Comparison of detailed capital expense estimates for two NGCC retrofits with capture by amine scrubbing

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Abstract

A major challenge to the adoption of carbon capture and storage (CCS) is the high and uncertain capital investment required. Of capture technologies in development, post-combustion capture (PCC) using amine scrubbing is the most mature. There has been extensive testing at pilot-scale, and commercial-scale demonstration projects are in various stages \cite{1}. However, most CCS cost analyses in open literature rely on “simplified” cost estimates, as the cost details of commercial-scale projects are generally not published in detail \cite{2,3,4}. There has been increasing awareness that for capture retrofit applications in particular, there can be significant costs to integrate the capture unit with the host site \cite{5}. These costs are dependent on the details of the host site, and are therefore frequently neglected in academic studies. Another important part of understanding the true cost of capture is comparing studies to “understand the causes of any significant differences” \cite{5}.

The goal of this work is to better understand capital expenditure (CAPEX) of amine scrubbing projects by comparing two detailed bottom-up CAPEX estimates developed for two proposed retrofits of NGCC power plants with amine scrubbing units. This comparison yields insights that could reduce the costs of future CCS projects. A key finding is that the layout and special requirements (such as water availability) of the host site can greatly increase the cost of ancillary equipment like flue gas ductwork and heat exchangers. The steam supply (extraction vs. boiler) also significantly affects the cost of utility equipment. We also compare absorber designs in detail and evaluate the costs of different absorber shapes.

One of the estimates analyzed in this paper is a part of a front-end engineering design (FEED) for the Piperazine with the Advanced Stripper (PZASTM) process at the Mustang Station power plant in Denver City, TX, USA \cite{6}. The second is from a FEED for another amine scrubbing process using 35 wt \% monoethanolamine (MEA) at the Panda Power Sherman Station in Sherman, TX, USA \cite{7}. In this work we first summarize key design parameters and features of the respective amine scrubbing applications. Then the following analyses are carried out:

- Estimated direct field costs of each project are compared and adjusted for differences in estimating methods and assumptions.
- The relative costs of different sections of the processes are examined, noting differences in the process designs and site layouts.

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The cost of the Mustang Station PZAS FEED design (“Mustang FEED”) is scaled to a design basis similar to the Panda Sherman NGCC FEED (“Panda FEED”).

- The cost impact of key design decisions in each FEED are estimated.
- Cost estimates for the absorbers in each FEED and some additional absorber designs are compared.

The intent of this comparison is to understand and reconcile differences in cost which are driven by the layout and constraints of the host sites or by differences in estimation methods. We discuss how the respective amine scrubbing technologies affect the cost of equivalent areas of each process. However, we do not attempt to reconcile these differences or compare the merits of the two technologies.

To compare direct field costs, the direct costs reported in each FEED are adjusted to be on the same basis. This analysis gives adjusted direct field costs of $574MM (Mustang) and $411MM (Panda).

The breakdown of direct costs by process area is also compared. The CO₂ absorption and steam generation sections make up a larger fraction of the costs of the Mustang design. This can be attributed to high heat exchanger costs due to the extensive use of air cooling, and the use of boilers for steam supply rather than steam extracted from the NGCC as in Panda. In the Panda design, the flue gas handling and CO₂ compression areas are relatively more expensive. The higher cost for flue gas handling is due to the host site layout requiring much longer ductwork, while the higher compression cost is likely due to the higher CO₂ compression ratio required by the Panda process. Scaling the direct costs of each area of the Mustang FEED to a similar capacity to the Panda FEED gives an estimated direct field cost of $489MM, compared to $411MM for the Panda FEED design. This analysis represents the estimated cost of the Mustang FEED if it were designed on a similar basis to the Panda FEED.

The specific layout and requirements of the host sites were found to have a significant impact on capital cost. The Panda capture unit is located much further away from the existing HRSG stacks than the Mustang capture unit due to space constraints, and as a result flue gas handling constitutes 29% of the Panda FEED adjusted direct field cost, compared to 9% of the Mustang FEED. The Panda FEED uses steam extraction to supply steam, and as a consequence also can use existing cooling water capacity all at minimal capital cost. Steam extraction was not an option in the Mustang FEED, and cooling water was severely limited. As a result, the steam supply and cooling contributed on the order of $65MM in additional costs to the Mustang FEED.

Absorber estimates by three different suppliers, after adjustment and scaling, come to $19.7MM, $18.2MM, and $14.9MM for the same absorber size and packing requirement. The rectangular absorber appears to be 10–30% more expensive than the round absorbers, although this difference may reflect the estimating methods of the three different suppliers. The rectangular absorber has a lower labor cost and higher material cost than the round absorbers, so this difference will depend on the ratio of the specific costs of labor and materials as a function of the site.

We intend to apply the cost estimates and insights developed in this work to future process modeling and optimization efforts. This data will be used to develop a realistic cost estimation model as part of a full process design model that will be made public.

**Keywords:** Carbon Capture and Storage (CCS); Post-Combustion Capture (PCC); amine scrubbing; cost estimation

**References**

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