons have been included in the Code of Practice for Deep Geothermal Wells. The New Zealand geothermal industry willingly works under this Code of Practice and is actively cooperating on improvements and updates to it. However, many countries around the world do not have such a code, and any safety incidents there have not caused multiple loss of life.

In terms of mapping the risk landscape for drilling, there does not appear to be justification for inclusion of geothermal drilling in high hazard industries.

6.2 Well Discharge

It is noted that the current Geothermal Energy Regulations also cover the discharge of wells. The author is more concerned about well discharge than drilling risk in terms of risk of catastrophe. It is possible for a cloud of CO_2 or H_2S to sit in hollows or low–lying ground with a suffocating effect. Deaths have occurred, including in domestic situations, such that bylaws in places like Rotorua have been developed to counter risks[3]. Two workers on the Kawerau field were recently overcome by gas (but survived) during steam purges leading to a test of the separators. The author was personally involved with two near-incidents elsewhere.

There does appear to be a risk associated with well discharges and steam blows during plant commissioning.

6.3 Binary Cycle Plant

The HHU is known to have an interest in risk associated with geothermal binary cycle plant. Their concern is the inventory of hydrocarbon on site. Binary cycle plant is a simple variant on refrigeration plant. The PureCycle binary cycle plant, as an example, was developed from standard Carrier refrigeration componentry (with some specific adaptions) to take advantage of the mass-manufacturing benefits associated with refrigeration and chilling technology. All this technology is currently covered by the PECPR Regulations and HSNO Act.

[3] Rotorua District Council Geothermal Safety Bylaw 2008 is an example.

The key question is whether or not there is a potential for catastrophic failure (multiple deaths) from the use of binary cycle plants. In the author's opinion, this has been tested and found not to be the case. There have been two known fires associated with this type of plant. There was a spectacular fire associated with a pump failure at the Steamboat plant in Nevada, USA in 1992, but this was soon extinguished and adjacent units were returned to service the following day. Safety systems present at Steamboat are likely to be similar to those at other ubiquitous Ormat plants. Another fire occurred at the Chena plant in Alaska, USA involving PureCycle units when a welder was welding above an open container of hydrocarbon. That fire was extinguished and the two Chena units are in service. There have also been major scrub fires beside two plants. Again the Steamboat plant was shut down as a precautionary measure during a 2002 scrub fire then returned to service. In New Zealand, the Ngawha plant was threatened with a scrub fire in November 2008 that required a controlled shutdown and, later, melted some control cabling. However that was quickly returned to service with no major damage. Many safety systems are applied to binary cycle developments, and sites are controlled such that the potential for catastrophe is minimal.

An assumption here is that the safety features present at Steamboat and other places will be present at future plants. Given that there may be other manufacturers (possibly including New Zealand companies as the Heavy Engineering Research Association's Above Ground Geothermal and Applied Technology (AGGAT) programme develops) then there may be value in codifying the current good practice so others will also protect our workers.

The extent of risk may also be gauged from the current HSE(PEE) Regulations. Exemptions from the preparation of comprehensive Safety Cases is given to lower-tier production facilities with liquefied flammable gas inventories less than 50 tonnes. A 20MW binary cycle plant could have an inventory of around 100 tonnes of pentane. For comparison, a large service station could have a total inventory of 100-200 tonnes of fuel. On this basis, a weak case for including this as a high hazard industry could be made. However, the fuel storage argument needs to be balanced against the proven safety of the plant in the event of fire described previously.

6.4 Pressure Equipment

Pressure equipment could also be considered. Wellheads may experience high pressures, but these are covered under the Geothermal Energy Regulations, and the Code of Practice and Guidelines for wells. Other pipes and pressure vessels are designed to usual codes, and are relatively low pressure steam applications, compared to pressures generated in steam boilers. Consequently, risk associated with this plant is less than it is at other steam plant. The PECPR regulations cross-references AS 4343 Pressure Equipment – Hazard Levels. This standard provides a rational and consistent approach to storage and handling of all fluid types and covers all hardware downstream of the well.

6.5 Hydrothermal Eruptions

Hydrothermal eruption remains a unique possibility in the geothermal sector and this may be at a location remote from the constructed facilities. Hydrothermal eruptions can occur naturally, but can also be triggered by reservoir changes due to development. Eruptions have occurred at the Taupo Pony Club on Broadlands Road (Wairakei/Tauhara) both before and after Wairakei development (Scott and Cody, 1982), fortunately without injury.

A consideration of the risk of hydrothermal eruptions indicates that a simple combination of PECPR and bore regulations is not enough. Major damage or loss of life could result remote from the designed, installed and operated equipment. This comes back to emergency management and what may be a simplified safety case.

A concern with hydrothermal eruptions is that field operators could be drawn into a "not my fault" non-cooperative response to calls for help from emergency services in an emergency. Independent of the cause of an eruption, a field operator supported by their engineers and scientists, will be well-placed to advise emergency services on a technical response e.g. should the eruption crater be flooded with water or should nearby wells be shut in to manage the ongoing risk. The Police or Fire Services have no competency in this area. This emergency response can be formalised ahead of time in a co-ordinated incident management system plan.

Photo 2: Taupo Pony Club hydrothermal eruption June 1981 (Source: Taupo Times)

Whether or not the industry is categorised as 'high- hazard', there are some clear hazards in the industry and sound regulation is recommended.

7. APPROPRIATE FORMS OF REGULATION

7.1 General Nature of Health and Safety Regulation

Ideally regulation should draw on the existing collective good practice of the industry and codify this. The effect of enforced regulation then is not so much to create a burden, as to provide a measure of assurance that well-codified and practicable steps are being taken to manage risk.

In his book on mine safety (Gunningham 2007), Professor Neil Gunningham notes "it is increasingly recognised that the nature of the OHS challenge is more complex than was previously thought. There has been a shift from a focus solely on engineering safety and safe design, and on equipment, methods and the immediate physical work environment, to recognising the importance of systematic approaches to safety and widespread reliance on safety management systems, audits and risk management. Most recently this has extended to a focus on behaviour, culture and leadership, and the recognition that most incidents are the result of a combination of failures at different places and at different times in the organisation…"

Gunningham also concludes that one of the best ways of achieving improved outcomes is through regulation. These can take several (not mutually exclusive) forms:

- Prescriptive standards – that tell a duty holder exactly what to do.
- General duties or goal-setting standards – that set out principles for the duty holders.
- Performance standards – that specify an outcome but leave methods open.
- Process standards – that stipulate particular processes or series of steps to be followed.

As a rule there has been a shift in recent years away from prescriptive standards towards performance and process standards. The most appropriate form of regulation will depend on the nature of the industry. The form of regulation for the geothermal industry may not be the same as that for the coal mining or petroleum industries. Underground coal mines vary significantly in nature with mines of varying sizes in varying formations, methods of working and propensity for spontaneous combustion. In contrast, geothermal developments at the large scale are all achieved through the operation of a surface drilling rig and the development of wells, even though the details for each well will vary. Consequently, it is easier to codify agreed good practice.

7.2 International Precedents

It is often administratively efficient to look to other countries for models of regulations. This has yet to happen for geothermal regulations. There may be useful geothermal models in California, USA or countries such as Iceland, Italy or Japan, although core legislation impacts on regulatory design. While the Philippines and Indonesia have similar geothermal environments, they are more likely to be followers than leaders of health and safety regimes.

7.3 Possible Petroleum Regulation Precedent

Some geothermalists, on the advice of the Chief Geothermal Inspector, are looking to the HSE(PEE) Regulations as a possible model for geothermal regulations. Law firm Chapman Tripp together with Petroleum Exploration and Production Association New Zealand (PEPANZ) have advised that operators of petroleum installations will be required to:

- Consult with the workforce in the preparation of a "safety case" which must be accepted by MBIE before operations commence. This should provide measures to control all potential hazards and must demonstrate that the risk to workers has been minimised as much as reasonably practicable. The safety case would primarily apply to a drilling rig operation, especially where this is an offshore operation or where all services are under an integrated contract. The situation becomes more complex for the multiple contracts required for onshore drilling. Safety cases would also apply to major onshore production facilities, but would currently exclude the refinery and facilities below a threshold size, though the latest reforms will bring all major hazard sites under a safety case regime. Note that MBIE will charge between $70,000 and $100,000 to assess full safety cases for the Petroleum facilities above the threshold, though assessments for other industries could be much reduced.
- Establish goals that will apply over the whole life cycle of the well, specifying how it will be designed, modified, commissioned, equipped, operated, maintained, suspended and abandoned.
- Arrange independent and competent persons to examine, assess and assure the wells and their plans to verify that they comply with the goals. Fitness for purpose will be up to these independent assessors to determine rather than MBIE staff.
- Report as soon as practicable "near miss" incidents that could have led to a major accident.

In the preparation of these regulations (categorised as "goal-setting" regulations), the petroleum industry has been extremely aware of the risk of catastrophic failure and loss of life from offshore oil and gas drilling. The Petroleum industry has been willing for the safety case concept, which already effectively is applied offshore, to be applied to onshore drilling situations, though recognise that risk of catastrophe is not as great.

If this regime is applied to geothermal drilling, there is a need to ensure that the very high regulatory costs indicated for preparation and then review of safety cases do not apply, especially to shallow wells. These wells have costs of the order of $20,000 so to load the drilling companies with regulatory costs an order of magnitude greater than the cost of the well could kill domestic geothermal development.

The Royal Commission report noted that "Safety-case documentation is extensive and can include the operational control arrangements, the hazard identification and management system, procedures for managing change, contractor management, competency, emergency arrangements, incident and accident investigation, communication and workforce consultation, auditing and quality assurance." The Commission was not convinced that such documentation should be mandatory.

Perhaps some of the concerns here are simply problems of terminology. There is a basis for lesser documentation, and whether it is called "code of practice" or "safety case" is immaterial. An industry standard defining process and content, but allowing detail levels that match scale and risk, including emergency management systems could be created

with schedules to be completed for specific projects or companies.

7.4 Underlying Standards

Industry representatives are currently reviewing NZS2403:1991 Code of Practice for Deep Geothermal Wells. Some incremental improvements are likely rather than any radical change. But what form should this eventually have? Options include revision or amendment, with some significant costs recovered by Standards New Zealand. Another option is to have the revisions considered for adoption as an "Approved Code of Practice" under the HSE Act 1992 or the new Act. Independent of the option chosen, having documentation reflecting current best practice is of high value as the industry moves toward a new regulatory regime that lines up with the lead legislation.

8. RECOMMENDED CHANGES AND FURTHER WORK

8.1 Changes from the Royal Commission Report

Many of the 16 recommendations of the Pike River Royal Commission easily translate to a geothermal situation. Focussing on the areas that this paper might have an effect on, and adjusting the recommendations for geothermal situations with changes from the original recommendations shown in square brackets [ ]:

- An effective [health and safety] regulatory framework for [geothermal development] should be established.
- Directors should rigorously review and monitor their organisation's compliance with health and safety law and best practice.
- Managers [on geothermal sites] should be appropriately trained in health and safety.
- Worker participation in health and safety [on geothermal sites] should be improved through legislative and administrative changes.
- The health and safety regulator [and industry should work up] code[s] of practice [including but not limited to revision of existing drilling codes of practice and guidelines] to guide managers on health and safety risks, drawing on best practice.
- The implementation of the co-ordinated incident management system (CIMS) in [a range of geothermal situations including well blowouts, hydrothermal eruptions, and gas discharge] should be urgently reviewed [to develop an industry standard].
- To support effective emergency management, operators of [geothermal facilities] should [review] equipment and facilities [to ensure they reflect the best practicable approach].

8.2 Additional Work from the Independent Taskforce

From the Independent Taskforce on Workplace Health and Safety, the industry should attempt to better map the risk landscape associated with geothermal development.

8.3 Specific Changes to Geothermal Energy Regulations

With respect to the Geothermal Energy Regulations, MBIE has already determined that these will be written from scratch and will be tied to the new legislation. However if the old regulations initially modified or considered during the drafting stage, the following changes should be made:

- Old assumptions about the presence of Ministry of Works engineers or DSIR scientists should be eliminated, and simple reference to the regulator or independent assessors should be made.
- There should be no reference to "geothermal works" as these appear to be adequately covered by PECPR Regulations, whether applied to power stations or direct heat plant. Specific geothermal regulations should apply to wells, and their design, drilling and testing.
- There should be no reference to land acquisition since all land negotiations are on a willing buyer-willing seller or willing lease arrangement. These are commercial matters and irrelevant to health and safety considerations.
- Any reference to rentals should be removed from regulations. It is considered inappropriate to have resource rental provisions in what are otherwise health and safety requirements. Similarly licencing provisions were related to resource consents, and should have been revoked along with other clauses when the Resource Management Act was passed.
- The industry is strongly supportive of a system of competent Geothermal Bore Managers. It is noted that one of the recommendations (8) from the Pike River Royal Commission related to appropriately trained managers with an emphasis on health and safety. These two concepts could be closely tied together.
- The fines outlined in the current regulations will have little deterrent effect. It would be better that the regulations stayed silent on deterrents so that the penalties of the new Act could take precedence.

8.4 Additional Work on Form of Regulation

Examples of other forms of geothermal regulation should be researched to see appropriate forms e.g. from international precedents. Ideally these should fit into a "Robens"-style legislative environment.

Details of the HSE(PEE) Regulations should be reviewed to see if this can be a platform for revised Geothermal Energy Regulations.

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