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A review of research facilities, pilot and commercial plants for solvent-based post-combustion CO_2 capture: Packed bed, phase-change and rotating processes

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ABSTRACT

Large-scale CO_2 abatement is key to avoid the detrimental environmental impacts of increased CO_2 emissions worldwide. Solvent-based absorption is a mature post-combustion capture technology for short- to medium-term implementation. However, high energetic requirements, capture costs and technical challenges have been prohibiting its wide industrial deployment. Extensive research efforts have enabled significant improvements that resulted in scaling-up of pilot plants to industrial-level systems and commercial installations. This work provides a detailed review of these activities for plants of different capacities in 37 locations worldwide. The presented information pertains to: a) baseline, packed bed, absorption/desorption flowsheets, originally developed for alkanolamines, b) flowsheets with significant structural modifications that increase the operating driving forces, c) flowsheets including modifications for phase-change solvents and d) flowsheets that incorporate rotating packed beds (RPB). Technical details are presented regarding tested solvents, energetic performance, operating conditions, types and capacity of equipment, emissions, degradation and corrosion. It is observed that energy recovery in the stripper enables significant regeneration energy reduction, as proven in a commercial-scale plant. Equivalent performance has also been achieved with the chilled ammonia process in large-scale pilots. Liquid-liquid phase-change solvents and RPBs exhibit high potential for operating and capital expenditure reductions, but require significant scaling-up effort. Research in RPBs includes mainly lab-scale, mass transfer investigations. Several large-scale plants are being developed in China.

Abbreviation: e, Porosity of packing material of RPB; AAP, Advanced Amines Process; AFS, Advanced flash stripper; AM, Additive manufacturing; AMP, 2-amino-2-methyl-1-propanol; BD, Boundary Dam; CAP, Chilled ammonia process; CAPEX, Capital Expenditures; CCGT, Combined Cycle Gas Turbine; CHP, Heat and Power plant; DCC, Direct Contact Cooler; DEA, Diethanolamine; DEEA, 2-(diethylamino)-ethanol; DEG, Diethylene glycol; DETA, Diethylenetriamine; DMCA, Dimethylcyclohexylamine; DOE, Department of energy; ED, Electrodialysis; EDA, Ethylenediamine; EPDM, Ethylene propylene diene monomer; ESP, Electrostatic Precipitation (or precipitator); EGR, Exhaust Gas Recycle; EOR, Enhanced oil recovery; FEED, Front-end engineering design; FGD, Flue Gas Desulfurization; H, Total column height; h, Total packing height in column; HEX, Heat exchanger; H_{pck}, Packing height of RPBs; HSS, Heat stable salts; I.D., Internal diameter of columns; IPCCS, Intergovernmental panel for carbon capture and storage; KEPRI, Korea Electric Power Research Institute; KSAR, Potassium salt of sarcosine; K_{Ga}, Gas mass transfer coefficient; k_La, Liquid side volumetric mass transfer coefficient; L, Length of rectangular column; LCOE, Levelized cost of electricity; L/G, Liquid-to-gas; LVC, Lean Vapor Compression; MAPA, 3-(methylamino)-propylamine; MDEA, N-methyldiethanolamine; MEA, Monoethanolamine; MVR, Mechanical vapor recompression; NAS, Non-aqueous solvent; NCCC, National Carbon Capture Center; NG, Natural gas; NGCC, Natural gas combined cycle; NTU, Number of transfer units; HTU, Height of transfer units; O.D., Outer diameter/Inner Diameter/Height; OPEX, Operational Expenditures; PCC, Post combustion capture; PHW, Pressurized hot water; P_{CO2}, Partial pressure of CO2 in the flue gas; PTFE, Polytetrafluoroethylene; PZ, Piperazine; RFCC, Residue Fluid Catalytic Cracker; RPB, Rotating Packed Bed; r_i, Inner radius of packing of RPB; r_o, Outer radius of packing of RPB; S1N, N1-cyclohexylpropane-1,3-diamine; SARMAPA, 3-(methylamino)propylamine/sarcosine; SCR, Selective Catalytic Reduction; SEM, Scanning Electron Microscope; SRD, Specific reboiler duty; SRP, Separations research program; TVR, Thermal vapor recompression; VOC, Volatile organic compounds; V_{pck}, Volume of packing material of RPB; W, Width of rectangular columns; WESP, Wet ESP; WFGD, Wet FGD.

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