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DEPT. OF RESOURCES, ENERGY AND TOURISM

DRET CCS Task Force Support

Pipeline and Injection Pumping Study

401001-00514-00-PL-REP-0001

21-Aug-09

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SYNOPSIS

The Australian Government Department of Resources, Energy and Tourism (DRET) has requested WorleyParsons to conduct a study to determine the required pumping power and costs associated with CO_2 injection.

This report presents pumping duties required for CO_2 injection based on a flow rate of 10.0 Mtpa at eight (8) different injection pressures (from 10 MPa to 24 MPa in 2 MPa increments) as well as high level CAPEX estimates for each of these cases.

Disclaimer

PROJECT 401001-00514 - DRET CCS TASK FORCE SUPPORT

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
0	Issued for Use	A Cook	P Cox				

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1. INTRODUCTION

The Commonwealth Department of Resources, Energy and Tourism (DRET) has requested WorleyParsons to provide specialist support for carbon dioxide (CO_2) pipeline networks as part of their review into carbon capture and storage (CCS). This report summarises the pumping duties, including associated high level CAPEX estimates, required for CO_2 injection based on different injection pressures for a proposed pipeline system transporting near pure supercritical carbon dioxide. In addition this report describes the relationship between pumping pressure differential, required pumping power, flow rate and project costs.

This document presents pumping duties required for CO_2 injection based on eight (8) different injection pressures (from 10 MPa to 24 MPa in 2 MPa increments) at a nominal flow rate of 10.0 Mtpa as well as associated high level CAPEX estimates.

2. PROCESS DESIGN BASIS

A hydraulic model of the proposed pipeline system was used to determine the pumping duties associated with different well injection pressures at a given pipeline terminal pressure and flow rate. This model has been developed based on the Summary of Pipeline Sizing Study [401001-00507-00-PR-REP-0001].

2.1 Process Modelling Software

The flow model was constructed using Aspen HYSYS version 6.5 with PIPESYS extension and Peng Robinson equations of state. Aspen HYSYS has been used in various CO_2 related pipeline projects, and as such, has been incorporated for this scope of work.

2.2 Gas Compositions

The following composition shown in Table 1 has been assumed in the hydraulic model to represent the carbon dioxide being transported through the system. Note that the CO_2 fluid is assumed to be free of water.

Table 1: CO_2 Composition

Component	Mole Percent
Carbon Dioxide	99.97
Nitrogen	0.02
Hydrogen	0.01
Total	**100.00**

2.3 CO_2 Injection Parameters

The following parameters and specifications have been used in the steady state model to determine the pumping requirements for CO_2 injection.

2.3.1 Flow Rate

The nominated flow rate to determine the pumping requirements is 10.0 Mtpa based on information supplied by DRET. However, it should be noted that flow rate and pumping duties are linearly related for the same pressure increment eg for any given pumping pressure differential as the flow rate is doubled the required pumping power doubles.

2.3.2 Pressure

The following pressure specifications have been used to determine the pumping requirements.

- Pipeline Terminal Pressure 8.0 MPa

- CO_2 Injection Pressures — Refer to Table 2

Table 2: Design Injection Pressures

Pressure Case	Injection Pressure (MPa)	Pressure Differential (MPa)
1	10.0	2.0
2	12.0	4.0
3	14.0	6.0
4	16.0	8.0
5	18.0	10.0
6	20.0	12.0
7	22.0	14.0
8	24.0	16.0

2.3.3 Temperature

The following temperature specification has been set to determine the pumping requirements.

- Pipeline Outlet Temperature — 25°C

2.3.4 Pump Specifications

The following pump specifications have been assumed to determine the pumping requirements.

- Adiabatic Efficiency — 75%
- Negligible pressure drop in piping between the pipeline terminal and pump inlet.

2.4 Required Pumping Power

Table 3 summarises the 8 injection pumping cases based on different injection pressures.

Table 3: Summary of Pumping Requirements

Pressure Case	Injection Pressure (MPa)	Pumping Duty (MW)
1	10.0	1.2
2	12.0	2.3
3	14.0	3.5
4	16.0	4.6
5	18.0	5.8
6	20.0	6.9
7	22.0	8.1
8	24.0	9.2

Important Notes:

1. Pipeline terminal pressure for all cases is 8.0 MPa.
2. Pump assumed to operate at an adiabatic efficiency of 75%.
3. Above results based on a nominal flow rate of 10.0 Mtpa.

3. CAPEX COST ESTIMATES

3.1 Cost Estimation Parameters

The project cost estimates are based on the following parameters:

- Nominal Flow rate of 10 Mtpa
- 100% pump redundancy ie a complete standby pump & engine in readiness if operating pump fails
- Diesel driven pump engines (if gas or HV electricity is in close proximity to the pump station, this would be a preferred alternative to reduce operating costs)
- Ancillary mechanical equipment including automatic & manual isolation valves, flow meter, flow control valve and diesel generator
- Ancillary instrumentation equipment including PLC system, SCADA and control room
- Onshore based injection facility
- Land acquisition and GST are excluded.

3.2 CAPEX Cost Estimates

Table 4: CAPEX Cost Estimates

Pump Suction Pressure MPa	Pump Discharge Pressure Mpa	Pump Differential Pressure MPa	Required Pumping Power (MW)	TIC $M
8	10	2	1.2	20.56
8	12	4	2.3	23.41
8	14	6	3.5	25.80
8	16	8	4.6	28.58
8	18	10	5.8	32.14
8	20	12	6.9	34.86
8	22	14	8.1	37.65
8	24	16	9.2	40.24

3.3 Cost Estimation Methodology

Although pricing was sought from four pump vendors as early as 23 April, the vendors have been slow in responding to the request. However, one quotation and an estimate of price for the largest required pumping power (9.2 MW) was received as well as budget pricing for the pump engines.

For the 9.2 MW pumping power case the pump & engine driver including a complete standby unit equates to approximately 45% of the total installed cost. In contrast for the 1.2 MW pumping power case the pump & engine driver including standby unit equates to approximately 12% of the total installed cost. This contrast is due to the fact that both stations require similar ancillary mechanical, civil and instrumentation works.

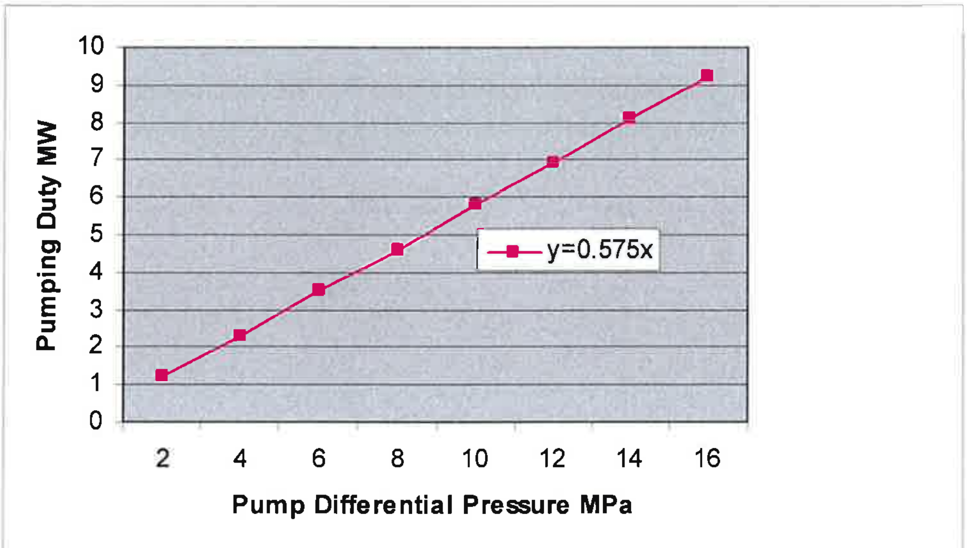
The ancillary project costs incorporate costs for supply and installation of mechanical and instrumentation equipment, civil works as well as engineering, procurement and construction management (EPCM). The estimates have been built up with consideration of several recent Australian compressor projects combined with estimates of upcoming compressor projects.

The CAPEX estimates are classified as ball park figures and are based on limited engineering information. Consequently, the estimates have an accuracy range in the order of +/- 40%.

4. SUMMARY OF RESULTS

4.1 Pump Differential Pressure & Required Power

The graph below shows the relationship between pump differential pressure and pumping duty for a designated flow rate of 10 Mtpa.



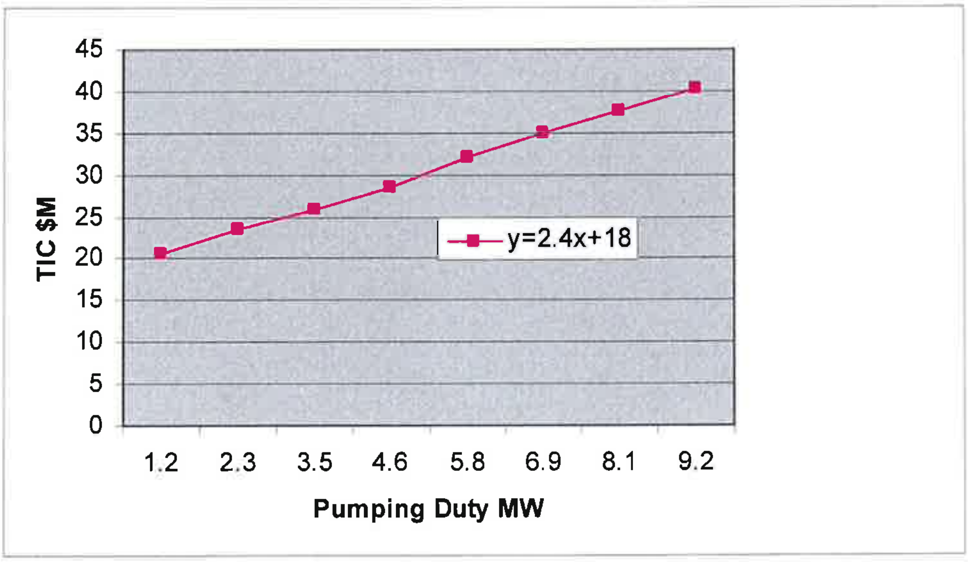
For the designated flow rate of 10 Mtpa the graph indicates that the pumping duty approximately equates to the differential pressure multiplied by 0.575 ie y = 0.575x where y is pumping duty & x is differential pressure. As described in Section 2.3.1 pumping duty is linearly related to flow rate. Hence, for any nominated flow rate and pressure differential the pumping duty may be easily calculated. For example for a differential pressure of 12.5 MPa at a flow rate of 13 Mtpa the required pumping power is approximately

= 0.575 * 12.5 *13/10 = 9.3 MW

NB. As noted in Section 2.3.4 the pumps are assumed to operate at 75% efficiency.

4.2 Required Pumping Power and CAPEX

The graph below shows the relationship between required pumping power and CAPEX for a designated flow rate of 10 Mtpa.



For the designated flow rate of 10 Mtpa the graph indicates that estimated CAPEX cost approximately equates to the pumping power multiplied by 2.4 plus 18 ie y = 2.4x +18 where y is estimated CAPEX cost in A$M and x is required pumping power. As described in Section 2.3.1 the pumping duty is linearly related to flow rate. Hence, for any nominated flow rate and pressure differential the estimated CAPEX may be easily calculated. Further to the example in Section 4.1 for a differential pressure of 12.5 MPa at a flow rate of 13 Mtpa the estimated CAPEX is approximately

= (2.4 * 9.3) + 18 = A$40M approx.

where 9.3MW is the required pumping power adjusted for a 13 Mtpa flow rate as calculated in Section 4.1.

Notes:

1. As noted in Section 2.3.4 the pumps are assumed to operate at 75% efficiency.
2. Due to limitations of pumps with respect to maximum pressure differential and flow rate that may be accommodated, the above rule of thumb for calculating CAPEX costs should not be used unless the pump parameters are within the range of this study or the pump range as specified by the vendor (in this case Clyde Pumps).
3. As noted in Section 3.3 the CAPEX estimates have an accuracy of +/- 40%.