Introduction

Components have been removed from gas streams by absorption into physical and chemically-reactive solvents for over a century. During the first 70 years or so, bulk removal of CO_2 and H_2S was the objective and required the use of only a very standardized flowsheet having absorbers and regenerators each with 18 to 22 trays. The design from plant to plant was nearly always the same, varying only modestly with the amine being used (monoethanolamine, MEA; diethanolamine, DEA; diglycolamine, DGA®, etc.). Designs were essentially off-the-shelf, with the previous installation serving as the basis for the current one. Thermal energy required for solvent regeneration was of little or no concern. But all this changed in the early 1980s when energy usage came to the forefront and became a factor of greater importance.

Attention began to focus on energy consumption and on removing no more CO_2 than necessary to meet pipeline or other specifications. Furthermore, treating increasingly sour gases became more commonplace, serious environmental regulation began to come into play, and satisfactory sulphur plant performance began to demand ever higher quality feeds. This drove improvements in the performance of existing solvents, the development of entirely new solvents, more innovative processing schemes, improved metallurgy, and the means to keep solvents working well over much longer periods of time. The biggest drivers for innovation in modern gas treating have been energy conservation and improved selectivity for H_2S over CO_2. The latter is best exemplified by acid gas enrichment to produce high quality Claus plant feeds from low quality gases, the former is illustrated by the development of the aMDEA® process used today in most ammonia plants and LNG facilities around the world.

Simultaneously with the development of better chemicals, improved equipment and more effective process configurations, engineers have been enabled by the advent of high-speed desktop computing to model and understand gas processing in far greater detail, and with much greater ease. Indeed, high speed computing has allowed many of the innovations in gas treating to come to fruition. In particular, mass and heat transfer rate-based column modeling as practiced by the leading solvent vendors has allowed the development of specialty (mixed) amine solvents and their use in a host of treating applications. It has also allowed gas treating to be

understood on a much deeper level. Mass and heat transfer rate-based modeling now allows absorption and regeneration columns to be analyzed in just as much detail and with the same reliability as we have taken for granted for 60 or 70 years in analyzing heat exchangers. Process simulation can be used to predict plant performance just from basic phase equilibrium, reaction kinetics data, and equipment configuration. In other words, it is now possible to build a virtual plant, to optimize its performance, and to determine *quantitatively and with surety* the effect of such factors as changing process conditions, solvent contaminant levels, and the effect of additives for enhancing regeneration and altering selectivity using nothing more than bench-top laboratory vapor-liquid equilibrium and reaction rate data. Rate-based process simulation also has now become a very powerful tool for troubleshooting.

Most of the developments of the last 20 to 30 years have not been well documented in a single source. This makes it difficult for process engineers, especially engineers new to gas treating or with only minimal gas treating experience, to develop and maintain the degree of expertise needed to perform at a high level of excellence. The present volume details most of the information presented at our seminars and workshops on advanced gas treating and was developed over the last five years. It aims to provide attendees with a level of expertise that goes far beyond what is available from the numerous introductory seminars provided by others. Truly sound engineering cannot be done using rules of thumb, anecdotal information, and simulation that is satisfied with the assumption of equilibrium stages.

This volume is laid out in essentially the same order as the classroom presentation. It starts with an exposition of what a mass and heat transfer rate-based model is (and what it is not). The level of detail is intended to be sufficient to allow participants to understand and analyze logically how the parameters active in gas treating interact with each other and affect process performance. Following the introduction of treating as a *mass transfer rate* process, we look in detail at what the most important process parameters are in both absorption and regeneration. Mixed amine systems (so-called specialty solvents) are examined from the standpoints of how they work and how they should be selected. Chemistry is key, and we give a detailed explanation of how stripping can be promoted via the use of additives. Process performance can be critically affected by the presence of heat stable salts (HSSs) and alkali metal ions even in quite small

concentrations, so their chemistry is examined and their effect on both stripping and regeneration is analyzed.

A large chapter is devoted to troubleshooting treating facilities using simulation as an essential tool in the analysis process. This leads to a study on the effect of the hydraulics of tower internals on their mass transfer performance. Acid Gas Enrichment (AGE) is used as an example of highly selective treating and some rather clever processing schemes are presented and analyzed via process simulation.

Rules of thumb are often applied (and mis-applied) in gas treating. Although at times useful, they can be extremely dangerous when used blindly. Removal of CO_2 by MDEA is examined as a case in point. The dimethyl ether of poly(ethylene glycol), DMPEG, can be a highly selective solvent for H_2S when the right processing scheme is used. This is demonstrated through process simulation. Another physical solvent is triethylene glycol, TEG, the most commonly used solvent for water removal in dehydration processes. Again, the dangers of blindly applying rules of thumb are pointed out.

Post-combustion CO_2 capture is dissected from the standpoints of energy usage and the chemistry of various solvents, including amino acid salts. MEA at 30 wt% is used as the benchmark solvent, and it is shown how basic vapor-liquid equilibrium and solvent net loading can be used to determine the potential advantage of one chemical solvent over another. Finally we discuss a detailed physical model for corrosion in amine systems.

The discussion leans heavily on chemistry throughout because it has been our experience that truly understanding process performance is intimately reliant on understanding processes at their roots, and process chemistry is a fundamental science, not art. Without chemistry, many aspects of gas treating remain obscure.