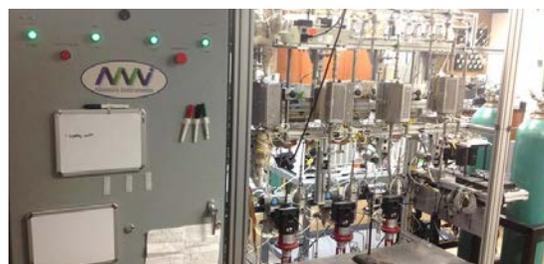


## CLEAN CATALYSIS (CLEANCAT) CORE FACILITY INSTRUMENTATION OFFERINGS

CleanCat provides a range of instrumentation and services for catalysis research. All instrumentation and services are available to Northwestern students, students of outside universities, and industrial researchers. If you have any questions or comments about the core's capabilities, are interested in using our equipment, or would like more details about rates, please contact the facility Operations Director, [Neil Schweitzer](#).

### Gas/Vapor Phase Reactions

CleanCat houses a heavily modified BenchCAT 4000 reactor system from Altamira Instruments. The BenchCat consists of four, fully automated, independently operated, plug-flow reactors used for catalyst screening and kinetic studies (reaction order analysis, Arrhenius analysis, and deactivation analysis). Each reactor has an on-line GC for direct gas analysis of the product stream. Each of the stations have been customized for specific applications, described below:



#### STATION 1

Station one has been modified specifically for vapor-phase, hydrogen peroxide chemistry (see our publication for more details: [J. Catal. 2015, 326, 107-115](#)). A syringe pump provides a continuous flow of aqueous, hydrogen peroxide that is vaporized in the reactor zone before coming into contact with the catalyst bed. This arrangement is accompanied by a vaporizer unit for the introduction of most, non-corrosive hydrocarbon vapors. Station 1 is equipped with an Agilent 7890A GC system utilizing both an FID (used to measure hydrocarbons) and a TCD (used to measure small gases such as O<sub>2</sub>, N<sub>2</sub>, CO, and CO<sub>2</sub>) to measure product stream components and concentrations.

#### STATION 2

Station two is used specifically for gas-phase chemistry. It is equipped with three flow controllers allowing for the use of up to three separate gases. This station utilizes an Agilent 6850 GC system equipped with a TCD, which provides analysis of gases lighter than C<sub>5</sub> hydrocarbons (including gases such as O<sub>2</sub>, N<sub>2</sub>, CO, and CO<sub>2</sub>).

#### STATION 3

Station three has been modified specifically for vapor-phase chemistry. One of three flowmeters is equipped with a bubbler system for the introduction of vapors to the catalyst bed. It is equipped with an Agilent 7890A GC system utilizing both an FID (used to measure hydrocarbons) and a TCD (used to measure small gases such as O<sub>2</sub>, N<sub>2</sub>, CO, and CO<sub>2</sub>) to measure product stream components and concentrations.

#### STATION 4

Station four has been modified specifically for vapor-phase chemistry. One of five flowmeters is equipped with a bubbler system for the introduction of vapors to the catalyst bed. It is equipped with an Agilent 7890A GC system utilizing an FID to measure hydrocarbon concentrations in the product stream.



#### Liquid Phase/High Pressure Reactions

CleanCat contains two Parr 4590 Micro Reactor Systems. These versatile systems are equipped with 50mL stainless steel reactor vessels rated to 350°C and 3000psi. Each are fitted with a gas manifold system designed to deliver up to three different reactive gases to the vessel. The reactor also contains a variable stirrer in order to eliminate transports or concentration gradients in the mixture.



#### Liquid Chromatography

The Agilent 1200 is a high-performance liquid chromatography system ideal for analysis of liquid phase reaction products that have low volatility. Equipped with a high performance auto sampler, a diode-array detector, and a refractive index detector, this system is capable of analyzing numerous samples consisting of a wide range of compounds. It is a great analytical accompaniment to the high pressure, liquid phase reactors, or can be reserved alone. Columns and solvents are provided by the core.



## **Temperature Programmed Experiments/ Chemisorption**

The AMI-200 is used for conducting temperature programmed experiments and pulse chemisorption studies. These experiments allow the user to measure the active surface area of a material, characterize the red-ox properties of a surface, measure the desorption characteristics of adsorbates, and even measure single-point BET surface areas after various treatments. Gases provided by the center include hydrogen, oxygen, carbon monoxide, ammonia, and inerts. A bubbler system is also available for the introduction of vapors.



## **in situ Infrared Spectroscopy**

The Nicolet 6700 DRIFTS system is an *in-situ* infrared spectrometer intended for analyzing solid powder surfaces under reaction conditions. Equipped with a gas manifold and temperature controller, the powder sample can be exposed to a wide variety of gases up to 550°C. Gases provided by the center currently include hydrogen, oxygen, carbon monoxide, ammonia, and inerts. A bubbler is also available for the introduction of vapors. Inquire about new cryogenic in-situ cell capable of reaching -150C.



## **Mass Spectroscopy**

The Universal Gas Analyzer – 100 is a portable, mass spectrometer intended for sampling gas streams at atmospheric pressure. The detection limit is  $m/z=0-100$  amu. This unit is intended as an add-on feature that can be used in conjunction with the other equipment available in the Core. Additionally, the unit is mobile and can be reserved for use as an add-on for equipment in your own lab. All that is required is an 1/8" Swagelok connection. Analysis software and computer are provided.



## **Surface Area/Pore Structure Analysis**

The micromeritics 3Flex is the state-of-the-art instrument for measuring surface area and pore characteristics of solid powders. Fully automated, this instrument performs many tests on three separate samples simultaneously, easily generating data quickly with minimal user labor required. Furthermore, its advanced vacuum system is ultra-stable allowing enhanced resolution for low pressure measurements (i.e. higher accuracy for low surface area materials and small pore sizes).

