The drilling and casing program for CO_2 storage

Načrtovanje in izvedba globokih vrtin pri skladiščenju CO_2

Željko Vukelić[1, *]

[1]University of Ljubljana, Faculty of natural science, Aškerčeva cesta 12, SI-1000 Ljubljana, Slovenia

*Corresponding author. E-mail: zeljko.vukelic@ntf.uni-lj.si

Received: May 20, 2009 **Accepted:** November 6, 2009

Abstract: This paper deals with the design and construction of boreholes, with respect to geologic feasibilities of CO_2 injection into boreholes and rocks capable of taking in carbon dioxide. The boreholes have to be carried out by following appropriate technologic standards which only will ensure adequate and economic storing of CO_2. The objective is to reach the foreseen depth and 100 % air tight of the borehole. The design and construction of the boreholes for the underground CO_2 repository is extremely demanding. Each single phase has therefore to be accurately planned, this process requiring thorough work and high-expertise engineering solutions.

Izvleček: V članku obravnavam načrtovanje in izvedbo globokih vrtin glede na geološke pogoje za vtiskovanje CO_2 v vrtine oziroma v hribine, ki sprejemajo ogljikov dioksid. Vrtine je treba izdelati tehnološko korektno, kajti le tako je mogoče zagotoviti ustrezno in ekonomično skladiščenje CO_2. Z vrtinami je treba doseči predvideno globino in stoodstotno tesnitev vrtine. Projektiranje in izvedba vrtin za podzemno skladiščenju CO_2 je izjemno zahtevna. Zato je treba posamezno fazo izvedbe vrtine skrbno načrtovati, kar pa zahteva poglobljeno delo in kakovostne inženirske rešitve.

Key words: CO_2, borehole, construction, underground repository
Ključne besede: CO_2, vrtina, načrtovanje, podzemno skladišče

Introduction

This paper deals with the design and construction of boreholes, with respect to geologic feasibilities of CO_2 injection into boreholes and rocks capable of taking in carbon dioxide. The boreholes have to be carried out by following appropriate technologic standards which only will ensure adequate and economic storing of CO_2. The objective is to reach the foreseen depth and 100 % air tight of the borehole. The design and execution of boreholes have been limited to rotary drilling technique, suitable for the performance of deep boreholes.

Principle of rotary drilling of deep boreholes

As a curiosity I should like to mention a case in Titusville, Pennsylvania, back in 1859, when oil flushed upon the surface from a 21 m deep borehole. Since then we have experienced huge development in the field of drilling, as oil deposits have been discovered at depths exceeding 1000 m. With rotary drilling technique a roller cone bit is being employed. When roller cone bit rotates, a force is applied to it by a weight. During drilling into rock, the roller cone bit is being cooled by mud, running continually through roller cone bit nozzles and flushing rock cuttings upon the surface. Special devices enable drilled rock cuttings to be removed from the mud, to be then returned purified into the borehole. As a rule, mud is being injected into the borehole by high-pressure piston pumps (Figure 2).

Deep boreholes design and construction

When designing and executing deep boreholes for CO_2 repository, the foreseen depth into which CO_2 shall be injected, must be achieved. The main objectives of the borehole are:

- to install communication between surface and geologic structure (rock) underground
- to enable the injection of CO_2 into underground rock
- to ensure 100 % air tight of the borehole
- to enable monitoring

Design of borehole performance

The depth of the borehole for CO_2 repository depends on the location of the underground repository, appearing at a certain depth below the surface. The average borehole depth is up to 2000 m, whereas boreholes from 3500 m to 4500 m are defined as very deep and boreholes exceeding 4500 m as extremely deep. A deep borehole design has to comprise the following aspects:

- general data of the borehole

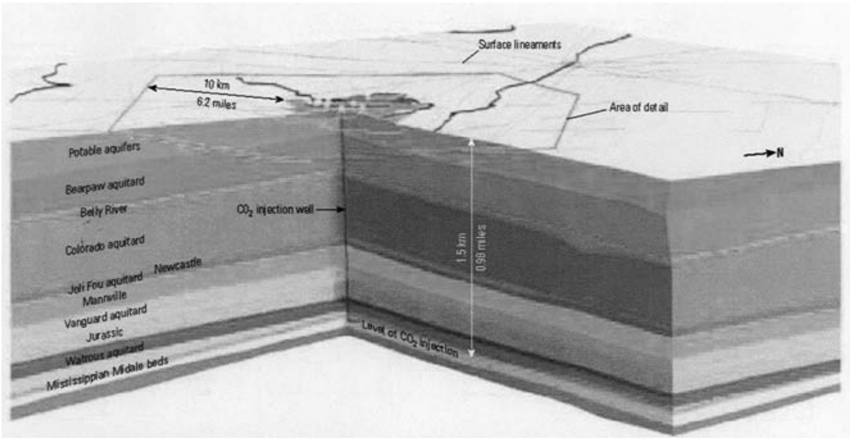

Figure 1. The principle of storing CO_2 through deep boreholes[2]

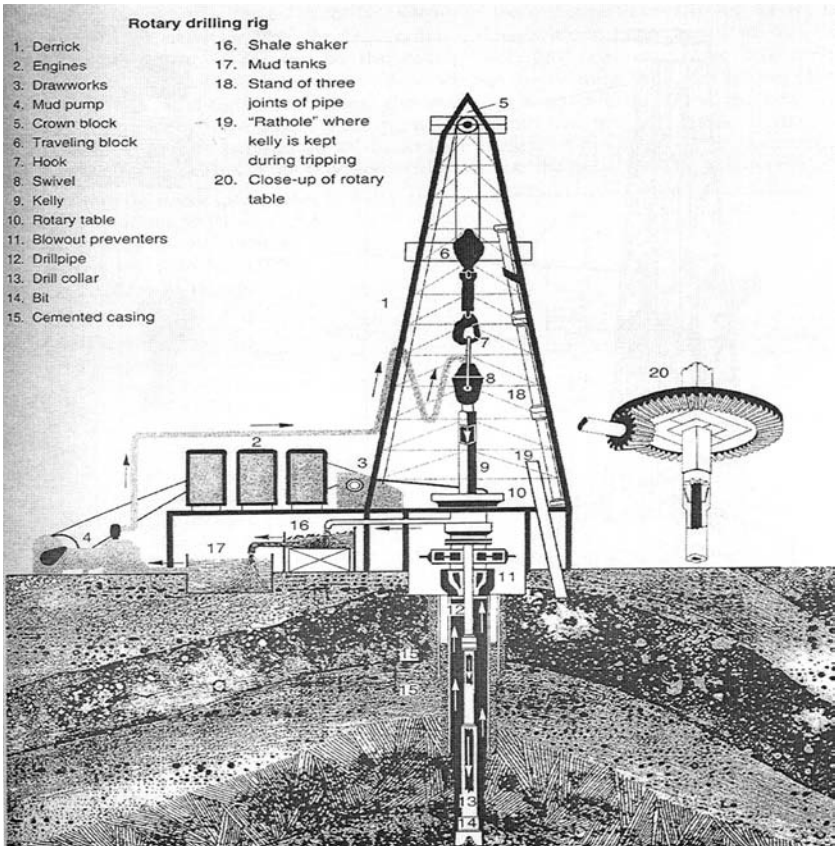

Figure 2. Drilling equipment for rotary drilling[1]

- program of the borehole performance
- method of drilling and borehole casing

General data of boreholes

The general data of the borehole have to be presented immediately after determining the location of the borehole performance. General data will help to define:

- borehole coordinates and location (place, country, etc.)
- purpose and scope of boring
- geology
- geophysics
- information on adjacent boreholes, if existing
- cost and time frame of the borehole construction

It is important, however, to make distinction between the boreholes with respect to their function, defining them as exploratory, monitoring or productive (boreholes with CO_2 injection) boreholes. Productive and monitoring boreholes must comprise precise geologic data and determine the method of construction, since all essential underground repository parameters have to be known. In the case of exploratory boreholes, however, frame parameters are adequate, as these will suffice for confirming or eliminating the location of the underground CO_2 repository.

Program of the borehole performance

This document is to be prepared after the investor has reached the decision on the borehole performance, this being already a constituent part of the contract between the investor and the client. This document shall be prepared by experts in the following fields:

- engineers who will determine the size of underground CO_2 storage
- engineers who will establish the functioning features of the underground CO_2 storage
- geologists
- engineers in charge of the boreholes construction

The main elements of the borehole design program are:

- micro location of the borehole mouth
- definition and purpose of the boring: exploratory, monitoring, productive
- precise geologic forecast
- precise description of geophysical data
- well logging measurements program (Gamma ray, resistivity, density, sonic, caliper)
- precise description of drilling and casing
- program of sampling and testing in the borehole
- borehole construction cost (cost

of preparing, transportation, daily operating cost, well casing cost, well cementing cost, well logging cost, etc.)
- timetable for the implementation of single phases of the borehole construction
- manpower
- drilling equipment and supplementary equipment for the borehole construction

Drilling and borehole casing program

The program of drilling and borehole casing program is the most important document for the construction of the borehole underground repository of CO_2. The construction of the borehole has to make possible the reaching of foreseen depths of the underground CO_2 repository. An efficient program of the drilling and borehole casing program is essential for a competent, safe and economic borehole construction. The borehole design and construction must consider the following technical feasibilities:
- choice of the roller cone bit diameter for drilling and drilling pipes
- number of different diameters of borehole casing
- method of cementing the annulus between pipes and borehole

Depending on the final depth of the boreholes, consideration needs to be given to optimum ratio between the borehole diameter and pipes in the borehole, where the following graph (Figure 3) can be of assistance:

In practice, however, when designing deep boreholes, either for oil and gas exploration or for underground CO_2 storing, we usually encounter the following performance technique, as shown in Figure 4.

It has to be pointed out that along with applying of high quality steel casing, the cementing of interspaces between pipes and borehole-wall has to be thoroughly planned, as perfect setting must be ensured, since CO_2 is injected with pressures exceeding several 100 bar. The cementing is being carried out applying cement slurry of a density of up to 1800 kg/m^3, respectively by water: cement ratio between 0.35 and 0.5 (1000 kg cement/500 L water). With deep boreholes, chemicals are added into cement slurry against its hardening due to increased temperatures in the borehole, and against increasing of its density. By applying these admixtures, the appropriate rheological parameters of the cement slurry are achieved, assuring satisfactory cementing of casing and consequently satisfactory borehole performance (Figure 5).

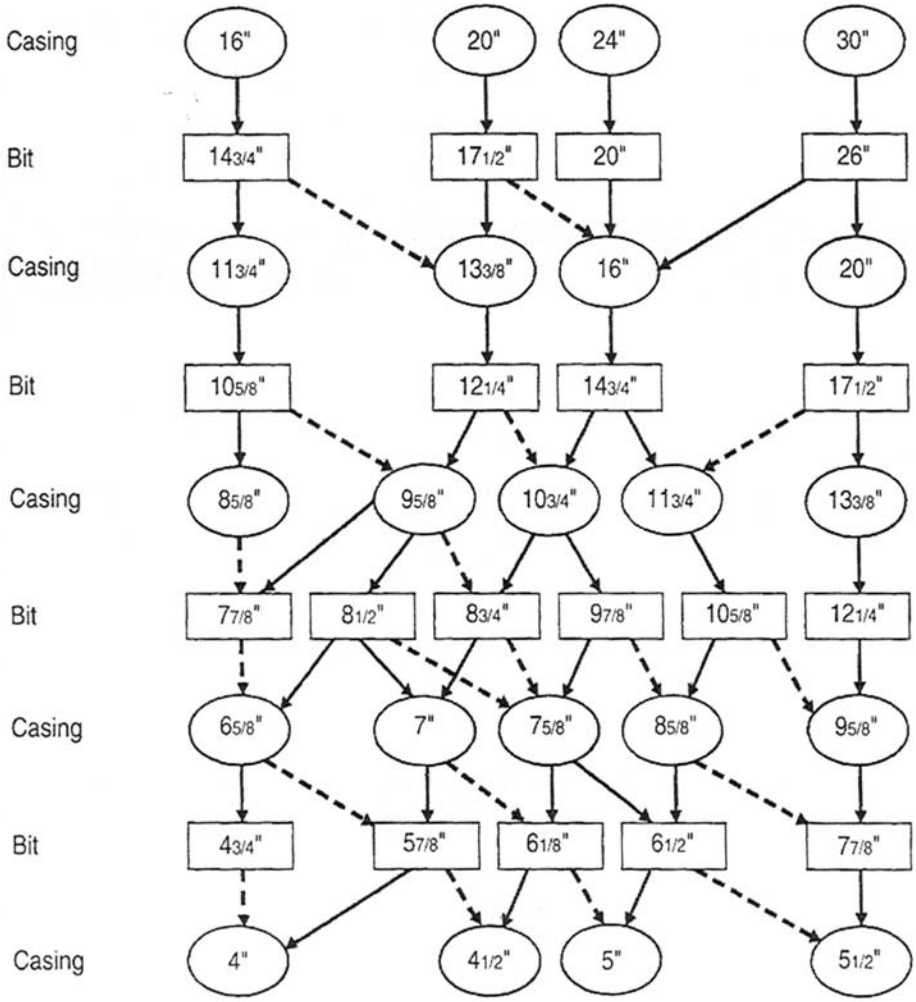

Figure 3. Optimum ratio between the drilling diameter and casing[1]

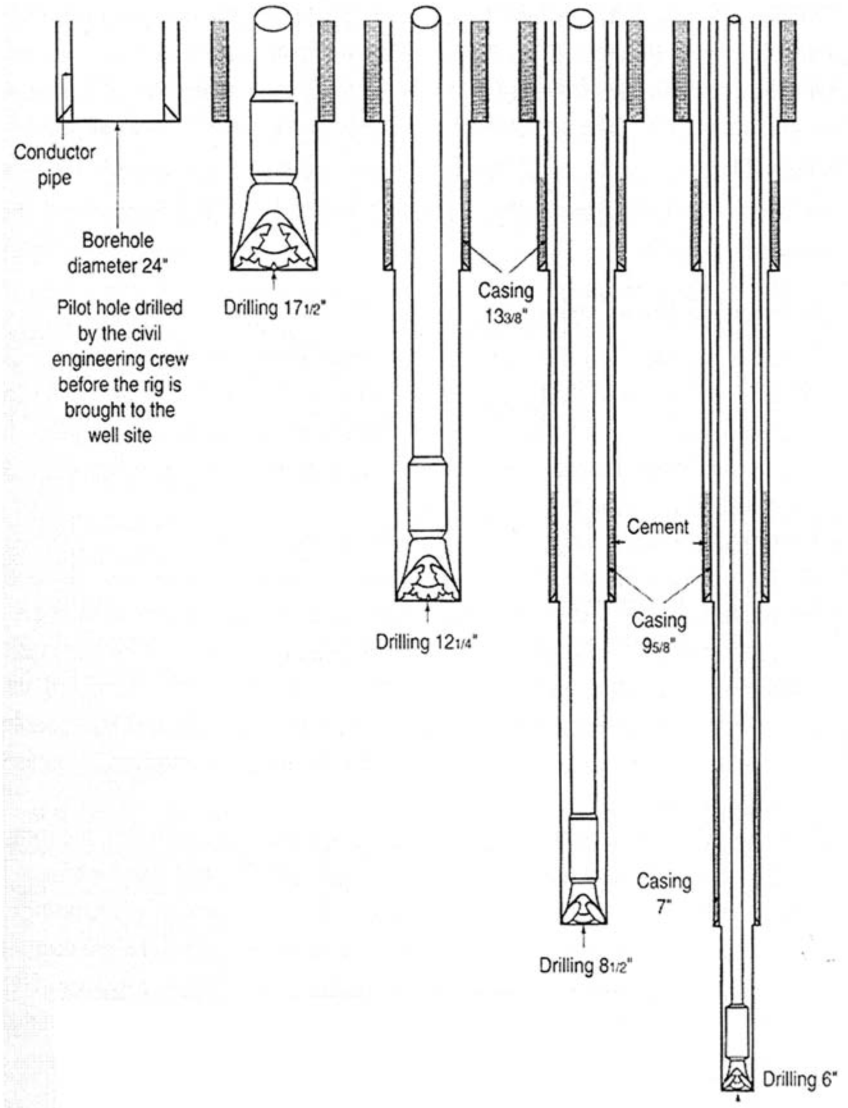

Figure 4. The construction of the borehole for underground storage of CO_2[1]

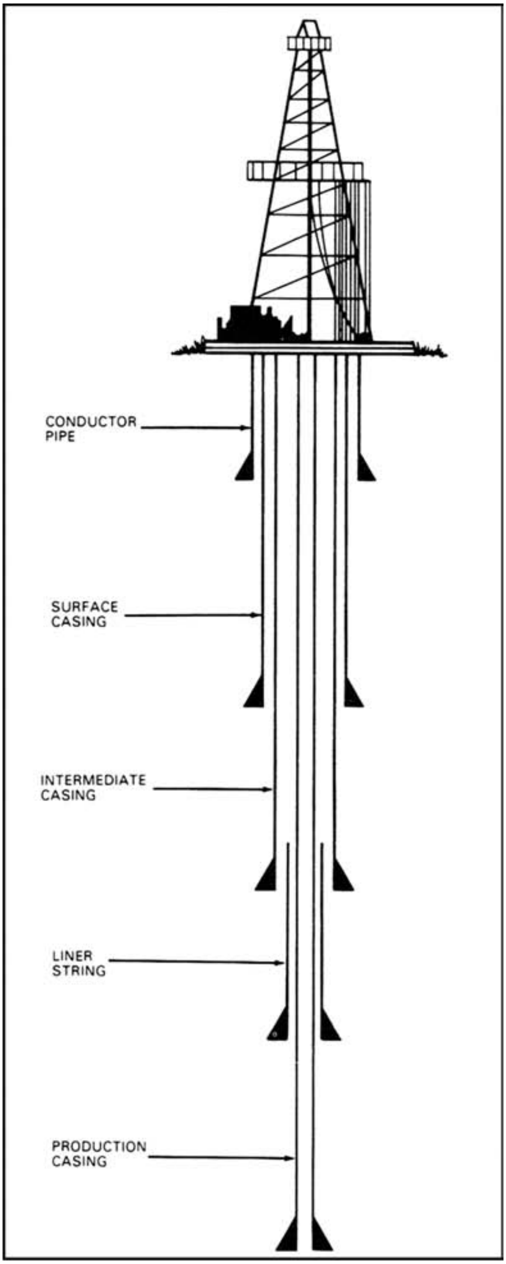

Figure 5. Final performance of the borehole for underground storage of CO_2[3]

CONCLUSION

This paper presents an overview of the design and construction of deep boreholes for the underground storage of CO_2. I have presented the principles of designing the boreholes and the way of their implementation in practice. The design and construction of the boreholes for the underground CO_2 repository is extremely demanding. Each single phase has therefore to be accurately planned, this process requiring thorough work and high-expertise engineering solutions.

REFERENCES

[1] J. P. NGUYEN: Drilling, Editions TECHNIP, 1996, Paris.

[2] www.greenfacts.org: CO_2 Capture and Storage, 2005.

[3] VUKELIČ, Ž., ŠPORIN, J.: *Rešene naloge iz vrtalne tehnike in projekt vrtine*, Ljubljana: Naravoslovnotehniška fakulteta, Oddelek za geotehnologijo in rudarstvo, 2007.