Modelling & Simulation of Dynamic CO_2 Transport Systems for the Purpose of Carbon Capture & Storage

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Introduction

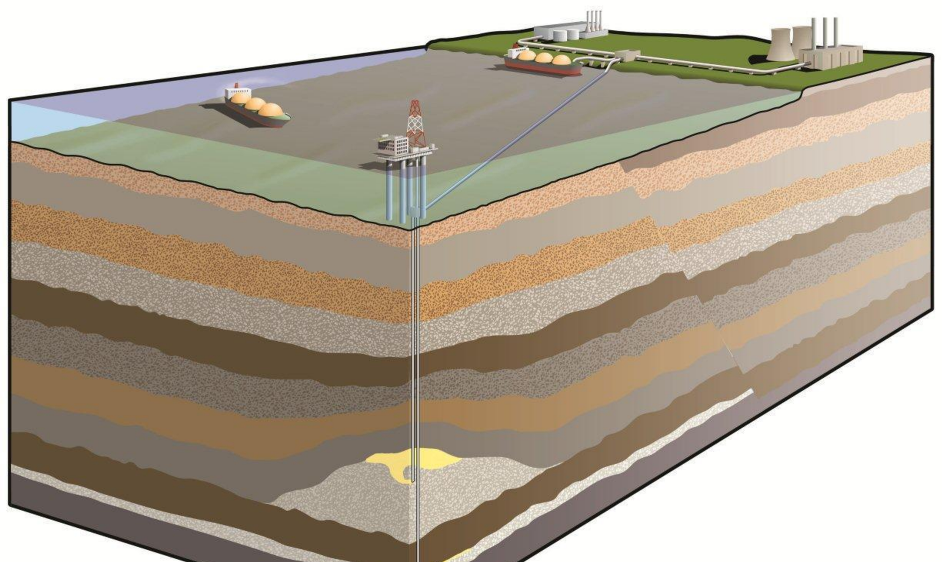

Figure 1: Full Chain CCS System

- An important part of the carbon capture and storage process is the transportation of CO_2 from the source to the reservoir where the CO_2 is to be sequestered.
- It has been found that the most economical method for transporting large volumes of CO_2 is via pipeline rather than by shipping.
- It is important that the dynamics within CO_2 pipelines is well understood to enable efficient, economical and flexible operation.
- To be able to have a greater understanding of the transport system a modelling and simulation tool known as gCCS has been utilised.

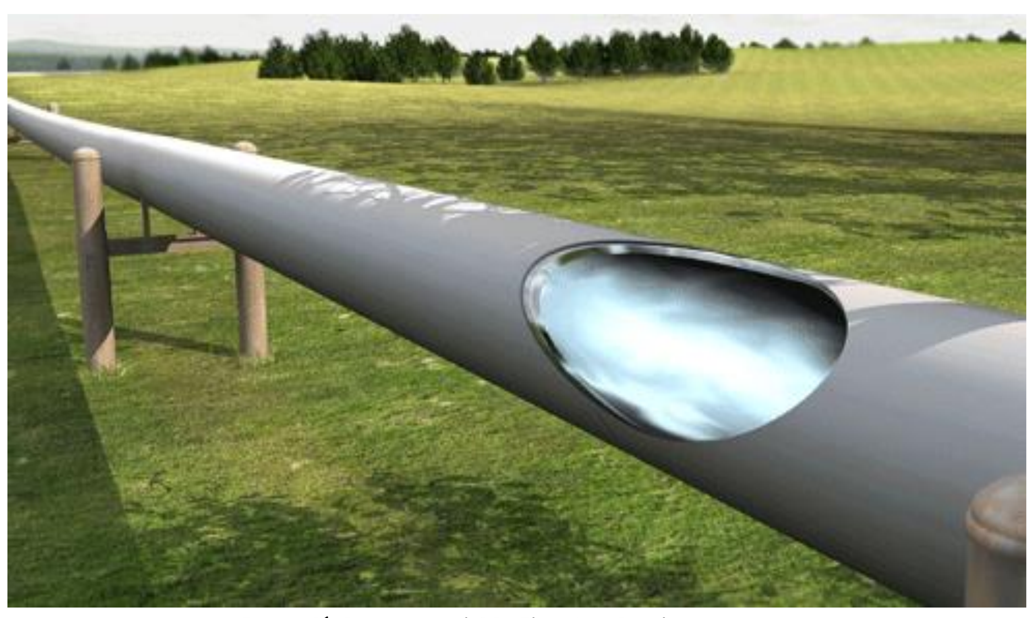

Figure 2[1]: Supercritical CO_2 Flow in a Pipeline

Research Aims

Given future limitations on construction of unabated fossil fuelled power stations, a question arises on whether power plants integrated with CCS can be as flexible as is required of them while remaining competitive with renewables. The aims of the research are to:

1. Understand the effects of changing flowrates on CO_2 transport.
2. Know if buffer storage of CO_2 is necessary to allow the system to remain flexible.
3. Deduce which phase of CO_2 is best able to cope with changes in flowrates.

Research Method

To carry out the research a newly developed piece of software has been utilised. The Energy Technologies Institute's System Modelling Toolkit which was developed by Process Systems Enterprise (PSE) allows for a full chain CCS system to be modelled and simulated. To answer the aims of the research the following actions will be implemented:

Flow sheet development → **Process Simulation** → **Data Analysis**

CO_2 Transport Model & Results

Model Development

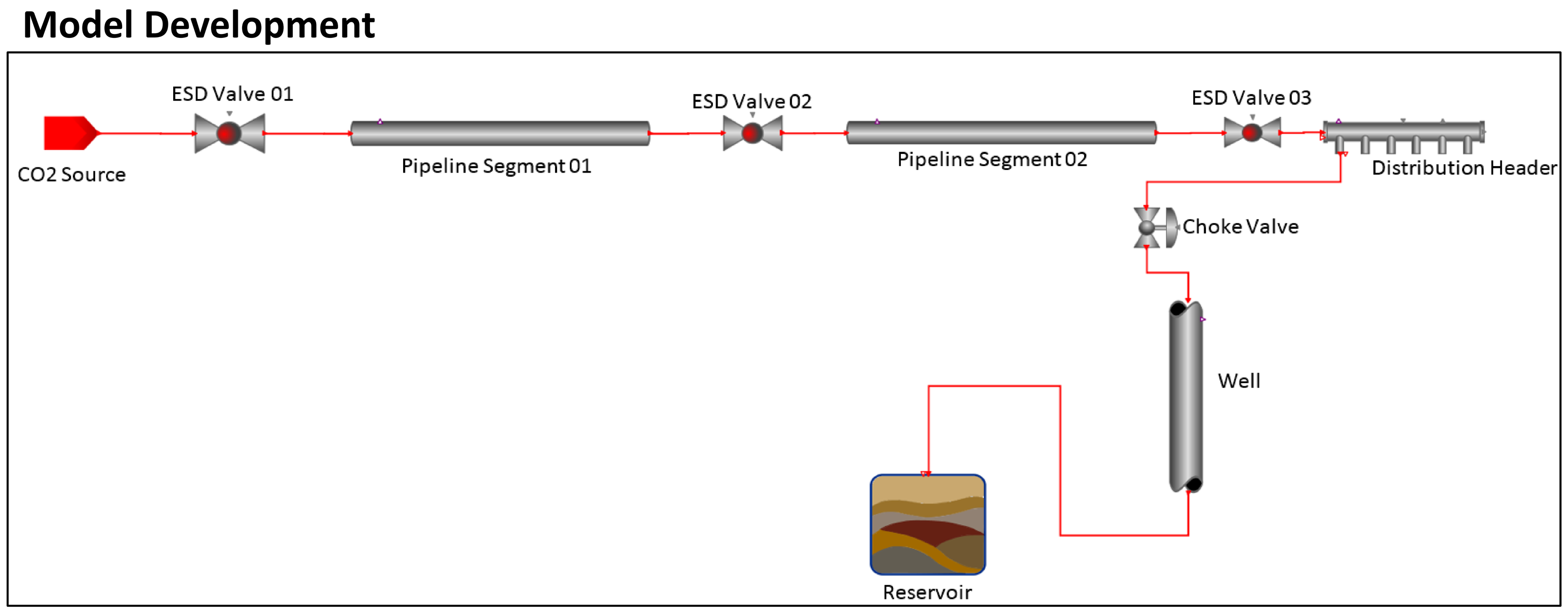

Figure 3: Flowsheet of a CO_2 Transport and Storage System.

Model Input	Value
Pipeline1 length	52,000 m
Pipeline2 length	52,000 m
Well depth	1,200 m
Pipeline Diameter	0.6096 m
Inlet Temperature	293 K
Reservoir Pressure	150 Bar

Process Input	Value
Initial Mass Flowrate	100 kg/s
Final Mass Flowrate	50 kg/s
Ramp Rate	-4 kg/s/min
Ramp Time	750 s
Total Simulation Time	500,000 s

Results

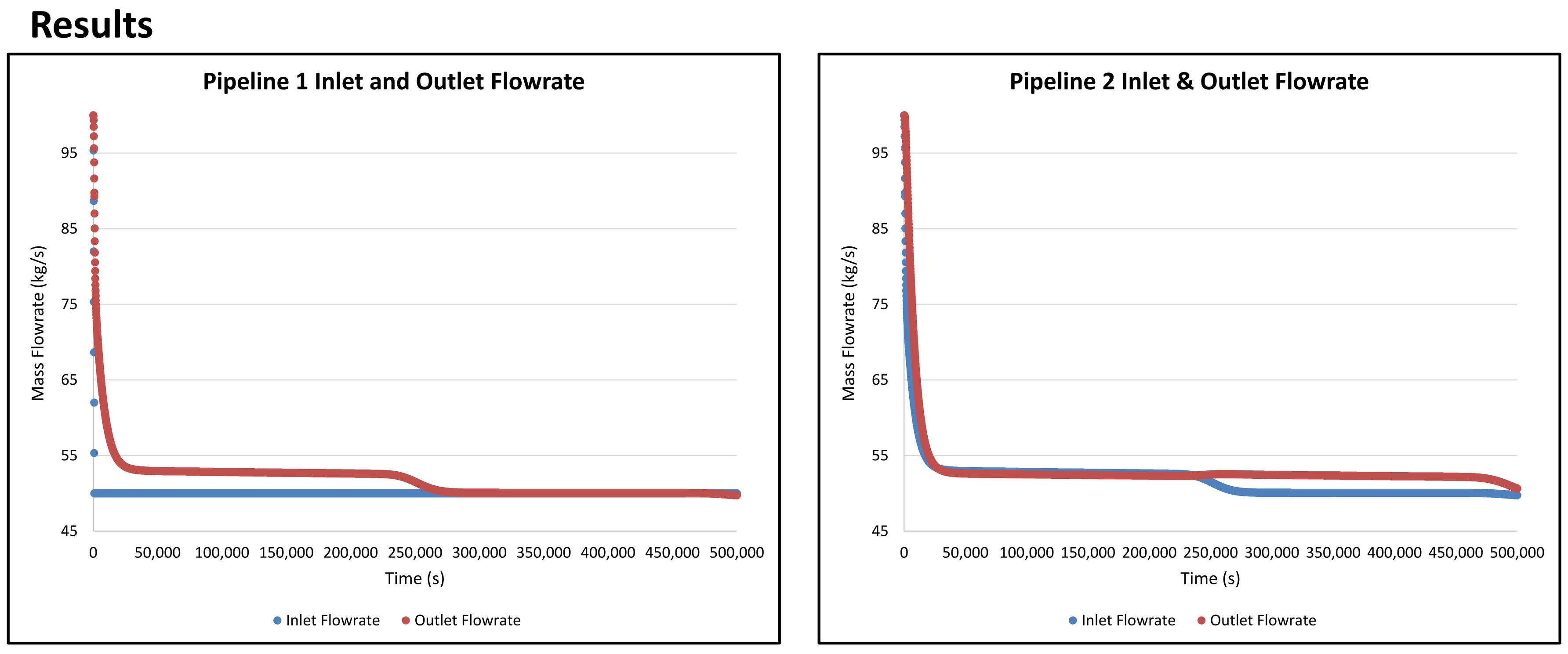

Figure 4: Inlet and Outlet Flowrate for Pipeline Segment 1 and 2

Figure 4 shows the flowrate profiles of pipeline 1 and pipeline 2 shown in Figure 3. After a ramp down of CO_2 from 100 kg/s to 50 kg/s it can be seen that it takes a significant time for the outlet flowrate to reach the same value as the inlet flowrate. This indicates that it can take a matter of hours or days for a disturbance in the flowrate to fully travel through a pipeline of the decided upon length.

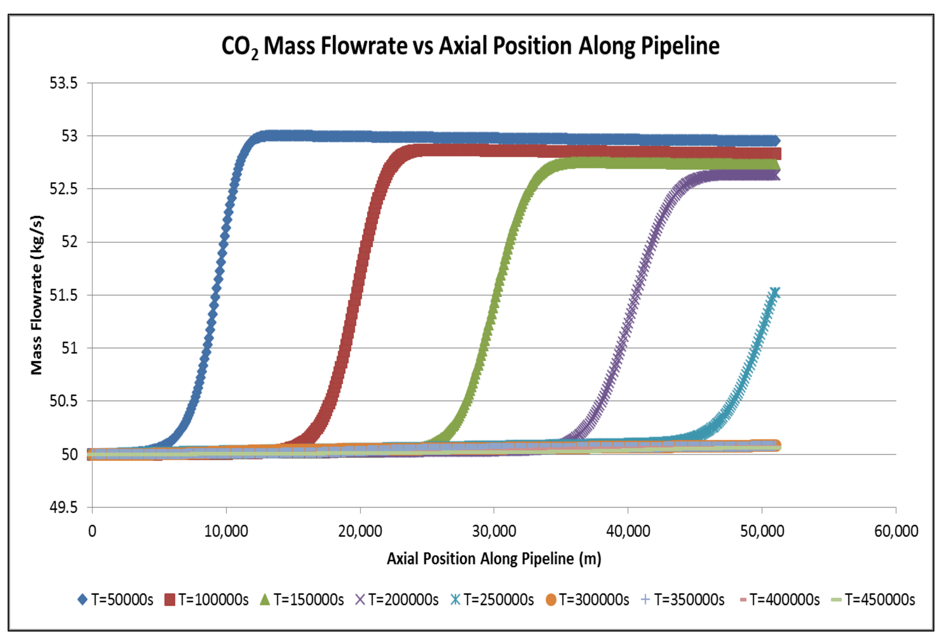

Figure 5: Mass flowrate Profile along Pipeline Segment 1

- The offset that is observed in the mass flowrate can be seen in Figure 5.
- The offset moves as a wave through the pipeline until it reaches the end.
- Once the wave has propagated through, the mass flowrate along the entire length of the pipe is equal.
- The wave moves through the pipeline at the same velocity as the fluid.

- The density profile along pipeline 1 can be seen in Figure 6.
- Similar to the mass flowrate a wave like profile is observed.
- Once the process has come to completion a linear increase in the density is observed.
- This increase can be explained by the temperature change within the pipeline due to relatively low ambient temperatures.

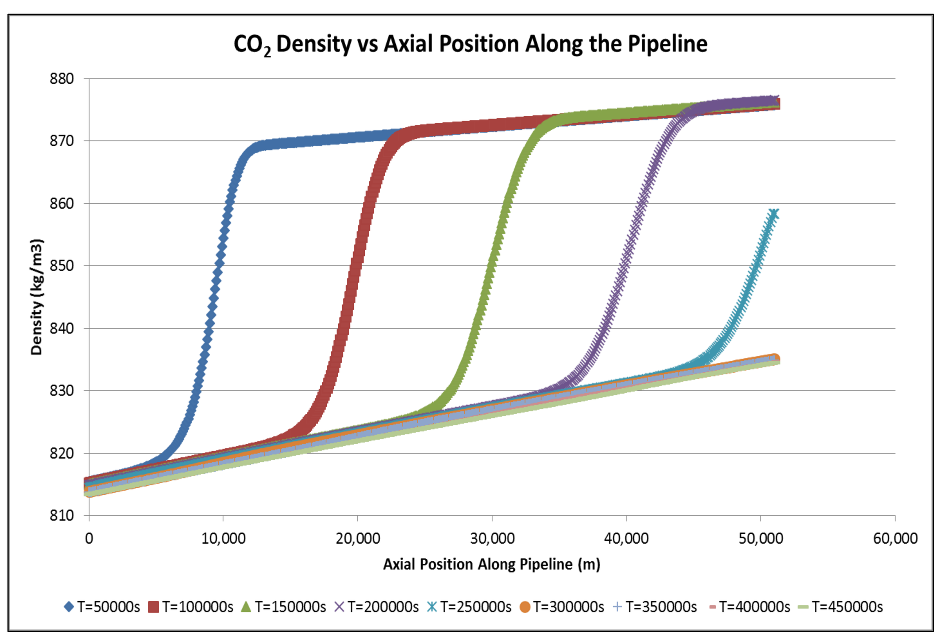

Figure 6: Density Profile along Pipeline Segment 1

Further Work

Further Work

From the results that have been obtained it is necessary to take the research further. The next step is to obtain a greater understanding of the reasons behind the results. This can be done through carrying out a sensitivity analysis looking at all possible variables and observing their effects on the offset. It will also be necessary to look at the effects of impurities on this offset as it is known that impurities such as nitrogen and oxygen change the phase diagram of CO_2.

Impact

The impacts of the results are potentially quite significant. The offset that has been observed will affect the way the transport system should be operated. This effect may potentially be quite advantageous to both power plant and reservoir operators as it allows some form of buffer storage in the system for significant periods of time. This will therefore allow a system to be more flexible without the need for significant amounts of buffer storage.

References:
[1] CO2PIPETRANS, DNV-GL, Available from: https://www.dnvgl.com/oilgas/innovation-development/joint-industry-projects/co2pipetrans.html. Accessed on 24/04/2015

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