Integrity Experience Advice

CO_2 Injection Well Cost Estimation

March 2009

Prepared for the

Carbon Storage Taskforce

Declaration

The Federal Government Carbon Storage Taskforce has commissioned Resource Investment Strategy Consultants ("RISC") to provide an independent estimate of well costs for CO2 disposal wells.

The assessment of petroleum assets is subject to uncertainty because it involves judgments on many variables that cannot be precisely assessed, including reserves, future oil and gas production rates, the costs associated with producing these volumes, access to product markets, product prices and the potential impact of fiscal/regulatory changes.

The statements and opinions attributable to RISC are given in good faith and in the belief that such statements are neither false nor misleading. In carrying out its tasks, RISC has considered and relied upon information obtained from the Department of Energy, Resources and Tourism as well as information in the public domain. The information provided to RISC has included both hard copy and electronic information.

Whilst every effort has been made to verify data and resolve apparent inconsistencies, neither RISC nor its servants accept any liability for its accuracy, nor do we warrant that our enquiries have revealed all of the matters, which an extensive examination may disclose. In particular, we have not independently verified, encumbrances, regulations or fiscal terms which apply to this field.

We believe our review and conclusions are sound but no warranty of accuracy or reliability is given to our conclusions.

RISC has no pecuniary interest, other than to the extent of the professional fees receivable for the preparation of this report, or other interest in the assets evaluated, that could reasonably be regarded as affecting our ability to give an unbiased view of these assets.

Our review was carried out only for the purpose referred to above and may not have relevance in other contexts.

DOCUMENT CONTROL

CO_2 Injection Well Cost Estimation

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1 INTRODUCTION

The Federal Government Carbon Storage Taskforce is currently developing a strategy for CO2 reinjection. As part of this work suitable geological basins have been identified as potentially suitable for CO2 injection. RISC has been requested to estimate costs for injection wells in each basin, based on information provided by the Department of Resources, Energy and Tourism (DRET, the Client). This report summarises RISC's findings using two future oil price scenarios.

2 CO_2 INJECTION WELL COST ESTIMATION

2.1 Client Provided Data

The client has provided characteristics for each basin using p90, p50 and p10 nomenclature to describe the range of cases. Water depth data for offshore injection basins and injection depth are shown in the Table below. RISC has not attempted to verify this data.

	QLD			QLD			QLD			QLD		
	Bowen			Denison			Galilee			Surat		
	P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
Water Depth, m	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Injection Depth, m	1,500	1,800	2,600	-	-	-	800	1,080	1,360	1,200	1,700	2,200

	SA/QLD			SA/QLD			NSW/QLD			VIC		
	Cooper			Eromanga			Clarence- Moreton			Gippsland		
	P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
Water Depth, m	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	64	52	70
Injection Depth, m	1,950	2,400	2,850	1,200	1,700	2,100	1,000	1,500	2,000	2,100	2,700	3,300

	VIC			VIC			VIC			VIC		
	Bass			Torquay			Otway - East			Otway -West		
	P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
Water Depth, m	-	77	82	78	73	79	N/A	64	85	-	-	85
Injection Depth, m	-	2,650	3,000	1,100	1,500	1,800	1,100	1,800	2,500	-	-	1,700

	WA			WA			WA			WA		
	Darling			Perth -Onshore South			Perth - Onshore North			Perth - Vlaming		
	P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
Water Depth, m	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	109	147
Injection Depth, m	900	1,300	-	-	-	-	-	-	-	1,800	2,130	2,630

Table 1 Data Provided by the Client

2.2 Assumptions

RISC has used its proprietry cost estimating tool to assess the cost of CO_2 injection wells of for the different depth in the various basins. Well time/depth data for the wells drilled between 1990 and 2007 has been gathered from the APPEA[1] Quarterly Drilling Statistics database and used for benchmarking. The figures below show the depth vs time distributions for onshore/and offshore wells drilled in the basins under consideration.

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[1] Australian Petroleum Producers and Exploration Association

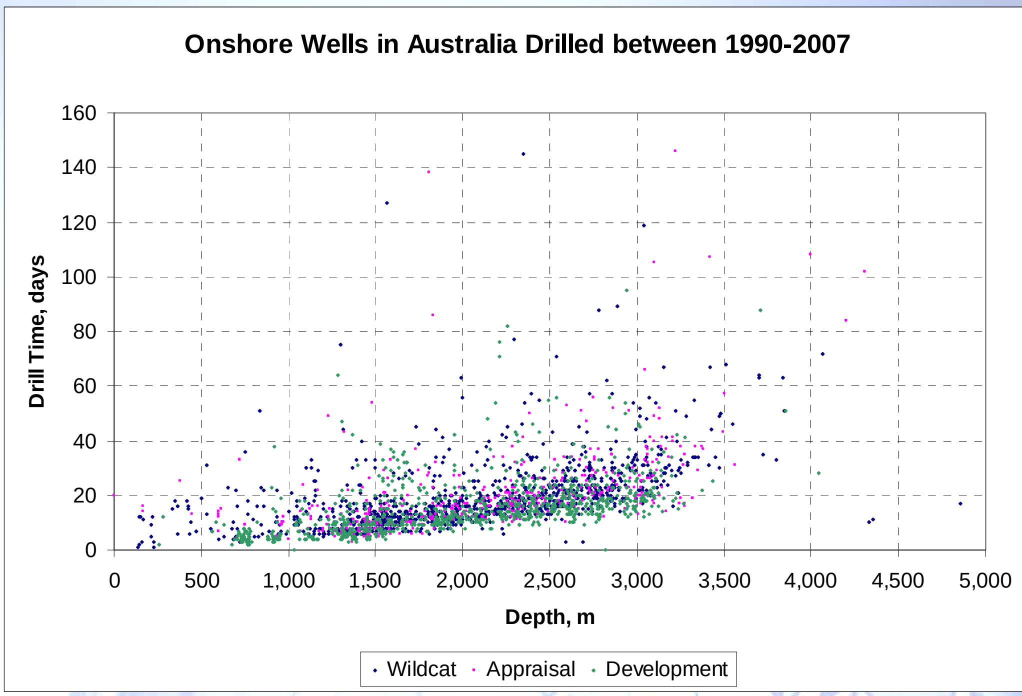

Figure 1 Depth vs Time Curves for Onshore Wells

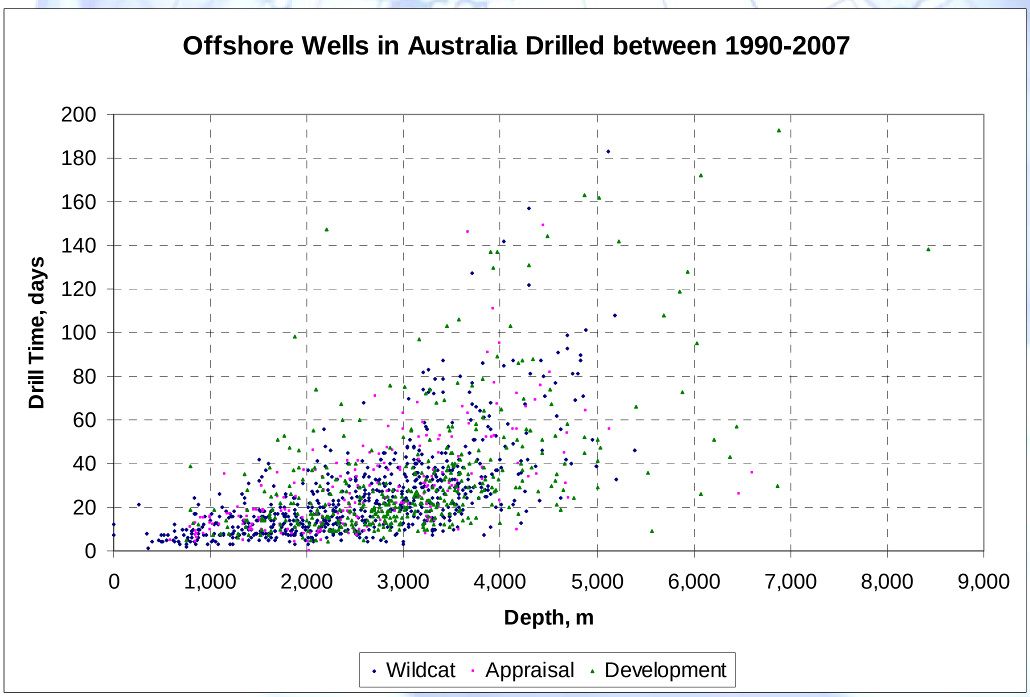

Figure 2 Depth vs Time Curves for Offshore Wells

Given the uncertainties in the oil and gas services market and drilling activities in particular, RISC has elected to create two estimates, for oil price environments of US$50/bbl and US$100/bbl. Increased market activity based on historically high oil prices has caused recent widespread cost increases and drilling rig rates in particularlr have been subject to extraordinary increases.

The figure below shows Upstream Cost Index (an index developed by IHS Energy to monitor upstream oil and gas cost developments) and ODS Petrodata Rig Rate Index movements since end-2004, with WTI oil price.

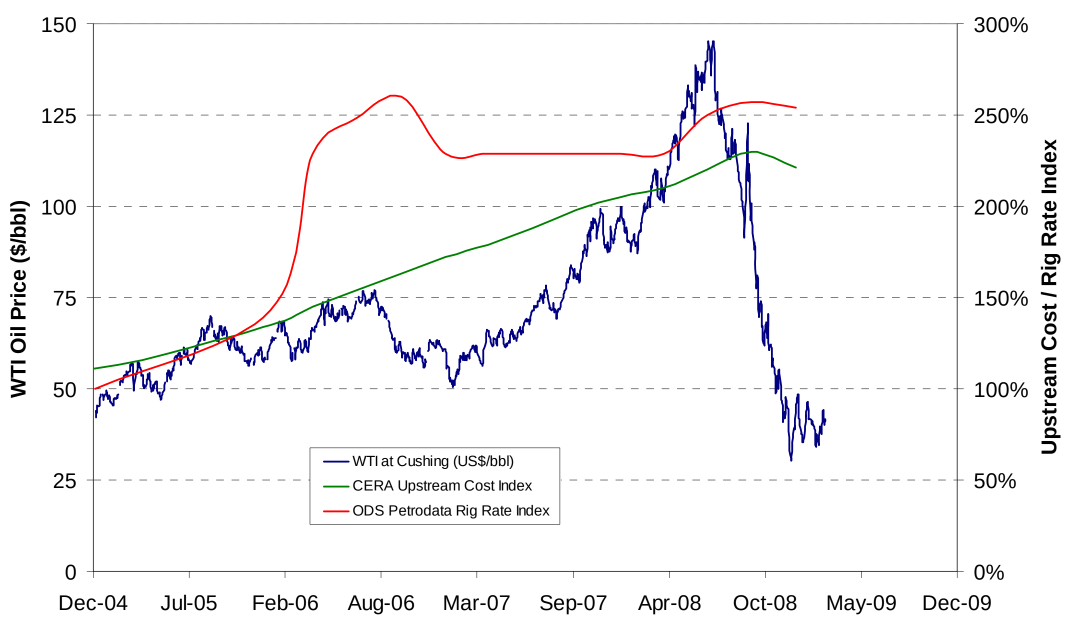

Figure 3 Oil Price vs CERA Upstream Cost Index and Rig Rate Index

RISC has also used the CRU[2]spi Steel Index for the two oil price environments to account for the effects of steel prices on the drilling and completion materials.

A summary of unit costs used by RISC for the well cost estimations is presented below:

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[2] Commodity Resource Unit

			Onshore <1000 m	Onshore >1000 m	Shallow Water	Deep Water
50$/bbl Oil Price Economic Environment	CRUSPI Index		150	150	150	150
	Rig Rate	US$k/d	12.5	17.5	140	275
	Service/Support Rate	US$k/d	10	12.5	125	150
100$/bbl Oil Price Economic Environment	CRUSPI Index		250	250	250	250
	Rig Rate	US$k/d	17.5	25	200	400
	Service/Support Rate	US$k/d	12.5	15	150	175

Table 2 Summary of Assumptions

- onshore wells up to 1,000-1,200 m drilled depth can be achieved by using a small capacity cheaper rig as used for CSG operations in Queensland.
- offshore, a water depth of 100 m is assumed as the limit for jack-up drilling rigs; at greater water depths a semi-submergible rig is assumed to be required.
- all wells are assumed to be vertical (although in practice projects may utilise horizontal wells).
- all well cost estimates have a 20% contingency related to the time component.
- an exchange rate of 0.7 has been used for conversion from US$ to A$
- costs are estimated in 2009 dollars

2.3 RISC Time vs Depth and Cost vs Depth Curves

RISC's time vs depth and cost vs depth curves for the estimates for onshore and offshore CO_2 injection wells are shown below:

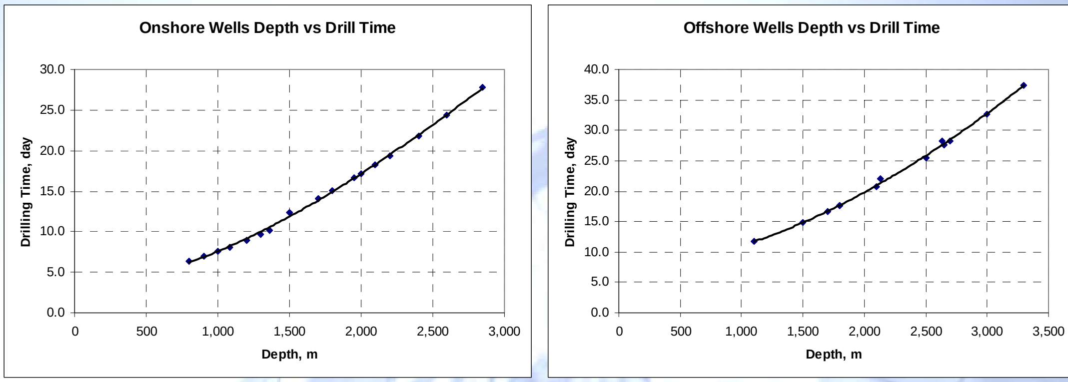

Figure 4 Time vs Depth Curves

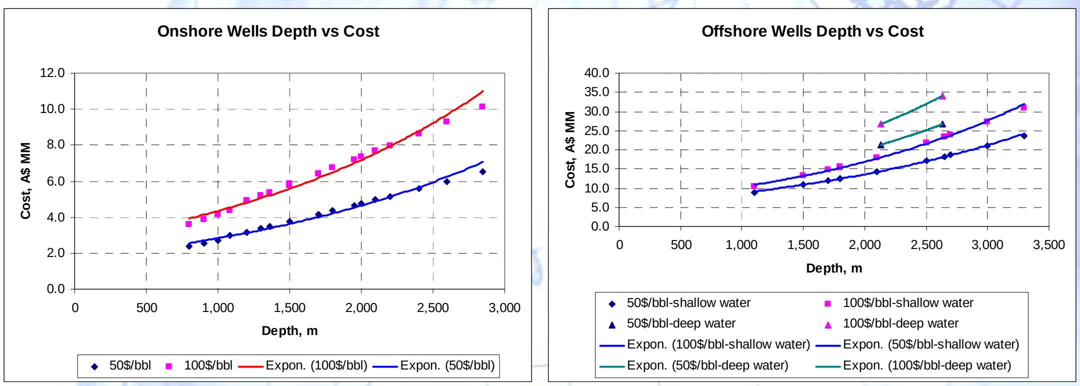

Figure 5 Cost vs Depth Curves

Cost estimates have been compared to the spread of historic data in the charts below, which includes all types of wells - wildcats, appraisal and development. RISC estimates include time for rig mobilisation, establishment and well completions, while some past actual well costs do not and RISC estimates include 20% time-related contingency.

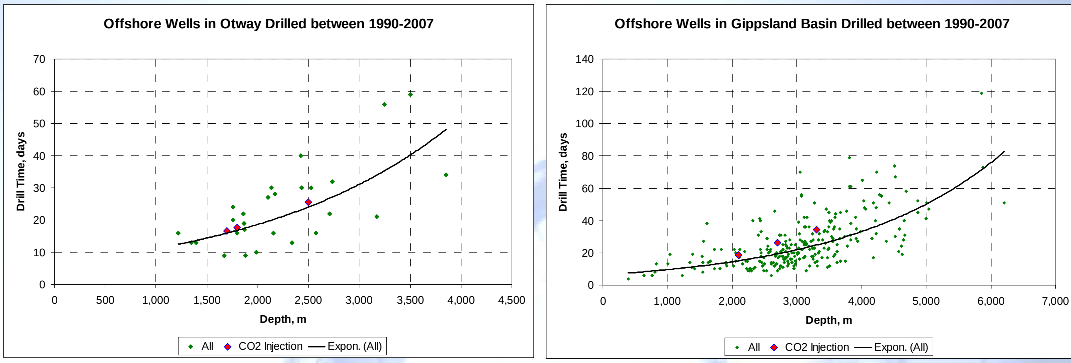

Figure 6 Comparison of Offshore Well Time Estimates against Historic Data

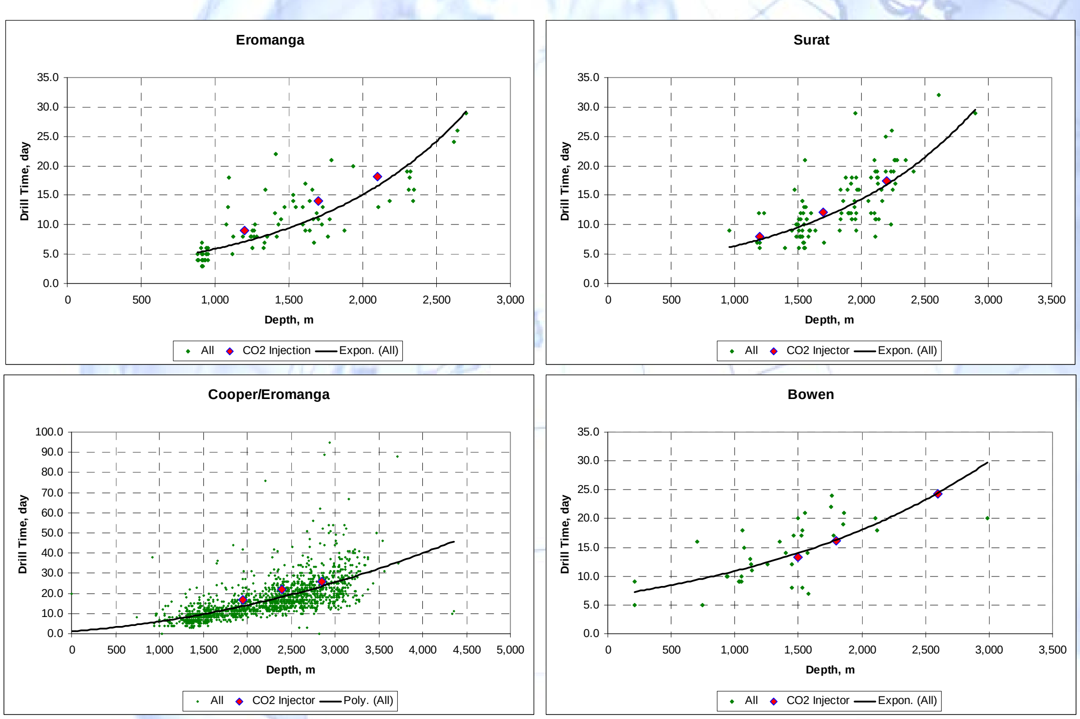

Figure 7 Comparison of Onshore Well Time Estimates against Historic Data

2.4 Well Costs

RISC's well cost estimates for all basins and depths under consideration are tabulated below:

			QLD			QLD			QLD			QLD		
			Bowen			Denison			Galilee			Surat		
			P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
	Water Depth	m	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Depth	m	1,500	1,800	2,600	-	-	-	800	1,080	1,360	1,200	1,700	2,200
	Drilling Time	day	11.3	15.1	24.3	-	-	-	6.4	8.1	10.2	9.0	14.1	19.4
50$/bbl	Unit Well Cost	US$ MM	2.6	3.1	4.2	-	-	-	1.7	2.1	2.4	2.2	2.9	3.6
		A$ MM	3.7	4.4	6.0	-	-	-	2.4	3.0	3.5	3.2	4.2	5.2
100$/bbl		US$ MM	4.0	4.7	6.5	-	-	-	2.5	3.1	3.8	3.4	4.5	5.6
		A$ MM	5.8	6.7	9.3	-	-	-	3.6	4.4	5.4	4.9	6.4	8.0

			SA/QLD			SA/QLD			NSW/QLD			VIC		
			Cooper			Eromanga			Clarence- Moreton			Gippsland		
			P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
	Water Depth	m	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	64	52	70
	Depth	m	1,950	2,400	2,850	1,200	1,700	2,100	1,000	1,500	2,000	2,100	2,700	3,300
	Drilling Time	day	16.6	21.8	27.9	9.0	14.1	18.2	7.6	12.3	17.1	20.7	28.2	37.5
50$/bbl	Unit Well Cost	US$ MM	3.3	3.9	4.6	2.2	2.9	3.5	1.9	2.7	3.3	10.1	13.0	16.6
		A$ MM	4.7	5.6	6.5	3.2	4.2	5.0	2.7	3.8	4.8	14.4	18.6	23.7
100$/bbl		US$ MM	5.0	6.0	7.1	3.4	4.5	5.4	2.9	4.1	5.1	12.6	16.8	21.7
		A$ MM	7.2	8.6	10.1	4.9	6.4	7.7	4.1	5.8	7.4	18.0	23.9	30.9

			VIC			VIC			VIC			VIC		
			Bass			Torquay			Otway - East			Otway -West		
			P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
	Water Depth	m	-	77	82	78	73	79	N/A	64	85	-	-	85
	Depth	m	-	2,650	3,000	1,100	1,500	1,800	1,100	1,800	2,500	-	-	1,700
	Drilling Time	day	-	27.5	32.6	11.8	14.8	17.6	14.3	17.6	25.5	-	-	16.6
50$/bbl	Unit Well Cost	US$ MM	-	12.8	14.8	6.2	7.6	8.8	2.4	8.8	12.0	-	-	8.4
		A$ MM	-	18.3	21.1	8.9	10.9	12.5	3.5	12.5	17.2	-	-	12.0
100$/bbl		US$ MM	-	16.4	19.1	7.2	9.2	10.8	3.4	10.8	15.3	-	-	10.3
		A$ MM	-	23.5	27.3	10.3	13.1	15.5	4.9	15.5	21.9	-	-	14.7

			WA			WA			WA			WA		
			Darling			Perth -Onshore South			Perth - Onshore North			Perth - Vlaming		
			P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
	Water Depth	m	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	42	109	147
	Depth	m	900	1,300	-	-	-	-	-	-	-	1,800	2,130	2,630
	Drilling Time	day	7.0	9.7	-	-	-	-	-	-	-	17.6	22.1	28.3
50$/bbl	Unit Well Cost	US$ MM	1.8	2.4	-	-	-	-	-	-	-	8.7	14.9	18.6
		A$ MM	2.5	3.4	-	-	-	-	-	-	-	12.5	21.3	26.6
100$/bbl		US$ MM	2.7	3.6	-	-	-	-	-	-	-	10.8	18.7	23.8
		A$ MM	3.9	5.2	-	-	-	-	-	-	-	15.4	26.7	34.0

Table 3 Summary of Cost Estimates

3 APPENDIX – WELL DESIGN CONSIDERATIONS[3]

Drilling and completion technology for injection wells in the oil and gas industry has evolved to a highly sophisticated state, such that it is now possible to drill and complete vertical and extended reach wells (including horizontal wells) in deep formations, using multiple completions and with corrosive fluids. On the basis of extensive oil industry experience, the technologies for drilling, injection, stimulation and completion for CO_2 injection wells exist and are being practised with some adaptations in CO_2 storage projects. In a CO_2 injection well, the principal well design considerations include pressure, corrosion-resistant materials and production and injection rates.

The design of a CO_2 injection well is very similar to that of a gas injection well in an oil field or natural gas storage project. Most downhole components need to be upgraded for higher pressure ratings and corrosion resistance. The technology for handling CO_2 has already been developed for Enhanced Oil Recovery operations and for the disposal of acid gas. Horizontal and extended reach wells can be good options for improving the rate of CO_2 injection from individual wells. The Weyburn field in Canada is an example in which the use of horizontal injection wells is improving oil recovery and increasing CO_2 storage. The horizontal injectors reduce the number of injection wells required for field development and has the added advantage that it can create injection profiles that reduce the adverse effects of injected-gas preferentially flowing through high-permeability zones.

An injection well and a wellhead are depicted in Figure 8.

Injection wells are commonly equipped with two valves for well control, one for regular use and one reserved for safety shutoff. In acid gas injection wells, a downhole safety valve is incorporated in the tubing, so that if equipment fails at the surface, the well is automatically shut down to prevent back flow. It is recommended that an automatic shutoff valve is installed on all CO_2 wells to ensure that no release occurs and to prevent CO_2 from inadvertently flowing back into the injection system. A typical downhole configuration for an injection well includes a double-grip packer, an on-off tool and a downhole shutoff valve. Annular pressure monitors help detect leaks in packers and tubing which is important in taking rapid corrective action. To prevent dangerous high-pressure buildup on surface equipment and to avoid CO_2 releases into the atmosphere, CO_2 injection must cease as soon as leaks occur. Rupture disks and safety valves can be used to relieve built-up pressure. Adequate plans need to be in place for dealing with excess CO_2 if the injection well needs to be shut in. Options include having a backup injection well or methods to safely vent CO_2 to the atmosphere.

The biggest difference between a typical gas injection well and CO2 injection well is cement and casing to cater for the CO2 corrosion factor. To cement a CO2 Sequestration well, a special (and very expensive) type of cement called “thermalock” needs to be used. Anything equipment that is going to come into contact with the CO2 i.e parts of the wellhead, casing shoes etc. should be chrome steel.

[3] IPCC Special Report on Carbon Dioxide Capture and Storage - 2005

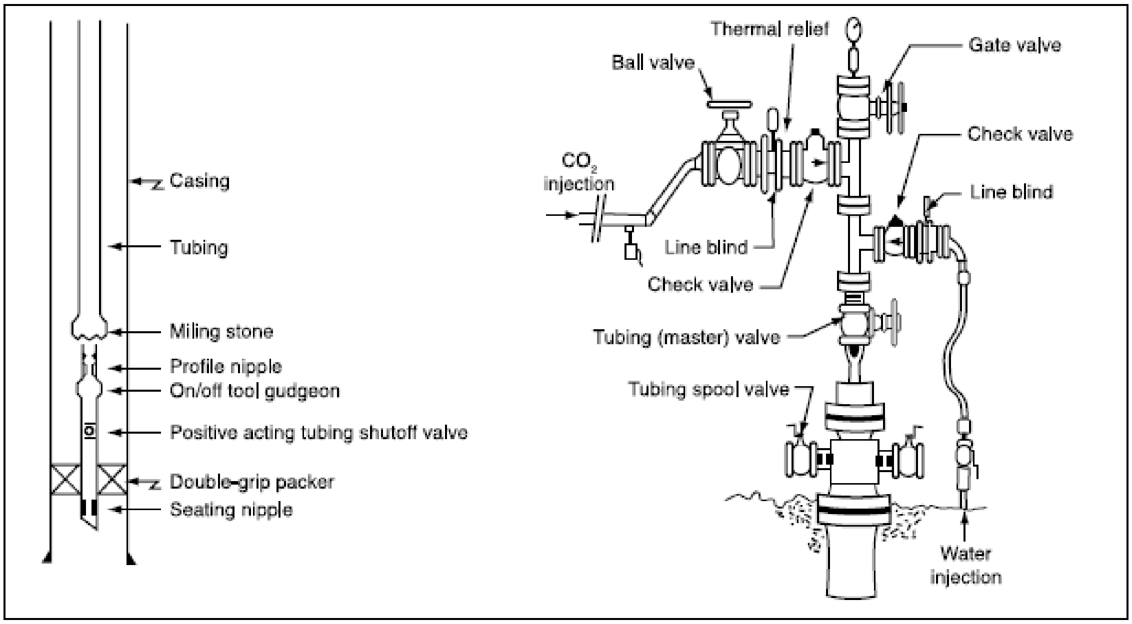

Figure 8 Typical CO_2 Injection Well and Wellhead Configuration

Proper maintenance of CO_2 injection wells is necessary to avoid leakage and well failures. Several practical procedures can be used to reduce the chance of CO_2 blow-out (uncontrolled flow) and mitigate the adverse effects if one should occur. These include periodic wellbore integrity surveys on drilled injection wells, improved blow-out prevention (BOP) maintenance, and installation of additional BOP on suspect wells, improved crew awareness, contingency planning and emergency response training.

For CO_2 injection through existing and old wells, key factors include the mechanical condition of the well and quality of the cement and well maintenance. A leaking wellbore annulus can be a pathway for CO_2 migration. Detailed logging programmes for checking wellbore integrity can be conducted by the operator to protect formations and prevent reservoir cross-flow. A well used for injection must be equipped with a packer to isolate pressure to the injection interval. All materials used in injection wells should be designed to anticipate peak volume, pressure and temperature. In the case of wet gas (containing free water), use of corrosion-resistant material is essential.

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