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13 Years Of Safe CO2 Injection At K12-B

V. Vandeweijer[1]*, C. Hofstee[1], H. Graven[2]
[1]TNO, [2]Neptune Energy Netherlands B.V.

Summary

Since 2004 the feasibility of CO2 injection and storage in depleted natural gas fields has been researched and demonstrated at K12-B, a gas field on the Dutch continental shelf. In total over 100 Kton of CO2 was injected. The entire operation at the K12-B field was completed without any major complications. It can therefore be stated that safe and uneventful underground storage in depleted gas fields is possible. During the many activities taking place at K12-B, numerous techniques were tested and enhanced and many processes, including corrosion tests, investigated. This has helped in assessing other projected CCS projects, such as P18. There is now a proven track record of over a decade of continuous CO2 injection, supported by many risk assessment studies. The findings of this extensive scientific CO2 re-injection research can be showcased and applied to other Carbon Capture and Storage Projects in the world. One year ago the project came to an end. In this abstract we present some of the highlights.

Introduction

Underground storage of CO_2 has been subject to a lot of discussion in the Netherlands and elsewhere for that matter. Public opposition even lead to ban of any onshore application of CCS in the Netherlands. The general public, may however have not been aware of a CCS demonstration project, which was active for over 13 years since 2004.
It all began on 7 February 2002, when the Dutch Minister of Economic Affairs introduced a new policy to promote studies into the feasibility of CO_2 storage in the subsurface. In that same year a feasibility study was kicked off. The project's aim was to investigate the feasibility of CO_2 injection and storage in depleted natural gas fields on the Dutch continental shelf. K12-B, a mature gas field, was selected as a demonstration site for offshore injection of CO_2. The project was subsidized by the Dutch Ministry of Economic Affairs and carried out by Gaz de France Production Nederland B.V., the operator of the K12-B platform, and TNO.
Since 2004, a little over 100 Kton of CO_2 has been re-injected. Over the years, the K12-B reservoir has served as a field lab, in which a variety of experiments and tests have been carried out. Many of the findings have been presented at conferences, workshops and other meetings. A highlight was a joint presentation with the operator ENGIE at the COP Paris 2016.
Since last year, production from the compartments, in which CO_2 was injected, has stopped, ending the first and so far last CCS project in The Netherlands. This paper aims to highlight the main findings.

K12-B

The K12-B gas field (figure 1) is located in the Dutch sector of the North Sea, some 150 km northwest of Amsterdam. The K12-B structure was discovered in 1982. Gas production started in 1987 and the platform is currently operated by Neptune Energy Nederland B.V. Gas is produced from the Upper Slochteren Formation. The reservoir lies at a depth of approx. 3800 meters below sea level, and the temperature of the reservoir is approx. 128 ºC. The gas contains 13% CO_2 which is removed from the gas stream directly offshore on the platform.
The K12-B gas reservoir is the first and so-far only gas reservoir in the Netherlands into which captured CO_2 was re-injected. Elaborate info on the CO_2 injection at K12-B can be found in Vandeweijer *et al*, (2011).

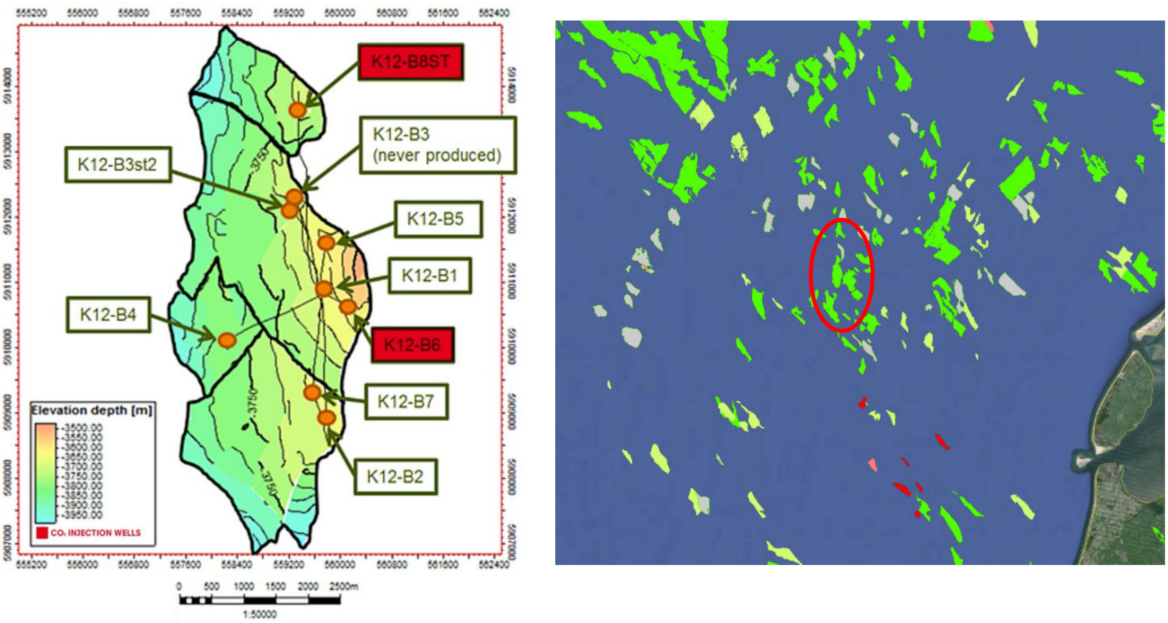

Figure 1 *Right: Compartment structure of the K12-B gas field. The CCS took place in the Northern Compartment (K12-B8ST) and the adjacent compartment (K12-B6). The CO_2 injection wells are indicated by red labels, and the gas producing wells with white labels. Left: Location overview, with Noord Holland and the island of Texel in the South-East corner.*

Timeline

Since 2003 the operator[1] and TNO have been in close collaboration on the CO_2 injection related activities at K12-B. In over 13 years, a whole range of projects (Figure 2) have been taking place. The acquired data and gathered information is centrally stored allowing for an ever growing understanding of the storage site. Throughout the injection project, a continuous monitoring and reservoir simulation program was carried out. In addition, occasional other studies such as geo-mechanical, risk assessment and geo-chemical evaluations were conducted and reported. Sadly CO_2 injection related research activities were still ongoing, when the removal van de CO_2 at K12-B came to an end, and further research had to be abandoned.

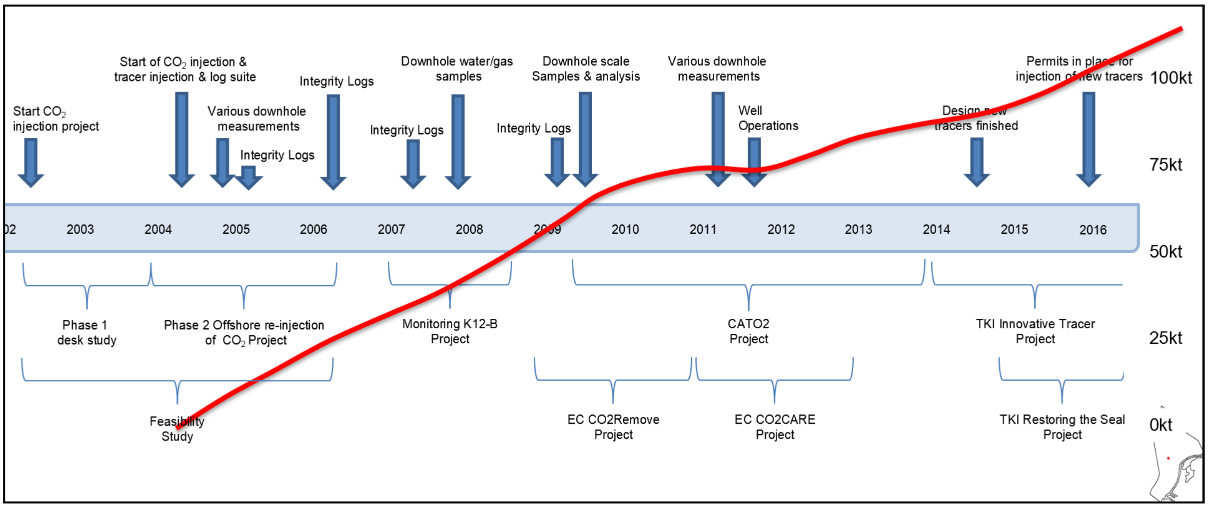

Figure 2 *Timeline indicating projects, measurements and operations and in red the total amount of CO_2 re-injected.*

Highlights

ORC – Offshore re-injection of CO_2, the first in its kind

Legal and regulatory aspects of underground CO_2 injection and storage have been studied during this first project. Although certain points, such as the ownership of the CO_2, were raised, no significant legal or social impediments against the CO_2 injection were identified. It was assumed that a demonstration project might enhance awareness of and support for this technique. The involvement of the Government, political parties, environmental groups and other organizations during the demonstration phase would likely enhance support for and acceptance of large-scale injection projects. Nice to know is that a former Minister of environment visited the K12-B platform during CO_2 injection operations.

Well integrity and monitoring

The reservoir at K12-B is sealed by a hundreds of meter thick layer of Zechstein salt. Leakage trough that layer has always been considered to be extremely unlikely. Risk analysis indicated wells penetrating the top seal as the most likely leak path, even though the risk of leakage is regarded very low. Therefore a lot of emphasis was given to the integrity of the K12-B6 well, the well with was used most intensively for the re-injection of CO_2. This well has been exposed to water and CO_2 for more than a decade. The combination of water and CO_2 is known to be corrosive mixture.
A variety of tools was used in the K12-B6 well to assess its integrity through time. This included conventional tools such as multi finger calipers and also, at that time, more innovative tools. Like the electromagnetic based tools to image wall thickness.

[1]Gaz de France Production Nederland B.V.(2001-2008), GDF SUEZ E&P Nederland B.V. (2008-2015), ENGIE E&P Nederland B.V.(2016-2017) and Neptune Energy Netherlands B.V. (2018…)

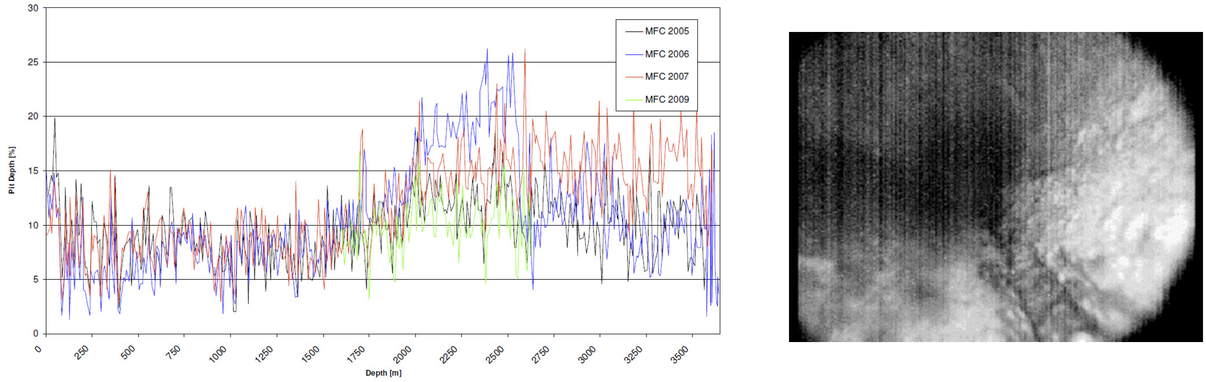

Figure 3 *Right: Time lapse results of the multi-finger caliper measurements in the K12-B6 well, Left: Downhole picture of the inside of the tubing at approx. 3600m depth.*

Figure 3 shows that the somewhat alarming pit depths around 2250-2750 m depth was not corroborated by measurements in 2009. This lead to the hypothesis that random fluctuation was caused by scaling in the bore hole, combined with the limited exposure area of the 24 fingers of the caliper. In 2009, Schlumberger introduced an alternative way to assess the integrity of the bore- hole: the electric magnetic tool or EMIT. This then still experimental log was unaffected by most solid components of the scaling and was therefore expected to be more reliable in a bore hole, which was known to contain scaling. The data indeed showed fully integral integrity of the range, which is covered in the figure. In 2009, already 6 years of injection had been carried out. It should be noted that the steel of the wells at K12-B is high grade as the initial composition of the gas already contains 13 % of CO_2.

Chemical tracers

Another technique, which has been tested is the application of tracers. At the start of the injection in K12-B6 (on Marth 1st 2005), two water-insoluble tracers were added to the CO_2 (Vandeweijer *et al*, 2011). A breakthrough curve was established at two producers. As these tracers were virtually insoluble in water, they were assumed to represent the methane. Comparing the arrival time of these gaseous tracers with the increases in CO_2 concentration was impossible as the detection limits were very different (10-12 versus 0.01 volume fraction for % CO_2). Attempts have started to find a tracer, which mimics the CO_2 in a methane reservoir.

History matching & reservoir simulations B6 injector

Several reservoir models (Simed, Eclipse, Though and others) were applied to investigate the fate and transport of CO_2 in the reservoir. One method, which was applied is the so-called history matching techniques, which to compare the predictions of the past production (since 1984) and known injection, production rates with actual measurements of pressure and composition at the injector and producer. During one of these so-called history matches, a very high skin was required to obtain a match between the very high (measured) pressure at the bottom of the injector in combination with a low injection. An interdisciplinary group of experts then went back to all available data & measurements. Soon, it was discovered, that due to production problem, production from this lower reservoir had ceased and the well was sealed with a cement plug (figure 4) After closing the lower perforations (mimicking a water column in the well bore), the pressure could be matched with the simulations. The water column also explained the changes in injection pressures, which were detected at the onset of an injection was found and a water table was detected when a camera was lowered in the bore hole. For all other observations, plausible explanations were eventually found.

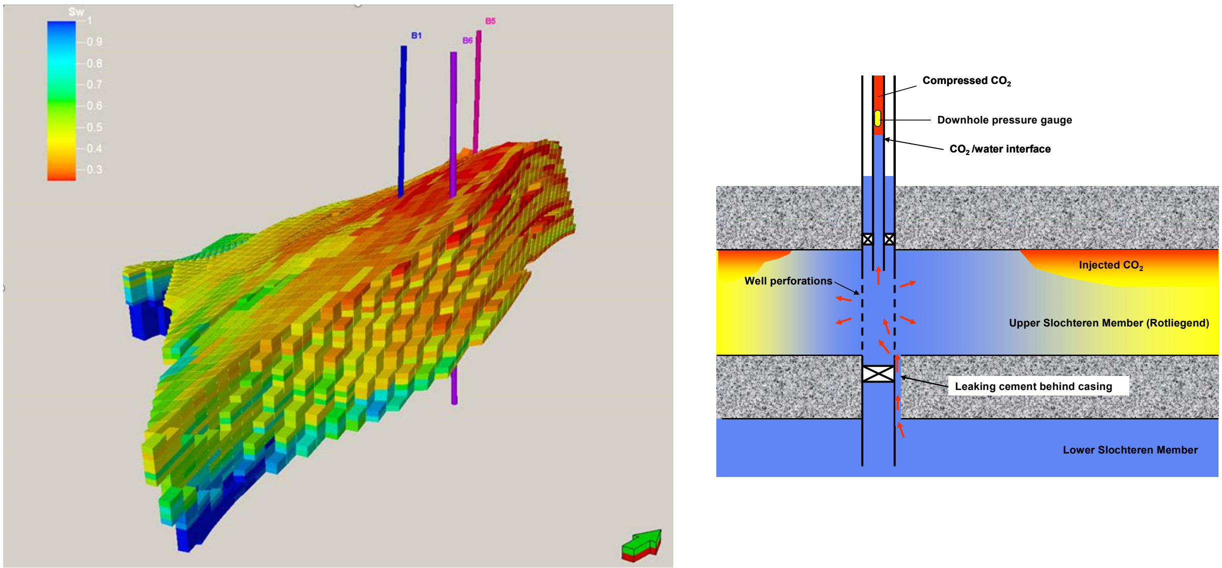

Figure 4 *Right: Cellular dynamic reservoir model of the center compartment of K12-B, indicating water saturation. Right: Artist impression of the plausible explanation of the miss-matches at the* CO_2 *injector.*

Conclusions

It is technically feasible to (re-) inject CO_2 in a safe way into depleted gas fields, and it can also be done simultaneous with E&P operations. There is now a proven track record of over a decade of continuous CO_2 injection, supported by many risk assessment studies. The findings of this extensive scientific CO_2 re-injection research can be showcased and applied to other Carbon Capture and Storage Projects in the world.
The overall project consisted of many smaller project, which together form a multiyear, continuing project, financed by a variety of funding agencies. This has proven to be good way to get such a multiyear project going, without having all the required funding needs in place at the start. For such a project it is paramount to be in a long-lasting and close collaboration with the operator and a research institute.
The entire operation at the K12-B field went without any major complications. It can therefore be stated that safe and uneventful underground storage in depleted gas fields is possible. During the many projects taking place at K12-B, several techniques were tested and enhanced and many processes investigated. This has helped in assessing other projected CCS projects, such as P18 (Arts *et al*., 2012), De Lier (Hofstee *et al*., 2008) etc.

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