Process Integration within the Broader Context of Process Intensification Supporting Greenhouse Gas Mitigation

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Systematic chemical process synthesis methods have been under investigation for more than forty years with several techniques now developed to the point of industrial applicability. One such method is the hierarchical task-based systematic generation approach to process synthesis based on the goal-oriented means-ends analysis paradigm with particular emphasis on task integration and process intensification.

Primary chemical process objectives usually include composition, purity and other chemical and physical fitness-for-use properties, and annual production rate. Designing a process to meet these primary objectives is logically not too difficult and various algorithms and computer programs have been proposed and implemented.

However, in addition to the primary process objectives there are always other objectives, constraints, or desirable performance characteristics which include economics (capital costs, operating costs, financial metrics, and value chain optimization), labor, energy efficiency, material efficiency, waste management, environmental impacts, mitigation of contributors to climate change, health and safety impacts, flexibility, controllability, maintainability, reliability, greenhouse gas mitigation, and many other elements of sustainable processing. Process intensification may be defined as many design actions that retain the primary process objectives of fitness-for-use criteria and production rate while improving or optimizing as best as can be done these other desirable performance characteristics. These are major process systems engineering challenges.

Process intensification is classically related to altering process rate and equipment size determining mechanisms. However, the concept of process intensification may be extended to issues related to chemistry (stoichiometry, catalysis, reaction thermodynamics, selectivity, etc.), issues related to process structure (recycle of incomplete conversion, reversal of undesirable reaction selectivity, etc.), issues related to heat and power management and thermodynamic efficiency (heat and power integration, altering process conditions to increase the opportunities for integration, minimizing entropy production, etc.), altering the order of tasks and the relationship between tasks and the equipment to execute them, choices related to advantaged scale-up or scale-down, and design choices to improve operability and controllability.

Examples of intensification in process design can be found in new procedures for heat exchanger networks, distillation sequencing, heat-integrated and multi-effect distillation, azeotropic, extractive, and reactive distillation, residue curve theory applications, constraint-oriented process synthesis for separation of mixtures with nonideal solution thermodynamics, and the design of equipment with integrated task functionality.