Ch En 461
Winter 2025 Project Summary

Andrew Fry, Todd Russell

Project #1 Title: Performance Evaluation of Moving-Fire Brick Kilns for Optimization and Emission Reduction

Creation of fired bricks is a major industry in Kathmandu, Nepal, with bricks being used in building construction throughout Nepal and in surrounding countries. The high temperature process by which bricks are created is low-tech and energy and manpower intensive. However, the transformations of the clay material and the operating conditions to cause them are complicated. The heat generated in this process originates from the combustion of mixtures of coal and biomass and the delivery of the heat to the bricks is controlled by flue gas flow through tortuous pathways between the bricks. In its current form this process is one of the largest air polluters in the region and working in a brick kiln is hazardous for this and other reasons. The objective of this project was to create a simple model of an operating moving-fire kiln which contains undetailed but correct physics and use it to suggest changes that could be made to optimize performance of the kilns.

Project #2 Title: Optimizing a Butane Isomerization Reactor through Purification of Reactant Feed Stream

Isobutane is a key reactant necessary for the creation of many other petrochemical products in a refinery. Isobutane is formed by running n-butane over a platinum catalyst under the correct conditions. The catalyst reactor is designed such that it typically achieves equilibrium. At one petrochemical plant, performance of the butamer reactor (isobutane producer) is poor because the inlet reactant stream already contains substantial amounts of isobutane. This plant is interested in increasing the conversion in the butamer unit by first separating isobutane from the reactant stream. The objective of this project was to design and evaluate changes to the butamer system that will improve its performance (increasing isobutane production at the lowest cost).

Project #3 Title: Evaluation of Performance Modifications for a Unifiner Reactor Recovery Heat Exchanger

A Unifiner Reactor is used to perform hydrodesulfurization on crude oil fractions to remove unwanted elements from the hydrocarbon prior to reforming. Because this process occurs at elevated temperatures, the feedstock must be heated prior to the reactor. The heating occurs in two phases, first the feedstock is flowed through a recovery heat exchanger, where the post-reactor material is used to preheat the feedstock and then a fired heater is used to bring the feedstock up to the final desired temperature. One petrochemical plant has observed that the recovery heat exchanger train on the Unifiner Reactor is restricting their capacity and causing operation difficulties. The objective of this project was to perform an analysis on the existing Unifiner recovery heat exchanger and suggest modifications to the hardware, operating conditions and control that will allow improved operation while also increasing throughput

Project #4 Title: Evaluation of the Performance of Vapor Traps for Molten Salt Nuclear Reactors

Molten Salt Nuclear Reactors (MSR's) form a gas phase that will accumulate in the headspace of the reactor. Any species that has a low solubility in the molten salt liquid will move into the gas phase. Some of the species that are expected in the gas phase are noble gases Xe, Kr and Iodine, acidic gases like HCl and ICl and Helium-3 and tritium and fission products that include radionuclides. It is important to maintain neutral pressure in the MSR as this is one of the desirable safety features. This means that the gases must be removed from the reactor continuously. However, these species cannot be emitted directly to the atmosphere, the gas must be processed and crucial species captured. The objective of this project was to evaluate, design, and model the performance of vapor traps for a molten salt nuclear reactor.

Project #5 Title: Development of a Functional Laser Ignition System for Industrial Furnaces Firing Gaseous Fuels

Industrial furnaces are often ignited using electric spark ignitors which require the use of a high voltage transformer and a spark plug. Alternatively, the flame can be initiated by a hot surface like a glow plug. Spark ignitors and glow plugs can easily develop faults that make them difficult to operate and troubleshoot. Additionally, these techniques are not effective for ignition of pressurized flames. The objective of this project was to develop an ignitor that utilizes a laser system that can replace a traditional ignitor. Such an ignitor is expected to be more flexible, safe and reliable under a broader range of conditions and burner geometries.

Project #6 Title: Correlating Signals from a Multi-Process Monitoring System to Boiler Operating Conditions through Machine Learning

A key technical challenge in operating solid fuel fired electric utility boilers is the effective management of ash. This is essential to maintain optimal heat transfer and reduce corrosion and erosion. A company developed a Multi-Process Monitoring System that provides real-time data on both ash deposit rate and corrosion. Developing a relationship between these measured parameters and the operating conditions of the boiler is difficult because of the multitude of data involved and the complex interrelated nature of multiple data points. A machine learning model to link these measurements with boiler operating conditions offers the potential for predictive control based on sensor data. The objective of this project was to analyze the relationship between measured ash deposition and corrosion rates and plant operating conditions reported in PI data sets using the most applicable machine learning codes and to develop a python tool to predict these conditions in real time.

Project #7 Title: Investigation of Separation Processes to Purify Helium-3

Tritium is an isotope of hydrogen and Helium-3 is an isotope of helium, and both are necessary for products and processes ranging from applications in industrial electronics and fuel for fusion reactors. Tritium decays into helium-3 by emitting a low-energy beta particle with a half-life of 12.3 years. Therefore, these two isotopes are linked, and use of either requires a process to separate or refine them. The only commercially available technology for their separation is cryogenic distillation. This is a very energy-expensive technology. It is desirable to develop other commercial methods of separation. One example of this is selective adsorption of tritium on metal hydride surfaces. The objective of this project was to develop recommendations for a robust demonstration unit for the purification of Helium-3.

Project #8 Title: Mechanical Fractionation of Hemp for Sustainable Building Materials

Bio-derived materials used in engineering and construction have become a concentrated focus of research as we strive to become sustainable. Plant material is usually separated into components including pulped fiber, lignin, extractives and sugar. These components can be used with other materials or recombined with ratios and methods that target specific physical properties. The processes for making this separation are referred to as fractionation and can include mechanical, chemical and thermal process steps. A company has developed a mechanical process to perform hemp fractionation. One of their targeted products is synthetic hemp boards which will be used to make pallets. These boards have extremely good mechanical strength, but they are not hydrophobic and degrade when exposed to water. Evidence from other industries suggest that recombining some lignin components with the pulped fiber can significantly improve the hydrophobic properties of the resulting material and improve its strength. The objective of this project was to evaluate and recommend upgrades to the hemp mechanical fractionation and recombination processes that will improve the recovery and isolation of lignin while maintaining high throughput and low energy use.

Project #9 Title: Evaluation of a Fuel Cell for Carbohydrate Processing
A fuel cell is an electrochemical device that converts the chemical energy stored in fuel into electricity through the reaction of O_2 with typically hydrogen or CH_4. An alkaline carbohydrate fuel cell was first demonstrated in 1963 by converting glucose to gluconic acid at 8% efficiency but was heralded as an important discovery because abundant and renewable glucose could be used to generate electricity. Carbohydrate fuel cell development has been actively studied since then because a 12-fold increase in power compared to a H_2 fuel cell could be theoretically attained. However, this outcome has not been fulfilled because an appropriate catalyst has not been commercialized. A company has recently demonstrated that methyl viologen (MV) catalyzes oxidation of glucose with O_2. The objective of this project was to demonstrate that an efficient carbohydrate fuel cell can be configured and tested by adapting a commercial methanol fuel cell and using a methyl viologen catalyst and glucose as a fuel through bench-scale experimentation.

Project #10 Title: Catalytic Production of Formate (A Hydrogen Precursor) from Carbohydrates
Whey is a liquid byproduct of the production of Greek yogurt which is rich in lactose. This byproduct is typically handled by spreading it across farmland or in advanced applications it is further fermented to produce methane. An alternate process is to catalytically decompose lactose into formate (formic acid) and glycolate, which both have commercial value. Homogeneous methyl viologen (MV) catalyzed oxidation of glucose and lactose has been demonstrated and evaluated at 50°C and kinetic parameters have been developed. The objective of this project was to develop a continuous or semi continuous pilot-scale process to convert lactose into formate starting with acid whey and evaluate the economics of such a process.