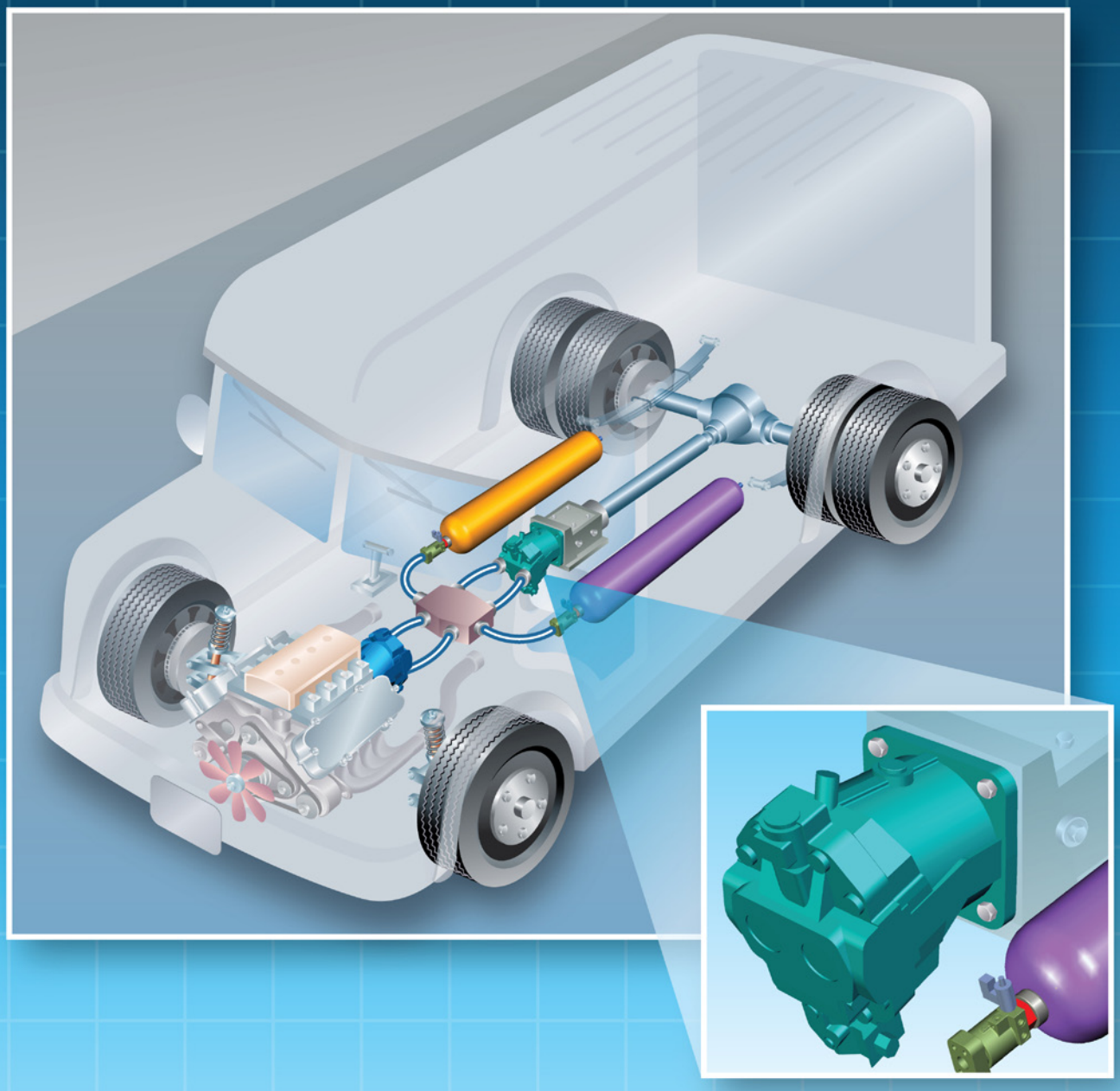
Hydraulic Technologies

HYBRID HYDRAULIC DRIVETRAINS



Southwest Research Institute®

San Antonio, Texas

For more than 15 years, Southwest Research Institute® (SwRI®) has been actively involved in developing prototype hybrid hydraulic components and systems. SwRI has extensive experience in hybrid electric and hybrid hydraulic vehicle development for pre-production, having developed demonstrator vehicles for both commercial and government clients.

Using computerized analysis tools, SwRI simulates components and systems to analyze problems, predict performance and optimize designs. The Institute offers a variety of analysis techniques that minimize product development time and costs, such as:

- 3-D CAD solid modeling
- Finite element analysis (FEA)
  - Thermal
  - Structural
  - Dynamic
- Transient component and system simulations
- Computational fluid dynamics analysis
- Probabilistic analysis
- Control system design and analysis
  - Classical and modern control theory
  - Fuzzy logic
  - Adaptive control
  - Neural networks
- Hardware-in-the-loop simulations
- Process-in-the-loop simulations

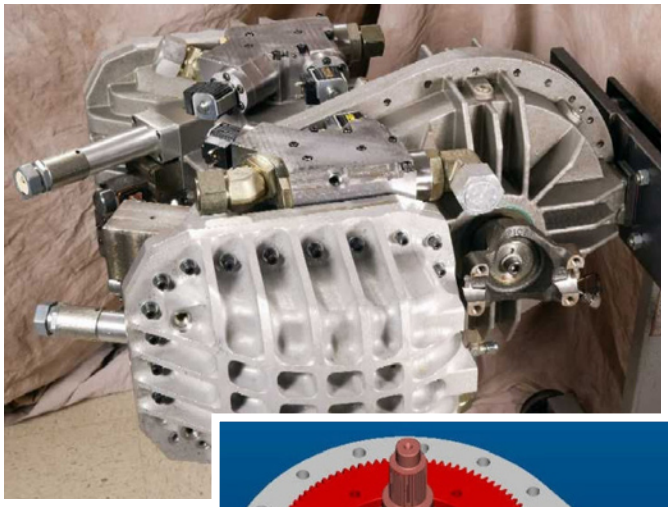
A full range of testing capabilities is available, including:

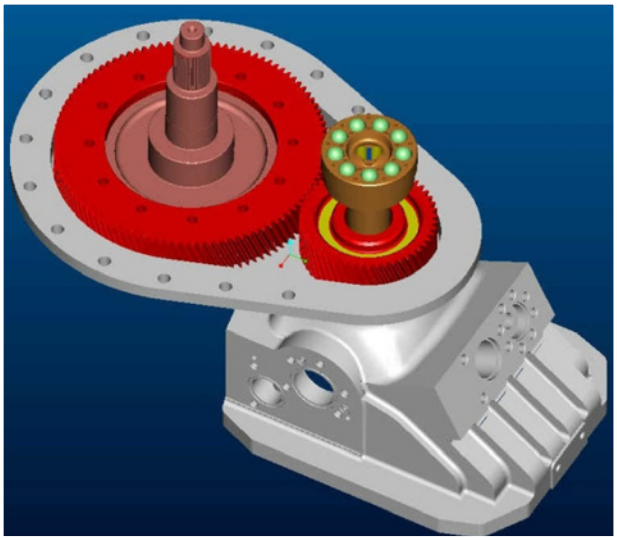
Hydraulic Pumps and Motors

- Efficiency
- Durability
- Response
- Energy loss characterization
- Wear analysis

Hydraulic Valves

- Flow loss
- Leakage
- Durability
- Performance characteristics
- Step response
- Frequency response





An SwRI-designed dual pump/motor integrated parallel gearbox provides efficient driveshaft power.

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Hydraulic accumulators built of composite materials provide the strength-to-weight ratios needed for efficient use in vehicles.

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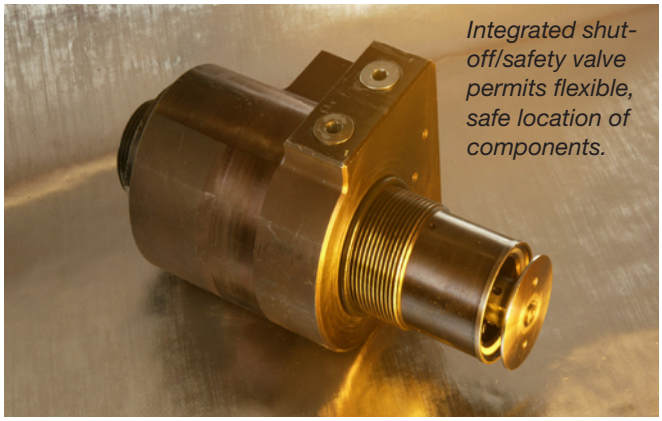
Heavy-duty vehicle chassis testing may include route mode, analog and CAN data acquisition, assessing emission control devices, hybrid vehicle testing, in-use emission studies, and thermal management studies.



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Integrated shut-off/safety valve permits flexible, safe location of components.

Hydraulic Accumulators

- Efficiency
- Energy capacity
- Durability
- Flow characteristics
- Permeability

Chassis Testing

- Route mode
- Analog, digital and CAN data acquisition
- Emissions control device assessment
- Hybrid vehicle testing
- In-use emission studies
- Thermal management studies
- Fuel economy

Specifications of the Institute's heavy-duty vehicle chassis dynamometer include:

- All-electric dynamometer, 48-inch diameter rolls
- Inertia to 120,000 lbs for tandem-axle vehicles
- 60,000 lbs for single-axle vehicles
- 600 hp
- Full-flow constant volume sampling emissions bench
- Transient or steady-state tests
- Drive cycle or route mode

Modeling and Simulation

RAPTOR®-H is commercial, off-the-shelf (COTS) modular simulation software developed by SwRI and a major automotive manufacturer to analyze conventional powertrains. RAPTOR-H allows engineers to model and test virtual vehicle systems by configuring, assessing and optimizing system performance of any on-highway vehicle. The software is coded entirely in MATLAB®/Simulink® and can be modified and secured at the user's discretion. Combined with database utilities, this capability ensures maximum interoperability with no loss of model integrity, data integrity or fidelity.

Accumulator Safety

The safety of accumulators is extremely important, and SwRI has worked with manufacturers of composite pressure vessels for many years to ensure they meet stringent safety regulations. Tests are performed to ensure that accumulators have sufficient ultimate strength to withstand several times the expected maximum internal pressure. Evaluations are performed to ensure that accumulators have the endurance to withstand the cyclical pressure loading over their expected service life.

Filter, Filtration Technology

The Institute evaluates filter performance, solves filtration-related problems, and develops improved filters. With broad capabilities in material sciences, engine design and development, and fuel and lubricant technologies, SwRI provides a significant, single resource to filtration manufacturers, suppliers and users.

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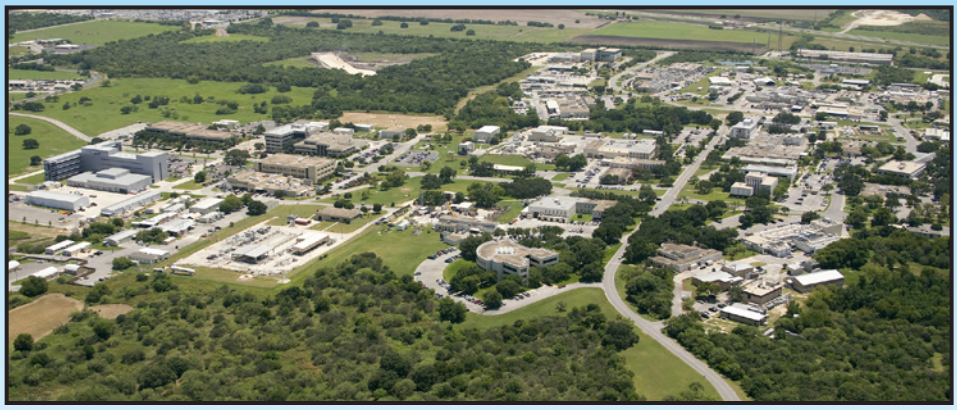

The Institute occupies more than 1,200 acres in San Antonio, Texas and provides more than 2 million square feet of laboratories, test facilities, workshops and offices for more than 3,200 employees who perform contract work for industry and government clients.

Founded in 1947 as an independent, nonprofit research and development organization, Southwest Research Institute provides a significant research, engineering and testing resource for industry and government. SwRI's 12 technical divisions, ranging from automobile research and space science to bioengineering and intelligent systems *(swri.org)* use a multidisciplinary, integrated approach to solve complex problems in science and applied technology. As part of a long-held tradition, patent rights arising from sponsored research at the Institute are often assigned to the client. SwRI generally retains the rights to Institute-funded advancements.

Benefiting government, industry & the public through innovative science & technology

We welcome your inquiries. For more information, please contact:

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ISO Certification — Engine, Emissions and Vehicle Research Division

The Office of Automotive Engineering (OAE) is certified to ISO 9001:2008 "Quality Management Systems – Requirements," accredited to ISO/IEC 17025:2005 "General Requirements for the Competence of Testing and Calibration Laboratories" and certified to ISO 14001:2004 "Environmental Management Systems." The OAE has also achieved Ford Tier 1 status for providing engineering services and the Engine, Emissions and Vehicle Research Division has received the Ford Q1 Quality Award. In conjunction with these divisional quality system accomplishments, the Petroleum Products Research Department is a Nuclear Procurement Issues Committee (NUPIC)-approved laboratory and the Fuels and Lubricants Research Division has maintained its status as an American Chemistry Council (ACC)-approved laboratory.