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GEOTHERMAL TRAINING PROGRAMME

LaGeo S.A. de C.V.

SLIM WELLS FOR GEOTHERMAL EXPLORATION

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ABSTRACT

One way to reduce the early drilling exploration cost for investigation of geothermal reservoirs is to drill small diameter wells. For these wells to be relevant as an exploration method they have to provide information on the reservoir productivity close to what a full-size production well would give. If the final diameter is less than 6" they have been referred to as "slim holes" or "slim wells". Several tests were made years ago to apply wireline coring equipment for the drilling of 3"-4" wells, sourced from the mineral exploration industry. The wells are drilled with tri-cone bits but the deeper sections with impregnated diamond coring bits. Slightly larger diameter wells using truck mounted rigs (50-100 t) and rotary drilling equipment have also been drilled (5"-6") (Figure 1). For this drilling tri-cone bits are used and a conventional bottom hole assembly. Drilling mud or water alone is used as the drilling fluid. The wells are drilled vertical but some shallow ones as "slant holes". It is apparent that these types of wells require smaller rigs, platforms and auxiliary equipment which mean fewer operators and less fuel. They also need considerably less materials (steel, cement, mud, etc.) than the larger wells (Figures 2 and 3) which is also directly linked to cost reductions. Problems related to hole cleaning and cementing because of the small annular spaces and less leeway to react to the unexpected might however quickly eat up some of the cost benefits.

Studies on slimhole drilling (Combs et al, 1999; Finger et al., 1996; Finger et al., 1994; Finger, 1996) and similar ones for petroleum drilling on "micro drilling" have been made in USA. These wells have been shown to be practical to identify the temperature and pressure distribution in the reservoir as they are wide enough to pass logging instruments. The stratigraphy and permeability structure can be mapped to 1000-1500 m, but they have not reached as deep as larger exploration and production wells (2000-3000 m). Attempts are being made to push the limit to ~2000 m but that depends on the temperatures encountered. A rig manufacturer in Sweden has lately developed coring rig for deep geothermal exploration to 2500 m. The wells may be difficult to induce flow and it may be too low for them to serve later as production wells. Results from USA and Japan (Gargs and Combs, 1993; Pritchett, 1993) have shown that the production characteristics of slim wells, if able to flow, are scalable to production sized wells. Down hole fluid samples may be obtained so in balance many of the sought after results from early exploration wells can be obtained.

Examples of casing programs of slim wells will be described in the lecture (Figures 4 and 5) and the how it affects the drilling rig selection (Figure 6). The rig

equipment, such as blow out preventers, will also be described (Figure 7). Because slim wells did not reach very deep and the cost advantage was not so great, their popularity was not as high in the past as might have been expected. Now there are ongoing exploration programs at several "green field" sites around the world where the early wells are slim wells. There have been problems of reaching the target depths and the cost has been higher than anticipated. Deep slim geothermal wells are still few in numbers but once the expected benefits have been confirmed and how deep it is possible to drill, it is expected that they will be come more common as part of geothermal exploration programs.

FIGURE 1: Rig (100 t) drilling a slim hole to 1500 m with 7" production casing and a 4½" slotted liner

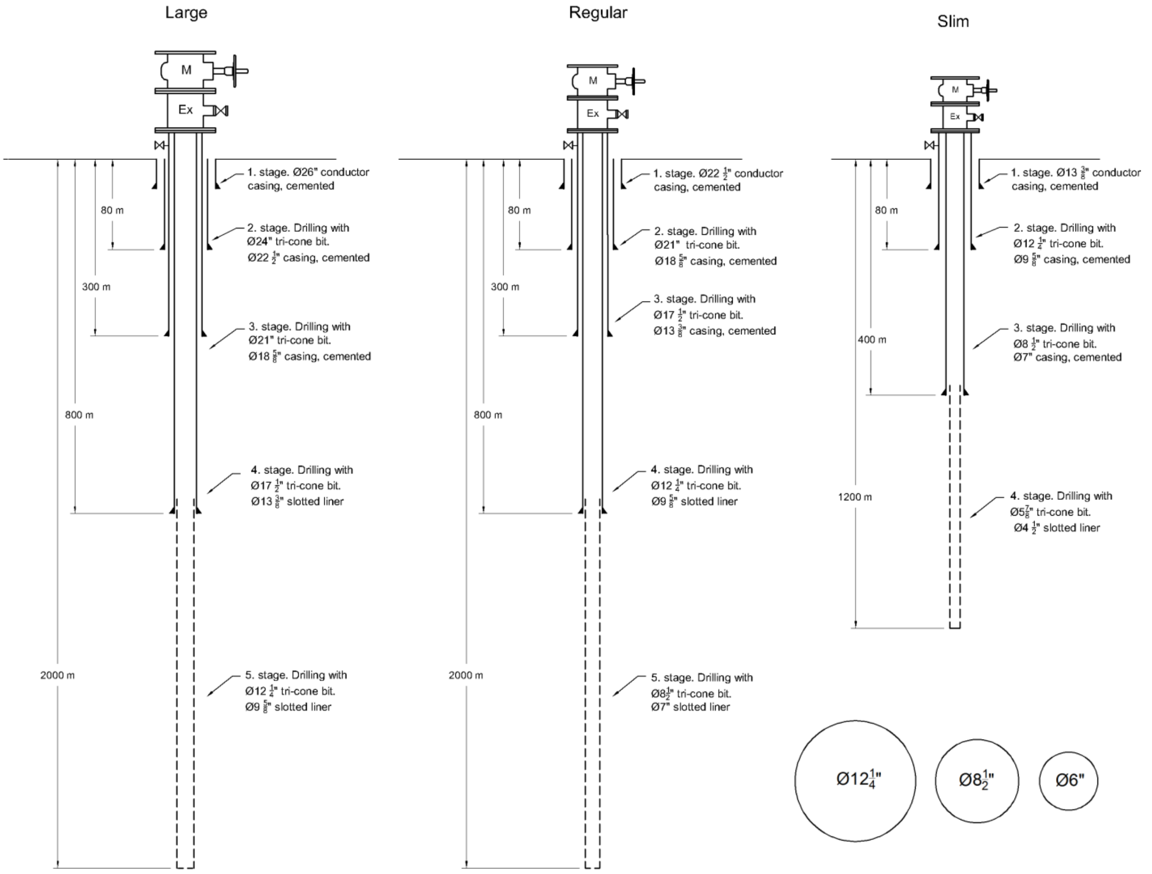

FIGURE 2: Comparison of casing programs for three well types. The large and regular are very common in geothermal areas up to date.

Type	Casings (ton)	Cement (m³)	Volume (m³)
Large (12 ¼")	200	84	278
Regular (8 ½")	135	55	143
Slim (6")	80	26	73

FIGURE 3: Shows the difference in the amount of materials needed to complete the casing programs in the figure above

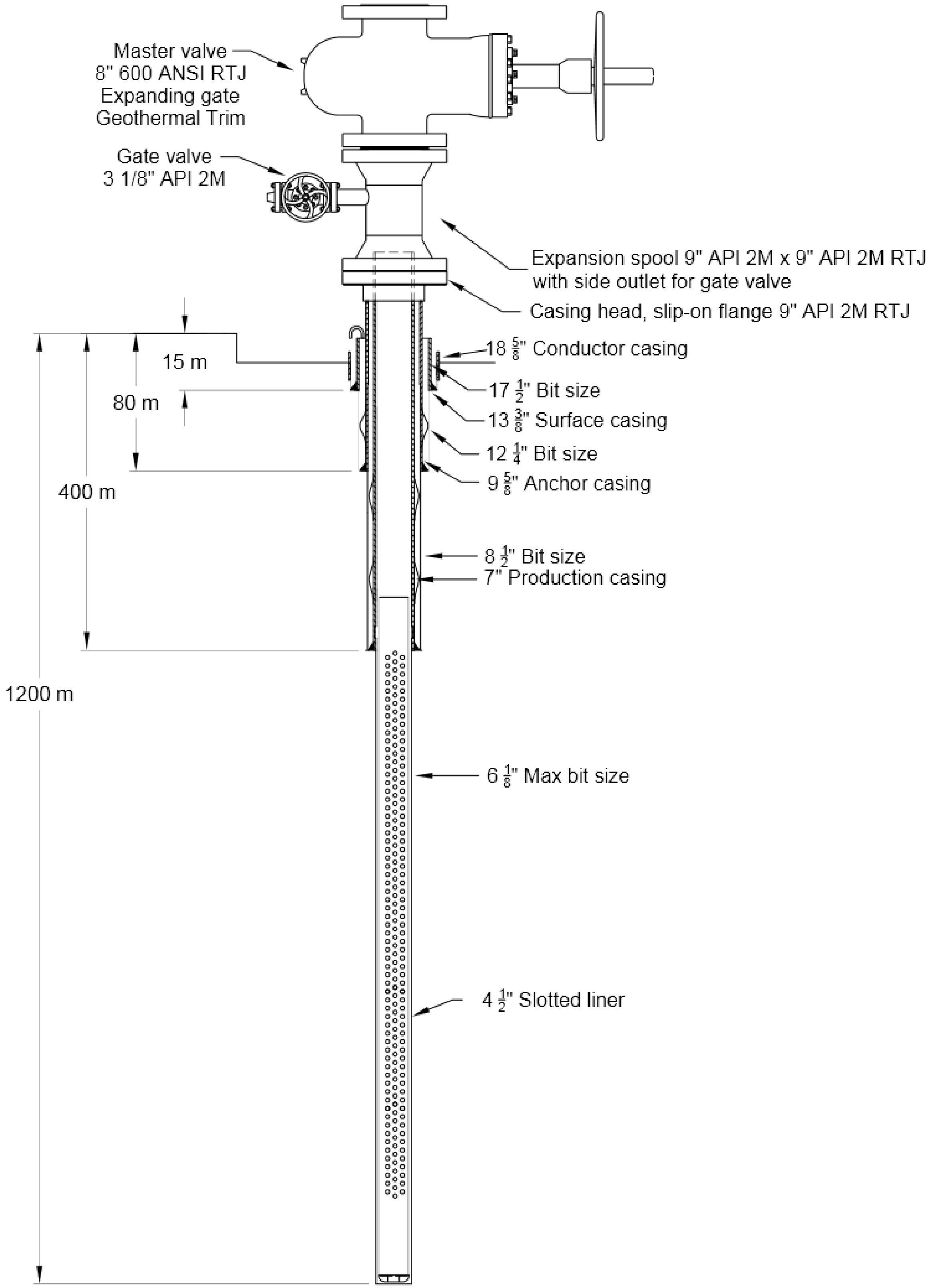

FIGURE 4: Slim hole casing program, drilled with truck mounted exploration rigs (60-100 t). The final hole size is 6 ⅛". Such wells can be drilled much deeper.

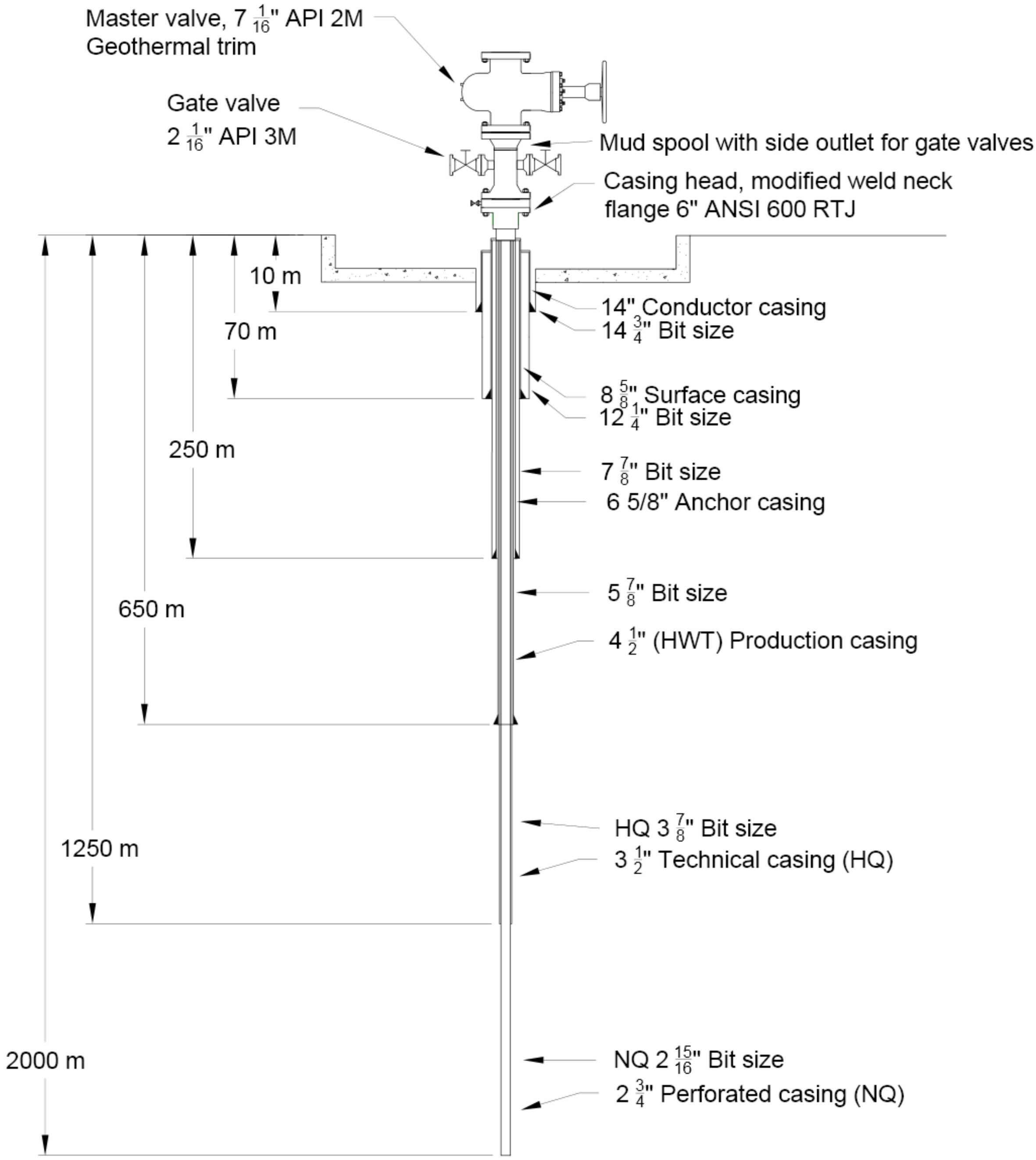

FIGURE 5: Slim hole casing program for drilling with a coring rig (20 t). The final hole size is 2 15/16". Such a well is reaching the depth limit for this design.

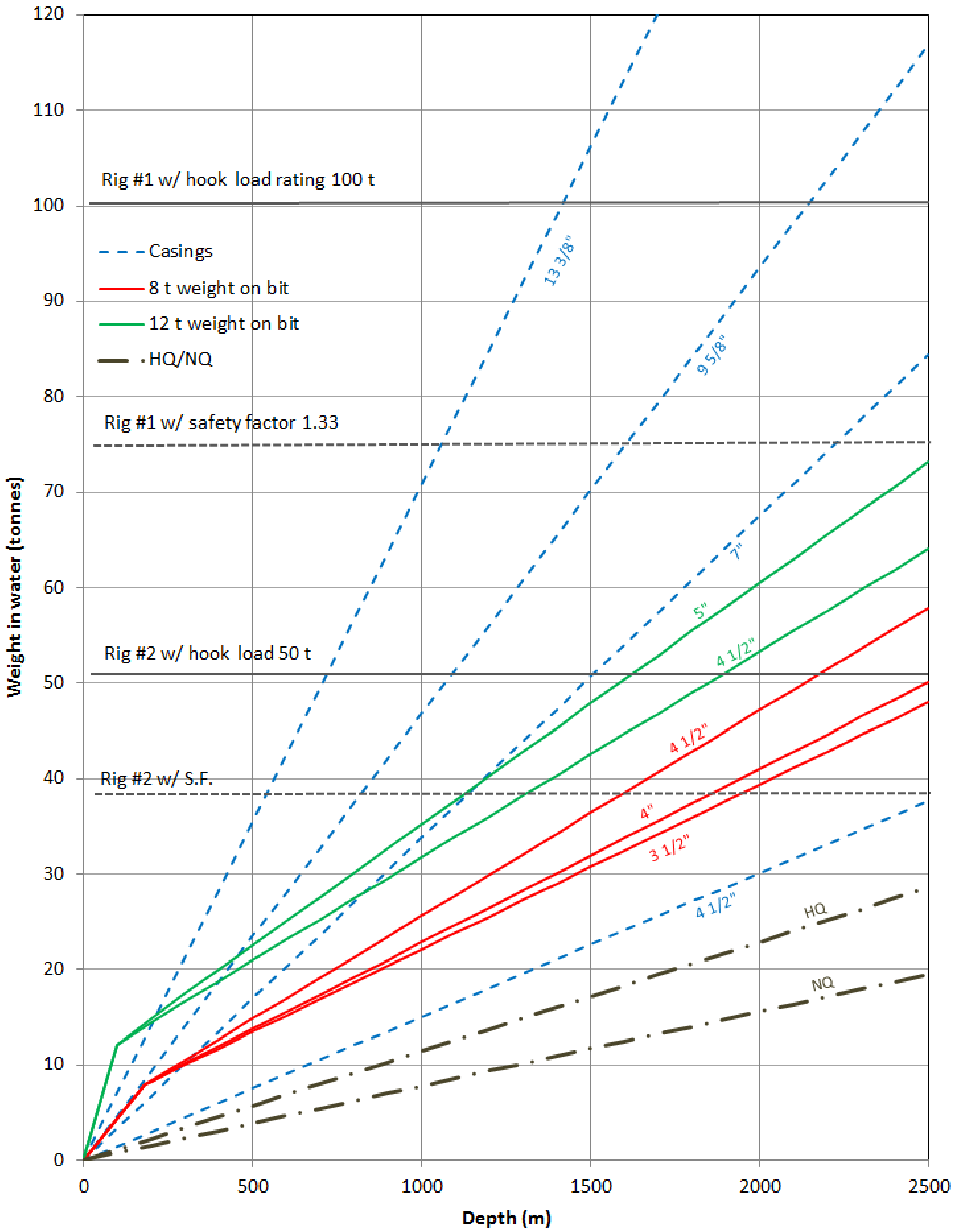

FIGURE 6: How deep can your rig go? The diagram shows the weight of different size drill strings and casings in water vs. depth. The NQ and HQ are coring rods, but an exploration rig will use 3½" or 4" drill pipes. The hook load rating of the rig has to exceed the weight in water by about ⅓ to allow for over-pull in case of getting stuck or fishing.

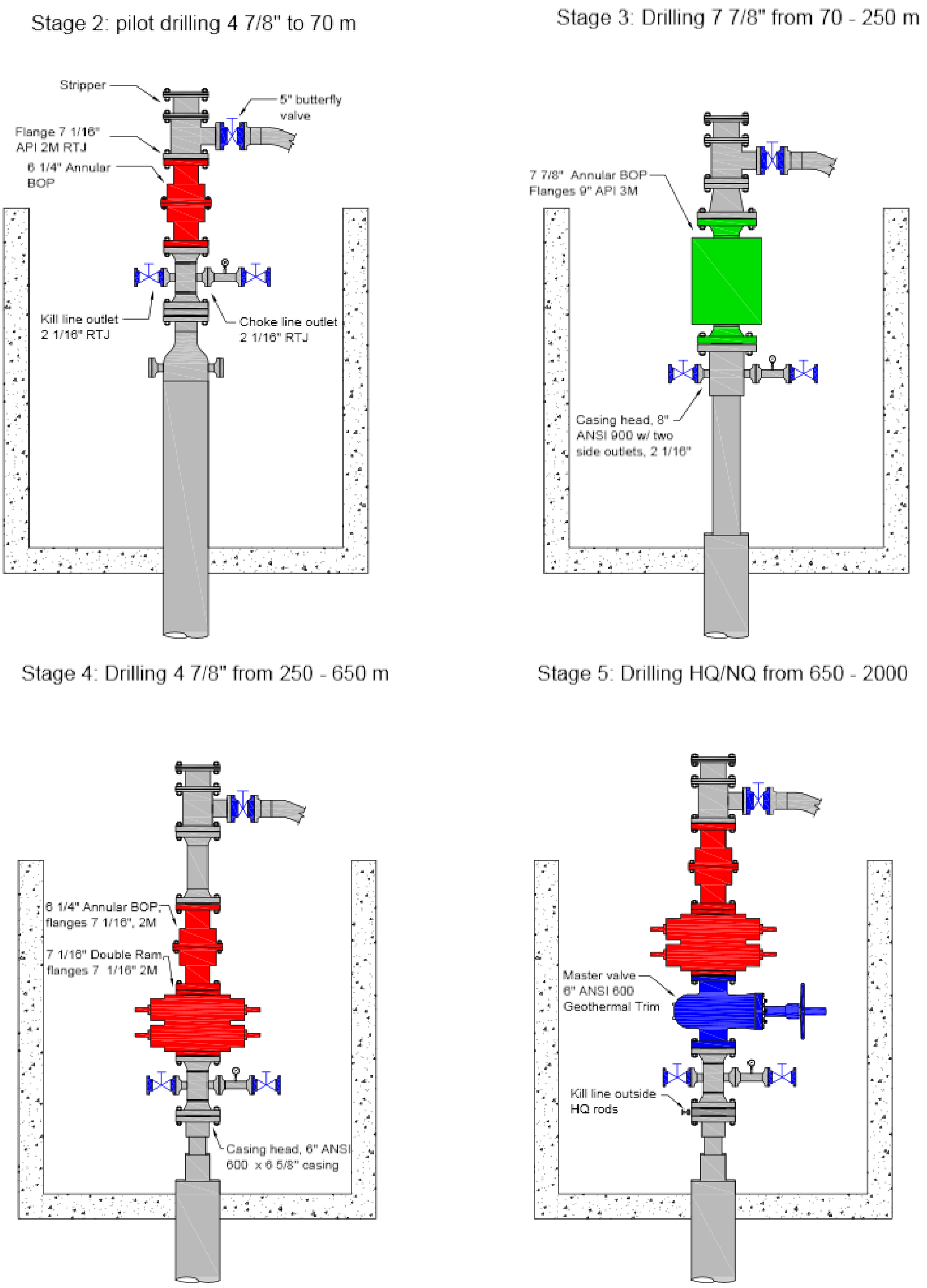

FIGURE 7: Blow out preventer (BOP) stack for each stage of slim hole drilling with a coring rig

REFERENCES

Combs, J., Finger, J.T., Goranson, C., Hickox, C.E., Jacobson, R.D., and Polk, G., 1999: *Slimhole handbook: Procedures and recommendations for slimhole drilling and testing in geothermal exploration*. Sandia National Laboratories, Albuquerque, New Mexico, USA, 163 pp. Website: http://www.osti.gov/geothermal/servlets/purl/13956-BlVnub/webviewable/13956.pdf

Finger, J.T., 1996: Update on slimhole drilling. Sandia Research Laboratories, Albuquerque, New Mexico, USA, 6 pp. Website: http://www.osti.gov/geothermal/servlets/purl/219460-WC8V7P/webviewable/219460.pdf

Finger, J.T., Jacobson, R.D., and Hickox, C.E., 1994: *Steamboat Hills exploratory slimhole: Drilling and testing*. Sandia National Laboratories, Albuquerque, New Mexico, USA, 104 pp. Website: http://www.osti.gov/geothermal/servlets/purl/10194116-qwhXfY/10194116.pdf

Finger, J.T., Jacobson, R.D., and Hickox, C.E., 1996: *Vale exploratory slimhole: Drilling and testing*. Sandia National Laboratories, Albuquerque, New Mexico, USA, 92 pp. Website: http://prod.sandia.gov/techlib/access-control.cgi/1996/961396.pdf

Garg, S.K., and Combs, J., 1993: Use of slim holes for geothermal exploration and reservoir assessment: A preliminary report on Japanese experience. *Proceedings Eighteenth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, USA*, 173-179. Website: http://www.geothermal-energy.org/pdf/IGAstandard/SGW/1993/Garg.pdf

Pritchett, J.W., 1993: Preliminary study of discharge characteristics of slim holes compared to production wells in liquid-dominated geothermal reservoirs. *Proceedings Eighteenth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, USA*, 181-187. Website: http://www.geothermal-energy.org/pdf/IGAstandard/SGW/1993/Pritchet.pdf