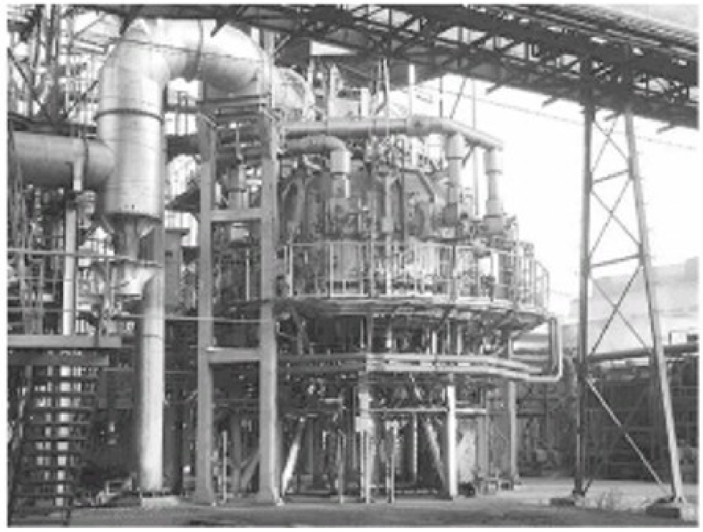
1.4.3 INDUSTRIAL PROCESS EFFICIENCY

Technology Description



A new one-step furnace operation could revolutionize iron making and substantially reduce energy use and associated emissions.

Industrial process efficiency is affected by a number of factors: technology design, age and sophistication of equipment, materials of construction, mechanical and chemical constraints, inadequate or overly complex designs, and external factors such as operating environment and maintenance and repair practices. Processes typically use a lot more energy than the practical minimum energy that is required. In the chemical industry, for example, distillation columns operate at efficiencies as low as 20%-30%. In this case, thermodynamic and equipment limitations (e.g., height of the column) directly impact efficiency and increase energy use.

Technologies under development focus on removing or reducing process inefficiencies, lowering energy consumption for heat and power, and reducing the associated greenhouse gas emissions. One example is a revolutionary cokeless iron-making process that redesigns the steel supply chain by relocating iron making to the iron-ore mine.

System Concepts

- Process efficiency is improved by optimizing individual processes, eliminating process steps, or substituting processes within the principal manufacturing steps for primary conversion of raw materials, secondary or value-added processing, and product separation. Optimizing the overall manufacturing chain also improves process efficiency, including the material and energy balance.

Representative Technologies

- Process redesign can eliminate energy-intensive process steps, as demonstrated by the cokeless iron-making process. Process intensification seeks to produce chemicals in one-two reaction steps rather than three-five, reducing feedstock and heat/power requirements. Technology options include developing a new route to the same product, or using innovative reactor designs and new process chemistry.
- Smaller changes to a process can also result in increased process efficiency. For example, DOE is supporting research to modify steel-casting methods that will reduce energy use and produce cleaner, lower-weight castings of improved quality.
- Advanced separation technologies include membrane separation and hybrid distillation systems, where novel separation technologies are combined to reduce energy demand. Advanced water removal technologies can also substantially reduce energy use in drying and concentration processes.
- Advanced separation technologies include membrane separation and pressure swing adsorption, where separation is facilitated by novel materials and is energy-efficient.

Technology Status/Applications

- Components of more efficient processing technologies under development (e.g., membranes) are in limited use today, but many need stronger economics or demonstrated technical reliability in service to increase their attractiveness to industry. The biggest opportunities to reduce GHG emissions in industrial processing will come from introducing revolutionary technologies as replacements for conventional operations. Examples include next-generation steelmaking and the use of membranes in conjunction with energy-intensive distillation. Other options include developing new processes that increase product yields, reduce byproducts and wastes, or use alternative manufacturing pathways.

Current Research, Development, and Demonstration

RD&D Goals

- The overall research program goal in this area is to contribute, before 2020, a 20% improvement in energy intensity by the energy-intensive industries through the development and implementation of new and improved processes, materials, and manufacturing practices.
- Specific goals for the pulp and paper industry include, by 2010, to assist efforts to implement advanced water-removal technologies in papermaking resulting in an energy efficiency improvement of 10% in paper production.
- For the iron and steel industry, by 2010, assist efforts to develop a commercially viable technology that will eliminate the use of blast furnaces and natural gas-driven, iron-making processes.
- More generally in the separations area, demonstrate advanced hybrid separations technology, by 2016, including separations combined with distillation (membranes, adsorption, and extraction), reactive separations, and separative reactors for use across various industries (chemicals, refining, pulp and paper).

RD&D Challenges

- Specific R&D needs are unique to each individual industry. In general, R&D challenges include economic and innovative separation techniques, improved understanding and prediction of chemical and material behavior, materials fabrication methods, demonstration of performance and reliability, *in situ* and/or rapid analytical protocols and process screening procedures, advanced computational tools, and more efficient process design.

RD&D Activities

- RD&D activities relating to these technology areas are sponsored by DOE, the Department of Commerce, the Department of Defense, the National Science Foundation, and the Environmental Protection Agency. DOE has funded projects to improve process energy efficiency and promote clean manufacturing; participants include industry, DOE laboratories, small businesses, private research institutes, and academia.
- Ongoing activities include development of technology to enable more efficient processes in the following industries: aluminum, chemicals, forest products, glass, steel, metal casting, mining, and supporting industries such as forging, welding, and others. The primary focus of R&D is the development of economic, energy-efficient, commercially viable, and environmentally sound manufacturing technology. Industrial partners are involved with R&D early on to facilitate deployment and commercialization. Specific selected activities include cokeless iron making, next-generation steelmaking, advanced water removal, hybrid distillation, microchannel reactors for process intensification, improved chemical reactors and synthesis pathways, and a metal-casting future plant initiative.

Recent Progress
• A fiber-optic sensor for on-line measurement of paper basis weight has been developed and tested to improve wet-end control in papermaking and produce fine paper with more uniform basis weight. The sensor enables continuous measurements across the full paper sheet and will minimize raw material and energy requirements in the paper industry. • A revolutionary process was developed with DOE support that could completely revolutionize iron-making capabilities. The ITmk3 process uses low-grade ore to produce iron nuggets that are superior in quality to conventional nuggets, without the coke and agglomeration steps. The process achieves a 30% reduction in energy use over conventional integrated steel-making processes.
Commercialization and Deployment Activities
• Applications of many of the described technologies already have an impact in the marketplace. For example, catalytic processes are responsible for about 75% by value of all chemical and petroleum processing products. Catalytic processes generate about $900B in products annually. The ready acceptance of certain applications of these technologies reduces barriers to implementation of process improvements or their application in new processes. Powerful drivers still exist for implementing advancements in these technologies for GHG reduction. The estimated total annual consumption of energy (fuels and electricity) by the U.S. chemical process industries is 5.8 quads; nearly 43% of that (2.5 quads) is required for separation processes, including distillation, extraction, adsorption, crystallization, and membrane-based technologies. Any process facilitating such separations will result in enormous savings of both energy and waste. Given the scale of many relevant industrial processes, the chief barriers to technology deployment are likely to be the capital expenditures required for any substantial process modifications. **Market Context** • The markets for these technologies are industry-specific. Targets of opportunity are the basic industries, including aluminum, chemicals, forest products, glass, mining, steel, and crosscutting industries such as forging, metal-casting, and welding.