Hydraulic Test Stand Capabilities of Southwest Research Institute®

Prepared by:
Michael A. Kluger
6220 Culebra Road
San Antonio, TX 78238

SOUTHWEST RESEARCH INSTITUTE®
SAN ANTONIO, TX • HOUSTON, TX • ANN ARBOR, MI • WASHINGTON, DC

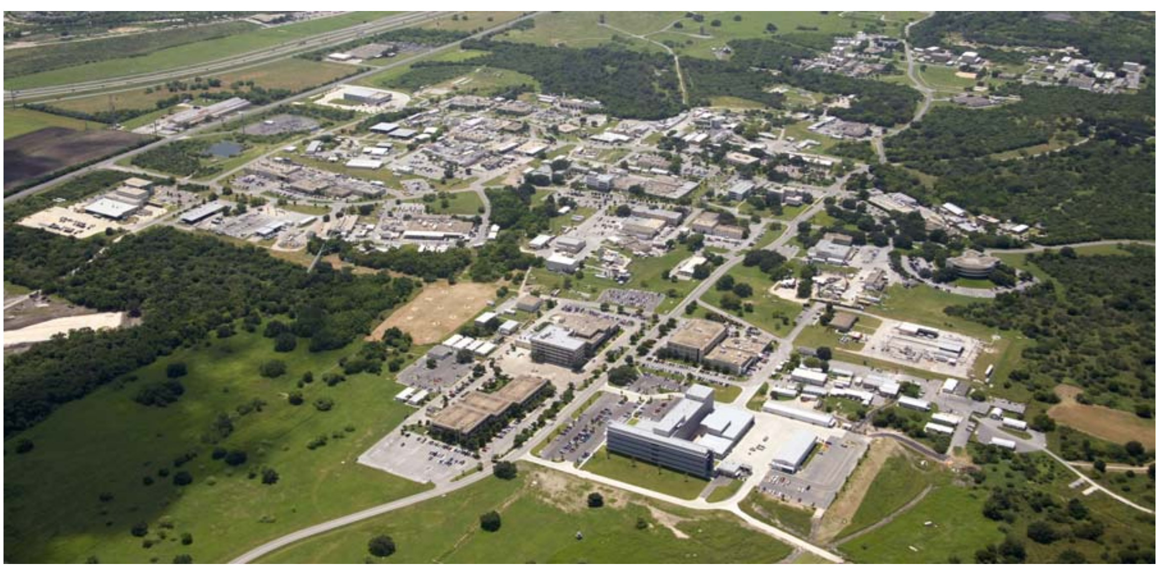
1.0 SOUTHWEST RESEARCH INSTITUTE® OVERVIEW

SwRI is an independent, contract research and development, not-for-profit firm whose charter is to expand the peaceful betterment of mankind through the application of science and technology. SwRI has successfully pursued this course over the past 60 years, providing engineering services to both the commercial and military sector across a wide range of technologies. SwRI employs a staff of 3,300 personnel, of which 2,350 are engineers and 800 are technicians.

In considering past performance, it should be noted that Southwest Research Institute and many of its employees have been recognized for quality performance and technical achievements. SwRI is a Ford Tier 1 supplier of Product Development Engineering Services and was the first service supplier to Ford to achieve Q1-2000 status; SwRI is ISO 9001 certified.

In FY 2008, SwRI performed over 2,000 projects valued over $560M, of this $348M was for the United States government, of which $62M was from Army funded contracts. The staff at SwRI works on a 1,300 acre facility that houses over 265 buildings and laboratories that contain over 2.2M square feet under roof. Southwest Research Institute is the recipient of 33 coveted "R&D 100 Awards," two of which were awarded in 2007 and one in 2008. The management structure allows decision-making at a level that provides fast response to clients' needs. The chain-of-command structure is only three levels deep between a work assignment manager and the division vice president.

The SwRI management has implemented Standard Operating Procedures for effective performance (goal) monitoring. The essence of these includes project planning and resource management. In doing so, labor resources are combined with facility and equipment resource requirements for accurate tracking. A picture of the institute is shown below.



2.0 PAST TEST STAND EXPERIENCE

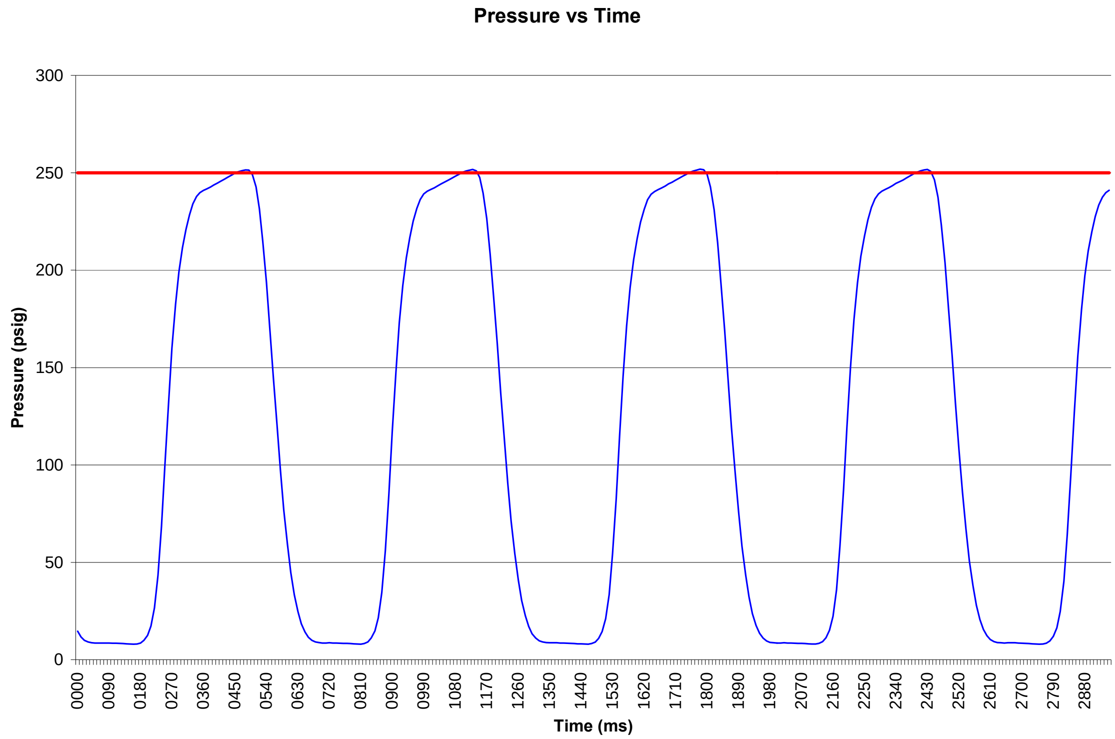
SwRI engineers continually design and develop numerous advanced technologies which are then validated on 240 dynamometer test stands located throughout the facility. As such, SwRI has considerable experience in designing, fabricating and operating test stands. As a service to its customers, and in response to direct requests by them, SwRI also fabricates test stands for them.

SwRI has considerable experience in the fabrication of test stands that involve:

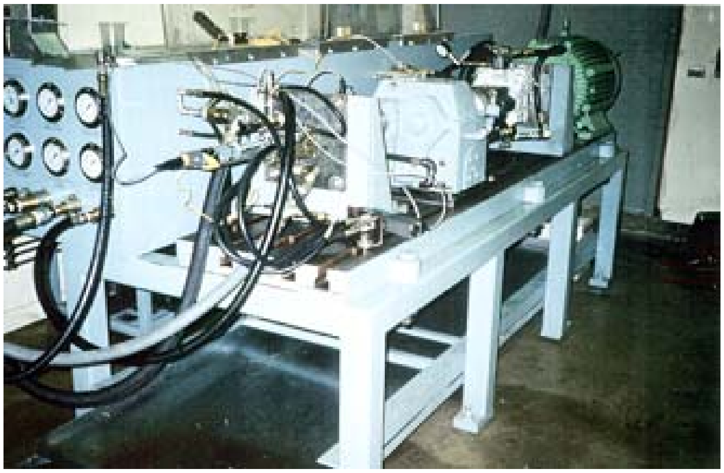
- Hydraulics
- Waveform application
- Pressure cycling
- High pressure

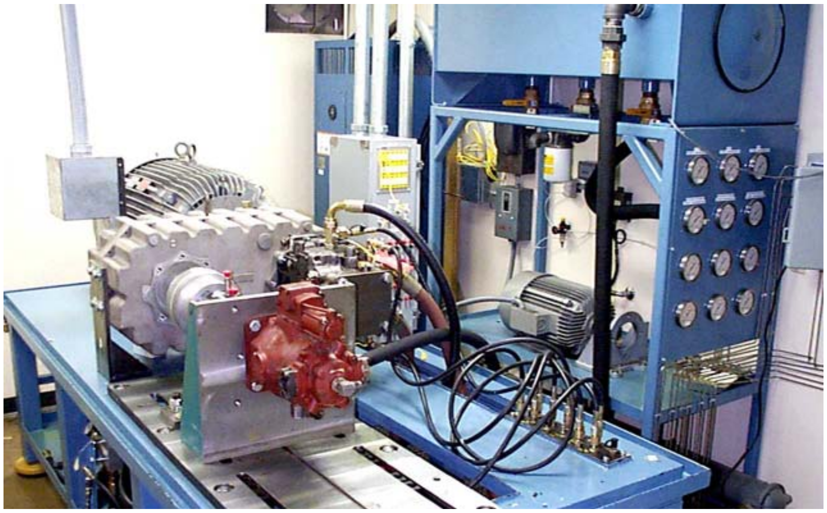
Over the past 10 years, SwRI has conducted extensive endurance testing of aircraft and drilling rig components to pressure levels between 10,000 and 20,000 psi. Components tested include: hose, tubing, housings, filters and valves, and must withstand 5,000,000 cycles. Critical to this type of testing is the application of **precision square waves with precisely defined ramp rates and waveforms with the <u>absolute requirement that there be no overshoot application of pressure</u> onto the test article.** Typical cycle times range from 1-5 seconds. Such testing is typically conducted at elevated fluid temperatures of 300°F in order to further stress the test components. Testing at elevated temperatures dramatically increases the complexity of the hydraulic components used in the test stand to create the waveforms.

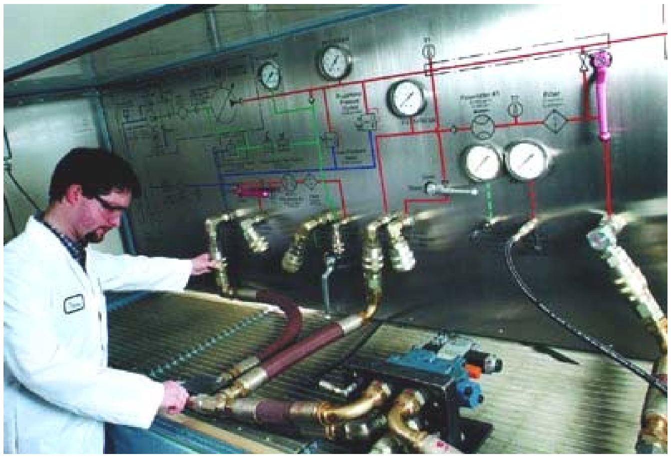
The most recent hydraulic test stand that SwRI fabricated was a pressure cycle test stand that is used to simultaneously evaluate up to 12 transmission components. The test stand can generate and apply square waves, stepped square waves and various square wave profiles. Ramp rates as quick as 25 msec and cycle times as short as 750 msec have been achieved with no overshoot. The stand is heavily instrumented and contains numerous safety circuits and runs in a fully automated mode using custom software prepared by SwRI. The software includes such displays and functions as test set up, calibration, warmup, test monitoring, data recording, flight recording, out of tolerance conditions and emergency shutdowns. Though extremely comprehensive in its breadth, operation of the software and test stand is easily mastered and performed by mechanical technicians because of the intuitive format implemented by SwRI. For this project, SwRI created 247 drawings, 7 test stand specifications, 5 software requirements specifications and associated test stand validation procedures. Some data produced by the test stand is shown below.



Over the past 15 years, SwRI conducted a very broad ranged program to develop a family of advanced, high efficiency hydraulic components for heavy duty vehicle applications that included bent axis and swash plate pumps, control valves, accumulators and controls. In addition to modeling, analyzing designing and fabricating these components, SwRI fabricated specialized test stands to conduct testing of these components. Some examples of the stands that were fabricated are shown in the figures below.







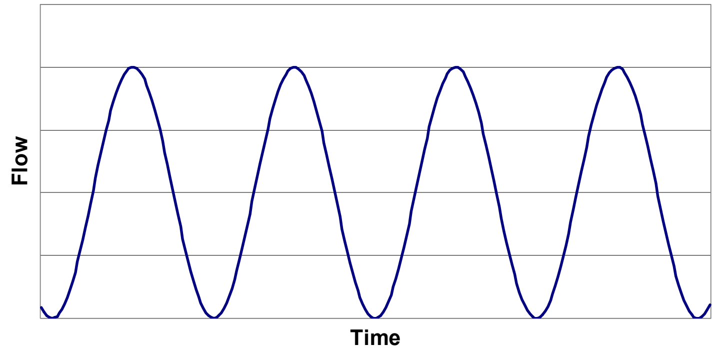
Another type of hydraulic test is used to qualify the performance of various types of pumps across a wide range of temperatures, flows and pressure conditions. Of the three operating parameters, extreme hot and cold temperature conditions are where failure modes occur or are exacerbated. To assist manufacturers in conducting aggressive and accelerated pump evaluations, a universal test stand was fabricated. The stand allows for thermal cycling, steady state operation, icing and cold temperature startup testing to be performed. Automated data acquisition, safety monitoring and control allow for long term cycle testing to be conducted.

The stand is capable of operation from -30°F to +160°F and with flows ranging from 25 to 100 gal/hr. Variable temperature ramp rates such as -20°F to +20°F in two hours or +50°F to +140°F in 40 minutes across a wide range of flow conditions can be met with accuracies of ±1°F to 5°F. The stand is capable of evaluating pumps operated on fuels such as gasoline, diesel, E85, biodiesels and JT 9. To allow for testing of integrally mounted, electrically powered pumps, special provisions were incorporated to eliminate sparking that would ignite combustible fluids. Specifically, nitrogen blankets are used to displace any oxygen within the insulated test reservoirs. Special provisions within the stand allow the effects of icing of the fuel and pump to be evaluated.

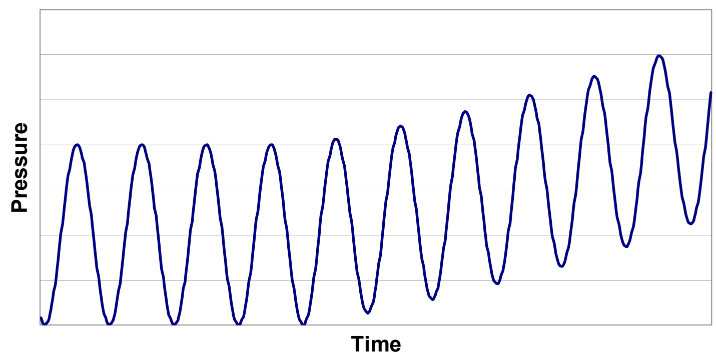
As regards high pressure hydraulic testing, SwRI engineers have been at the forefront of developing state-of-the-art, gasoline and diesel engines that meet ever increasingly stringent emissions requirements. One of the empowering technologies that has allowed engine technology to successfully meet these requirements, is precise control of fuel injected during the combustion process through the implementation of advanced fuel injection systems. Such systems operate at pressures approaching 30,000 psi and are routinely tested by SwRI. An example of such a test stand with multiple injectors under test is shown in the figure and pictures below.

In addition, SwRI has conducted testing of future, experimental systems at pressures to 60,000 psi.

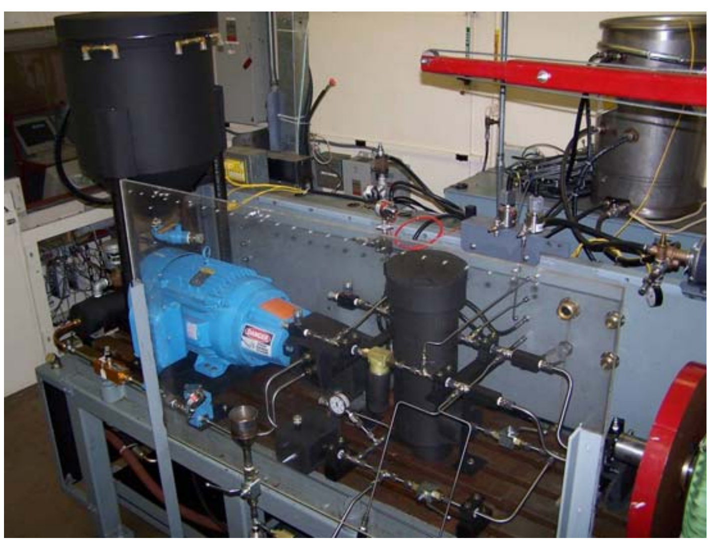
SwRI has fabricated a flow fatigue test stand. Flow testing of components such as valves and filters is critical in order to be able to ascertain when a reduction in their efficiency occurs. The test stand was designed and built such that it could produce varying rates of flow of up to 30 gpm as a function of time in a sinusoidal wave form pattern as shown below.



While flow is continually varied, contaminate is incrementally added at various times while fluid temperature is maintained at values ranging from 70°F to 250°F. As the component under test begins to plug and foul, its internal restriction increases, thus raising the operating pressure that must be applied to it. Testing continues for hundreds of thousands of cycles until an elevated threshold pressure is required to maintain the initial sinusoidal flow as shown below.



Increasing and decreasing flow control is achieved through the implementation of unique valving as shown in the following figure.



3.0 TECHNICAL PROJECT APPROACH

At the initiation of any SwRI project, a dedicated project team will be created and personnel from various disciplines will be assigned responsibility and resources associated with personnel and fabrication equipment being committed to the project. Leading the team will be a project engineer who will head up the project and also be the single point contact with the client. The project engineer will be responsible for providing biweekly project status reports. He will also be responsible for coordinating all technical personnel and for making sure the project schedule is strictly enforced.

Initially, a test stand specification describing all aspects of the stand's performance, footprint, facility interconnects, operator interface and the test stand commissioning procedure will be created. The specification will be prepared in conjunction with the client's personnel. Once completed, the specification will eliminate any ambiguity associated with the performance requirements for the stand and will also act as a guide upon which the project will be conducted.

Quickly thereafter, a final test stand design will be completed that will include a hydraulic and electrical schematic. Selection of hydraulic and electric components, and a CAD model of the test stand will be prepared. A parallel effort associated with the data acquisition hardware and software will be completed. A detailed drawing package will be created. Data acquisition and control software will also be created. Mechanical and electrical hardware will be ordered and any weldments or machined components will be fabricated.

The components will be assembled onto the test stand. Preliminary testing of the components and subassemblies will be performed to validate their integrity prior to final assembly testing.

Witness testing of the test stand will be conducted in San Antonio with the client's personnel in attendance. Testing will be to a test procedure developed and approved by the client at the onset of the project.

After completion of the witness testing in San Antonio, the test stand will be shipped to the client's facility. The test stand will be installed by SwRI personnel. This will include all hookup to facility electrical, water and compressed air lines.

After installation of the test stand, SwRI will conduct validation testing of the test stand for the client's personnel, along with operational training for operators, technicians and maintenance personnel.

4.0 RECENT HYDRAULIC TEST STAND PROPOSALS

Two recent test stand proposals prepared by SwRI in conjunction with Texas Management Associates, Inc. were 1) for a Hydrostatic Test Stand (HTM) for testing mortar housing to a maximum pressure of 30,000 psi for Blue Grass Army Depot and 2) for an Oil Test Stand for end of line production testing of F-100 gearboxes for Tinker AFB.

5.0 HYDROSTATIC TEST STAND

This project will consist of the design, fabrication, validation testing and installation of two self-contained hydrostatic test stands capable of simultaneously pressure testing ten aluminum mortar housings (p/n 11726795) to a minimum pressure of 17,000 psi. The test stand will consist of the following major functional modules:

- Hydraulic pressure and wave form application
- Manual aluminum loading and unloading
- Safety protection
- Data acquisition hardware and software

The design of the stand will be to apply square waves based upon a controllable ramp rate, and an application of a sustained working pressure for three seconds with an upper-most pressure capability of 30,000 psi. Pressure to the aluminum housing will be applied and monitored via a data acquisition and closed loop control system. Because of the high working pressures that can be generated by this test stand, considerable emphasis will be applied to assure the safe operation of personnel at or around the test stand at all times, and under all conditions during testing. Hydraulic operation of the test stand will be fully automated, and test data from each housing will be recorded. Included with the test stand will be a control station.

The oil flow test stand design would be a simple to use, robust assembly that will provide automated, closed loop control of fluid flow and temperature, along with an integrated National Instruments LabView for Windows data acquisition . The test stand capabilities will be as follows:

- Flow 0-10 gpm
- Pressure 0-1000 psi
- Temperature 5-275°F
- Viscosity 1.5-200 cst

The oil flow test stand will consist of the following components:

- Test chamber with a 48” x 48” viewing windows and lighting.
- 30 gallon insulated hydraulic reservoir.
- Fixed displacement check ball piston pump rated for high temperature operation
- Oil mist collection system
- Flow meter
- Pressure transducer
- Thermocouples
- Circulation centrifugal pump
- Hydraulic circulation heater
- Shell and tube heat exchanger
- Cooling water valve, pneumatic actuated
- Test chamber ceiling mounted extendable boom

- 1/2 ton boom mounted, electric hoist
- PID closed loop controllers
- Data acquisition system

With these features, throughput of test articles will be increased, test stand downtime will be reduced, maintenance issues will be minimized, and yearly operating costs will be lowered. A model of the stand is shown in the figure below.