Title: **ENGINEERING DESIGN AND AUTOMATION IN THE APPLIED ENGINEERING TECHNOLOGIES (AET) GROUP AT LOS ALAMOS NATIONAL LABORATORY**

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Submitted to:

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ABSTRACT

This paper provides an overview of some design and automation-related projects ongoing within the Applied Engineering Technologies (AET) Group at Los Alamos National Laboratory. AET uses a diverse set of technical capabilities to develop and apply processes and technologies to applications for a variety of customers both internal and external to the Laboratory.

The Advanced Recovery and Integrated Extraction System (ARIES) represents a new paradigm for the processing of nuclear material from retired weapon systems in an environment that seeks to minimize the radiation dose to workers. To achieve this goal, ARIES relies upon automation-based features to handle and process the nuclear material.

Our Chemical Process Development Team specializes in fuzzy logic and intelligent control systems. Neural network technology has been utilized in some advanced control systems developed by team members. Genetic algorithms and neural networks have often been applied for data analysis. Enterprise modeling, or discrete event simulation, as well as chemical process simulation has been employed for chemical process plant design.

Fuel cell research and development has historically been an active effort within the AET organization. Under the principal sponsorship of the Department of Energy, the Fuel Cell Team is now focusing on technologies required to produce fuel cell compatible feed gas from reformation of a variety of conventional fuels (e.g., gasoline, natural gas), principally for automotive applications. This effort involves chemical reactor design and analysis, process modeling, catalyst analysis, as well as full scale system characterization and testing.

The group's Automation and Robotics team has at its foundation many years of experience delivering automated and robotic systems for nuclear, analytical chemistry, and bioengineering applications. As an integrator of commercial systems and a developer of unique custom-made systems, the team currently supports the automation needs of many Laboratory programs.

**AET DESIGN AND AUTOMATION EFFORTS**

1.0   ARIES

AET has played an integral role in the Advanced Recovery and Integrated Extraction System (ARIES) program since its inception. ARIES is designed to enable workers to dismantle nuclear weapons, separating the plutonium from other weapon components. The ARIES approach prepares weapons plutonium for long-term storage or disposition in a form that can be quantifiably verified by nondestructive assay. ARIES consists of five modules; each designed to carry out a specific function. Each module incorporates advanced technologies that minimize waste and exposure to nuclear materials, as well as increasing operational efficiency. AET has historically provided major engineering design support for each of the five ARIES modules and continues to support operation and maintenance of the system within the Laboratory's plutonium facility. The AET ARIES Team is now assisting in the formulation of the design basis for the Pit Disassembly and Conversion Facility (PDCF) intended to be the production version of ARIES. At this point, however, upgrades of various technologies and development of new methodologies for part decontamination and processing are the main focus of the team. These recent efforts include the following:

> Development of a new oxidation and calcinations furnace system for the actinide metals,
> Incorporation of a part sanitization furnace for the non-nuclear components,
> Utilization of a robotics system for handling material with high radiation fields, and
> Process development for cleaning of enriched uranium parts.

Part sanitization furnace.

Past AET efforts for ARIES, particularly in its early demonstration phase, involved specific module design with a focus on process design for glovebox compatibility, process control, and automated material transport for nondestructive assay. The monitoring and controlling of various system processes is accomplished by an AET designed I&C system. This I&C system is a distributed system with three levels of hierarchy. These include instrumentation (sensors, local controllers), data acquisition (PLC based interfaces), and the computer level (module development computers and supervisory control and data acquisition (SCADA) computers). The entire system is operated from the SCADA computer through a graphical man-machine interface. The nondestructive assay system is designed to measure fissile material content in storage containers. AET also provided a unique system for automating the assay process that features a telescoping, glovebox-compatible gantry robot.
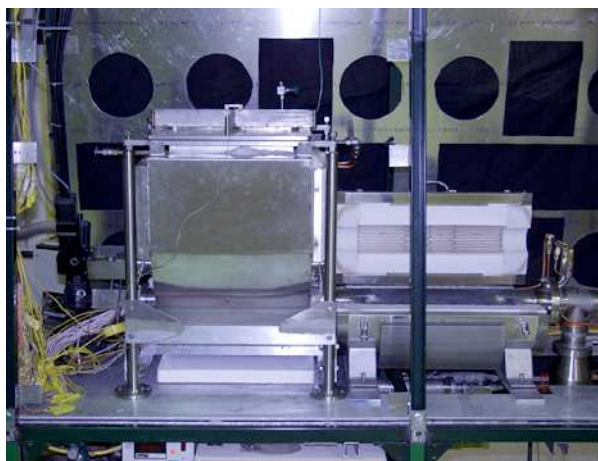
Direct metal oxidation (DMO) furnace.

2.0   Chemical Process Development

The Chemical Process Development Team has traditionally specialized in research focused on the development of new chemical processes. The team has expanded its capabilities to work with peripheral systems that could potentially enhance new and existing chemical processes. Examples of such a peripheral are intelligent control systems. These intelligent control systems differ from classical control systems in that they are often developed with software-based methodologies and subsequently executed with the use of a computer. Classical systems are typically complicated and based upon programmable logic controllers with PID or simple on-off capability.

Centech three-phase centrifuge.

The Chemical Process Development team employs two technical approaches in its development of intelligent control systems, namely, fuzzy logic and neural networks. The neural network control systems include controllers for a distillation column as well as a propellant extrusion unit for the U.S. Navy. The fuzzy logic control systems include a control system for a silicon carbide whiskers production furnace and an oil field centrifuge.

The distillation column control system used an adaptive neural network to control boil-up and reflux rate. This system represents a multi-input, multi-output system. The propellant extrusion controller was designed on the basis of laboratory-collected data as well as real-time operation data to determine and control propellant packing density.

The fuzzy controller for the silicon carbide whiskers production furnace was a first generation intelligent controller and worked more like an expert consultant for an operator providing operating instructions based on existing conditions. The fuzzy control system for the oil field centrifuge is a full-blown control system providing complete automatic control. A fuzzy control system was employed here because the centrifuge system is multi-input (time varying), multi-output, and is highly non linear. In this case the control system was built around an intelligent model of an expert operator instead of a mathematical model of the centrifuge.

The team has also employed fuzzy logic in conjunction with statistical process control. This fuzzy statistical process control is being developed for quality and exposure control for items manufactured under hazardous conditions (e.g., beryllium parts).

Finally, the team often uses enterprise modeling or discrete event simulation in their process design and modeling work. They have used genetic algorithms to optimize these simulations.

3.0   Fuel Cell Research

The AET Fuel Cell Team is working on providing solutions to various fuel processing needs in support of the U.S. Fuel Cell program. Historically, the team has conducted applied research and development in the general area of fuel cell systems for power generation for use in both the transportation and stationary applications sectors. More recently, the team has focused on developing technologies required to produce Proton Exchange Membrane (PEM) fuel cell compatible feed gas, essentially a hydrogen rich gas stream with low levels of carbon monoxide, from reformation of a variety of conventional hydrocarbon fuels. This effort involves chemical reactor design and analysis, process modeling, catalyst analysis, as well as full scale system characterization and testing.
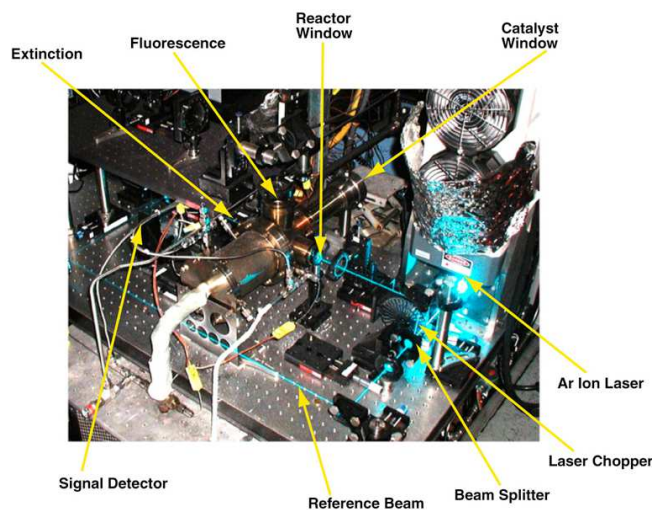
Fuel cell research reformer system.
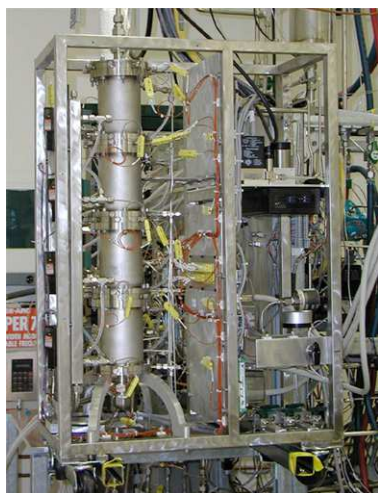
A critical component of gas cleanup process is the preferential oxidation (PrOx) reactor used to remove CO from the feed stream. Recent designs of a full scale PrOx reactor have reduced CO concentrations in the feed stream from about 1% (10,000 ppm) to levels below 20 ppm, meeting requirements for long-lived PEM stack operation. This PrOx reactor operates using not only preferential catalytic oxidation but also methanation for the final cleanup, easing control problems and minimizing hydrogen consumption. Current work focuses on expanding the fundamental knowledge of the CO removal process through steady state and transient experiments conducted on well-characterized laboratory PrOx reactor hardware.

Three-stage PrOx reactor.

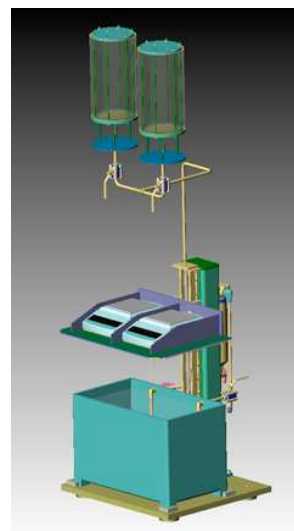## 4.0   Automation & Robotics

The AET Automation and Robotics Team directly supports the Stockpile Stewardship mission at Los Alamos National Laboratory by devising and integrating automated and robotic systems that increase productivity, reduce personnel exposure to hazardous material, and minimize waste production for various processes within the weapons complex. In its efforts to support the Laboratory and its principal mission, the Automation and Robotics Team is currently working on several efforts for the pit-manufacturing project (PMP). The team is helping to update several manufacturing technologies by either modifying existing equipment or if necessary, replacing it all together. Representative projects include Immersion Density, GB339 Apparatus, and the 5-Axis Mill Modifications.

The purpose of the immersion density effort is to design and build an automated density measurement station that incorporates computer controlled features to enhance operational safety and measurement accuracy. It includes a new mechanical handling system with advanced process controls all designed for use in a glovebox environment.

CAD rendering of Immersion Density apparatus.

The team will also design, build, and qualify an improved unit for the GB339 pit processing system. This new unit will be an updated version of the existing refurbished processing system currently installed within the processing line.
The 5-mill project involves converting a Deckel-Maho 5-axis mill for deployment within a glovebox. The team will modify all the controls to work remotely and will make minor modifications to ensure the machine is maintainable within the glovebox. This project also includes the design of the glovebox itself as well as associated equipment.
The Automation and Robotics team is also supporting advanced Stockpile Stewardship Strategies, namely the Advanced Hydrodynamic Facility (AHF). The AHF, a proton radiography facility, can provide high-resolution images of hydrodynamic implosion tests that represent a significant improvement over current x-ray based diagnostics. The A&R team is working on automation concepts that could be utilized at the various AHF firing sites. Employing automated techniques at such sites will help to minimize personnel exposure to hazardous materials while establishing a more efficient, cost effective cleanup process. Technologies under consideration for these sites include robotic arms and/or crawlers incorporating brushers or high-pressure sprayers with grippers and camera for effectively removing waste materials.

SUMMARY

The Applied Engineering Technologies group is directly involved in several ongoing efforts in the engineering design and automation arena. This paper provides a brief overview of the group's involvement in the Advanced Recovery and Integrated Extraction System, chemical process development activities particularly those employing advanced control approaches, fuel cell research activities with a focus on gas cleanup processes, and finally projects requiring utilization of automation technologies. In all cases technical approaches and relevant technologies as well as capabilities have been highlighted.