



analytical engineering, inc.

Analytical Engineering, Inc (AEI) has been a market leader in engine and component development since 1994. Founded as an instrument development and manufacturing company, AEI has grown into a multi-faceted research and development establishment on 72 acres of land. AEI has strategically built a strong supporting infrastructure which includes 300,000 sq/ft of facilities, engine development equipment, and knowledgeable staff that enables new projects to be quickly launched and completed. This combination of in-house capabilities, in conjunction with a cooperative development approach, enables AEI to help our customers find rapid solutions leading to innovative new products.

Facilities

AEI is located in Columbus, Indiana on Technology Boulevard. The company is comprised of two facilities: AEI Central and The Rock. Inside these facilities you will find test cells, laboratories, offices, fabrication capabilities, machine shop, project support equipment, and rigs.

The entire AEI Central building is gated and locked to ensure privacy and security of all work. Additionally we have security surveillance with remote viewing capabilities for off site facility monitoring. Large overhead doors allow

access for over sized equipment/projects as well as a semi loading/unloading dock for ease of shipping. Offices are located above the laboratories adjacent the cells providing visibility of the hallway outside the cells, but are so designed to prevent visibility of an engine in the cell.

The Rock is located less than a quarter mile from AEI Central on the same street. The Rock is over a quarter million square feet and was acquired to accommodate space needed for expanding customer requirements. This is also the location of our off road/vehicle engineering center.

Both facilities provide customers a comfortable and ergonomic office space without compromising the intellectual property integrity of the test cells. In essence, both facilities are designed to provide visitor access without the concern of viewing anything belonging to another client; therefore, protecting intellectual property of customers and internal projects.

All of the controls and associated electronics for facility operation were developed at Analytical Engineering, Inc. This, in conjunction with skilled in-house programmers, assures complete flexibility, reliability, and optimum control of both buildings.

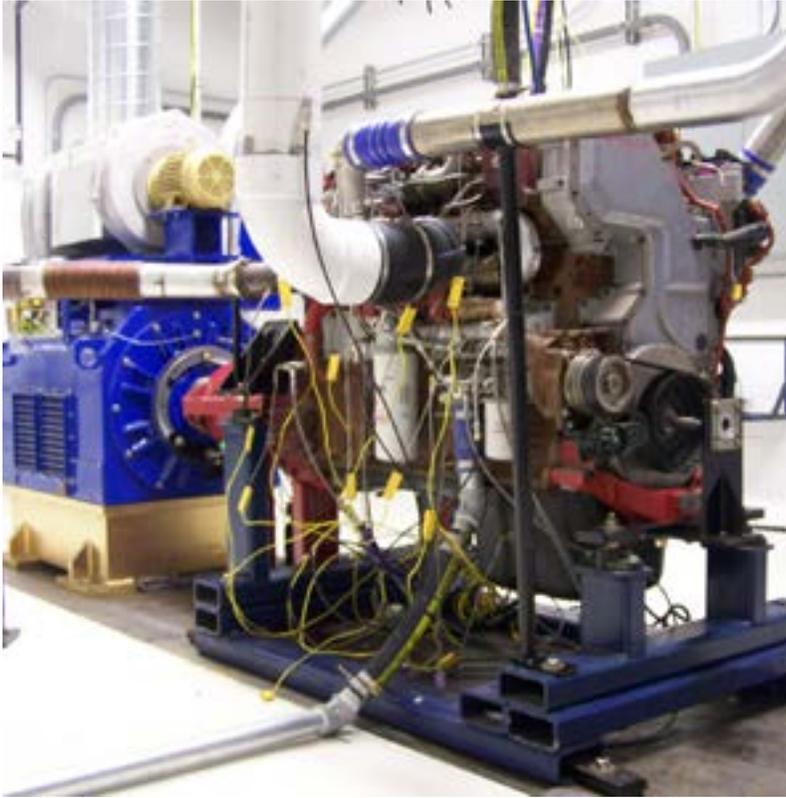




Environmental Statement

AEI seeks every available avenue to minimize its impact on the environment. This systematic utilization allows AEI to conduct its research and development for our customers while effectively maintaining a net zero carbon footprint. AEI maintains 72 acres of industrial property. All grounds that are not roads and buildings are maintained to the highest order with rolling, groomed pasture, manicured lawns, a wetland estuary, 10 acre fruit tree orchard, employee vegetable gardens, berry farm, vineyard, and honey bees.

Engine Development



The AEI facility, which includes twenty six engine dynamometer test cells, is uniquely designed to provide a research and development environment in support of a breadth of diesel engine and vehicle development programs. Numerous engine testing services are offered, ranging from basic test cell endurance work with an AEI technician to advanced engineering technology development with an experienced AEI engineer leading the project.

Advanced/Specialized Cells:

- Altitude
- Cold Start (down to -40°C)
- Super Cell (altitude, hot and cold running, hot and cold motoring)
- Winter Driving Simulation
- CVS

AEI's test cell privacy configuration is

structured for protecting proprietary projects and providing an effective work environment for customers and AEI support personnel. Each test cell console room is isolated from the other test cells and equipped with an individual entry door. Privacy blinds may be closed to prevent others from viewing the engine or other hardware. These console rooms provide a laboratory-like environment, where customers may view the control screens and see the engine test cell through a window. Large double doors for installing and removing engines are located on the opposite side of the cell from the console area. This arrangement limits access to visitors, and only allows authorized personnel in all areas where engines are stored, maintained, torn down, inspected etc.

Cold and Altitude Testing

Super Cell

The Super Cell's capabilities at AEI were developed to simulate the mountain road conditions in Colorado. Field testing engines and components in this environment presents engineers with a major problem; test repeatability. The Super Cell easily allows repeatable test cycles without having to worry about uncontrollable testing factors like traffic, weather, and driver variability. In order to provide qualitative information about smoke visibility and color, an exhaust stack mounted camera can be viewed at the test cell console.

Summary of Capabilities:

- Up to 12,000 feet altitude simulation for steady state and transient testing
- Altitude is maintained during transient cycle
- Temp to -35°C at startup
- Driving simulation
- Continuous raw emissions measurement and smoke
- Temperature controlled intake air from 110°F to below 32°F
- Temperature controlled CAC out down to 40°F
- Humidity controlled intake air at 77°F and 75 gr/lb

Cold Motoring Friction

The AEI Super Cell is capable of cooling the entire test cell to as low as -35°C, this includes not only the engine but also all the engine's fluids and accessories, providing an ideal test environment. The motoring dyno utilized by the Super Cell can operate the engine from 1 rpm to 8000 rpm. State-of-the-art data acquisition systems are used to control and provide a myriad of measurements.

Cold start testing

Two test cells at AEI are dedicated cold cells, capable of soaking the entire engine, aftertreatment, fluids, and accessories as low as -40°. Starting an engine at -40° is no easy task, requiring extensive calibration development. Traditional dynos used for cold testing cannot apply adequate loads under cranking conditions. To address this, AEI has developed and installed special engine loading equipment that offers the ability to simulate the transmission parasitic load during cranking, while the engine idles, and up through certain engine speed ranges. This test cell can provide starting torque from 70 ft/lbs up to approximately 800 ft/lbs during cranking and while the engine idles. Batteries can be used for starting and can even be placed in the same ambient temperature as the engine if needed, or AEI can supply current up to 2000 amps and 12-25 volts DC. Continuous data acquisition includes: white smoke (unburned hydrocarbons), exhaust smoke opacity, engine speed, and several temperature and pressure channels.

AEI's Super Cell is uniquely configured to simulate altitude conditions, with controlled intake air supply sources that are maintained isobarically with the exhaust out pressure. The majority of other facility's engine test cells that offer "altitude" capability are only able to maintain exhaust out pressure, and then create a simulated intake supply pressure by increasing intake restriction. Then for transient operation, that intake restriction valve must be modulated to attempt to achieve a certain pressure level. AEI's isobarically controlled intake and exhaust systems eliminates the need for feed forward control of the intake restriction, therefore, providing a better altitude environment for transient development requirements

Engine Component Testing

Temperatures, pressures, flowrates, and vibration conditions can be mimicked while simultaneously testing more than one part, saving time and allowing a project to be completed faster. While this does not provide exact engine conditions, the critical development parameters can be simulated.

AEI has designed, built, and installed a variety of test rigs for component development and evaluation. These rigs are operated and monitored according to test plans cooperatively developed with our customers.

Engine component testing options vary widely for each test set up. AEI is able to provide a test facility as basic as a laboratory with power and WiFi, to “turn key” fully automated endurance rigs capable of logging and reporting data during test cycles.

Component Tests:
HALT
HASS
Durability Bench
Environmental
Thermal
Altitude

Vehicle Engineering Center

Vehicle Center:

- **Custom Engine Installation**
- **Aftertreatment on-vehicle research**
- **Class 8 Trucks, buses, medium duty vehicles**
- **ECM Communication interface**
- **Off-Road Test Track**

AEI's vehicle engineering center provides an open span, high clearance height, and ample area for performing a wide variety of vehicle engineering activities on practically any conceivable wheeled vehicle platform. On-site land has been utilized to test numerous different types of non-road vehicles, including tractors, bulldozers, backhoes, front wheel loaders, scrapers, rollers, and compactors.

AEI has led and cooperatively worked on numerous different types of on-vehicle programs. The engineering and technical personnel at AEI have developed and installed engines, aftertreatment systems, emissions measurement systems, hybrid drives, computer acquisition, and computer controls onto vehicle platforms ranging from class 8 trucks to bulldozers.

On-Site Support

Emissions

AEI's emission measurement capabilities are state of the art and include a fully staffed emissions laboratory where analyzers are packaged, maintained, and repaired. AEI builds and/or packages the sampling system as well as our standard emissions rack; these can be installed in a test cell as needed. Also available from our emissions lab are FTIR analyzers, smoke meters, multiplexers, and lubricant oil soot measurement. This equipment in conjunction with our ability to run transient cycles allows for accurate and precise emissions measurements. At AEI Central, test cells one and two have CVS capability complete with particulate measurement, supported by a temperature and humidity controlled weigh room. This system enables AEI to provide customers with affordable, repeatable, pre-certification testing.

Fuel Selection

AEI routinely stocks ultra low sulfur diesel (ULSD) fuel, JP8, and higher sulfur level fuels. High volume high pressure natural gas delivery up to 80psi is available at AEI through our direct connection to a main distribution line for Columbus, Indiana. Smaller fuel tanks are available for short-term testing with specialty fuels such as gasoline, propane, and ethanol. Additionally, the ability to run tests from 55 gallon drums with unique fuel is available.

Machining and Fabrication

Our machining and fabrication shop allows us to bring the design,

prototyping, and testing together in one location with a single harmonious approach. On-Site support of rapid prototyping includes:

- Mazak Multi-Axis Machining Center
- Waterjet
- CNC Mills
- CNC Lathe
- TIG/MIG Welding
- Solids Modeling/CAD

The Mazak Multi-Axis Machining Center allows for more work in less time. A single part containing a complex machining process can now be loaded once and finished without any intervention from the machinist. This ability in combination with experienced personnel allows AEI to meet the demands associated with high volumes of rapid prototyping.

On-Site fabrication in conjunction with our advanced machining facilitate swift and professional vehicle, engine, and component modification. AEI engineers routinely apply this capability to support projects, ranging from basic instrumentation to engine and component development.

Emission

Cycles:

FTP
FTP75
RMC SET
NRTC
WHTC
5 Mode
13 Mode

Species:

CO
O₂
CO₂
HC
NOx

Air Flow

The Air Flow lab has a research flow rig capable of up to 4500 cfm with pressures to 30" H₂O. In addition to the dedicated flow lab, the AEI facility has several locations for performing vehicular flow research and development. Three individual flow paths, 3", 6", and 12" provide precise and accurate ($\pm 1\%$) flow measurements utilizing laminar flow elements to span a flow rate range of 20 cfm to 4500 cfm.

Data Acquisition

AEI's Data Acquisition package was designed for our in-house use and is a robust system built on proven and reliable hardware. This hardware is readily available off the shelf, but it's the user interface that distinguishes AEI from our competitors. Custom built and maintained AEI DAQ software allows our IT support team to interface with virtually all systems as well as develop solutions to unique projects. AEI has a reputation for taking even the most complicated testing scenarios and creating a straightforward, configurable, intuitive solution at our test cells. We've extended this philosophy to combustion analysis using our High Speed Data Acquisition (HSDA) system.

Combustion Analysis

The HSDA is a 500K sample/second simultaneous capture differential 16 bit analog system. The system is a data acquisition, storage, combustion analysis, and user interface tool rolled into one. Multiple systems can be synchronized for capturing very high channel counts of data. Historically AEI has utilized HSDA on projects to generate combustion analysis and heat release data, as well as magnetic flux measurements performed real-time on a variety of injector types.



Products



AEI designs, manufactures, distributes, and supports custom instruments that analyze engine-related fluids and contaminants.

BTSA

Oil soot is a critical diesel engine development parameter due to its negative impact on an engine's mechanical durability and reliability. In the world of lubricant oil soot measurements on diesel engines, the BTSA saves time and money by compressing 100 to 500-hour tests into a few minutes. The methodology through which this is accomplished requires extreme measurement precision and a very robust continuous oil sampling system. This combination allows engine oil to be continuously circulated from the engine to the instrument and back during measurements. The oil soot is measured with an extremely sensitive optical subsystem that provides fast and precise soot concentration measurements in real time.

PM Sample

Measuring Particulate Matter (PM) emitted by diesel engines has become increasingly complex throughout the past decade. As the worldwide mandated emissions levels have become more stringent, the need for sophisticated and very accurate exhaust sample handling systems has become necessary for good and repeatable results. Following ten years of development with Cummins, AEI evolved the PM1065 PM Sampling System into a single unit design that is portable. The system has exceeded 40CFR part 1065 requirements in its testing and is recommended for use in both transient and steady state applications. Originally a single dilution system was developed for use with a CVS test cell, while later development focused on a system that would be able to measure raw exhaust. A dual dilution system was developed for PM measurement on larger displacement engines. This dual stage dilution provided a more accurate, higher dilution ratio. The increased dilution returns data that mimics CVS test cell data but with significant savings to the development project.

