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Mechanical Components Branch Test Facilities and Capabilities

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Mechanical Components Branch Test Facilities and Capabilities

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The Mechanical Components Branch at NASA Glenn Research Center formulates, conducts and manages research focused on propulsion systems for both present and advanced aeronautical and space vehicles. The branch is comprised of research teams that perform basic research in three areas: mechanical drives, aerospace seals and space mechanisms. Each team has unique facilities for testing aerospace hardware and concepts. This report presents an overview of the Mechanical Components Branch test facilities.

Drives Team Facilities

The Drives Team conducts research on transmissions and gearing for rotorcraft and for geared fan propulsion systems on conventional aircraft. The primary goals of drives team research are to improve the safety, reduce the weight and noise and increase the life and reliability of gear transmissions. This research involves advanced transmission concepts, transmission load distribution, drive system diagnostics and health monitoring, gear failure mechanisms, gear materials, gear tooth surface improvement and lubricants, gear vibration and noise, gear thermal analysis and analytical optimization programs to develop improved methods for transmissions design.

Spur Gear Fatigue Rigs

NASA Glenn Research Center has performed gear surface fatigue research since 1972. This research has provided an extensive database showing effects on gear pitting fatigue life of parameters such as gear steels, heat treatments, tooth surface treatments, tooth profiles, contact ratio, lubricants, lubrication methods and lubricant additives. The facility is also used to conduct gear crack propagation, gear health monitoring, and gear loss-of-lubricant research. This research has been performed on a set of six identical, specially designed gear fatigue rigs, including two new rigs commissioned in the year 2002.

The gear fatigue test rigs (fig. 1) re-circulate power in a closed-loop torque-regenerative (four-square) arrangement with test gears at one end connected to “slave gears” at the other end. With this arrangement, the drive motor needs to provide power only to overcome the frictional losses in the system. These rigs employ hydraulic loading mechanisms that apply torque by twisting one gear relative to its shaft. A schematic is shown in figure 1(b). Pressurized oil supplied to the loading vanes inside a slave gear applies torque to the system. The test gears are started and run up to the 10 000 rpm test speed under a light load, and then additional load is applied gradually without changing the running track on the gear teeth.

NASA usually tests gears with faces offset as shown in figure 1(b). This means each test runs on slightly less than half of the face width of the test gears. Offset testing produces the desired high contact stress without excessive bending stress that might cause undesirable tooth breakage failures. Offset gear testing reduces the loads on the test machines, which minimizes test machine failures. Another advantage of testing with the faces offset is it allows four tests per gear pair as opposed to only two tests per pair if the tests are conducted over the full face of the gears. A test gear with a typical fatigue failure is shown in figure 2.

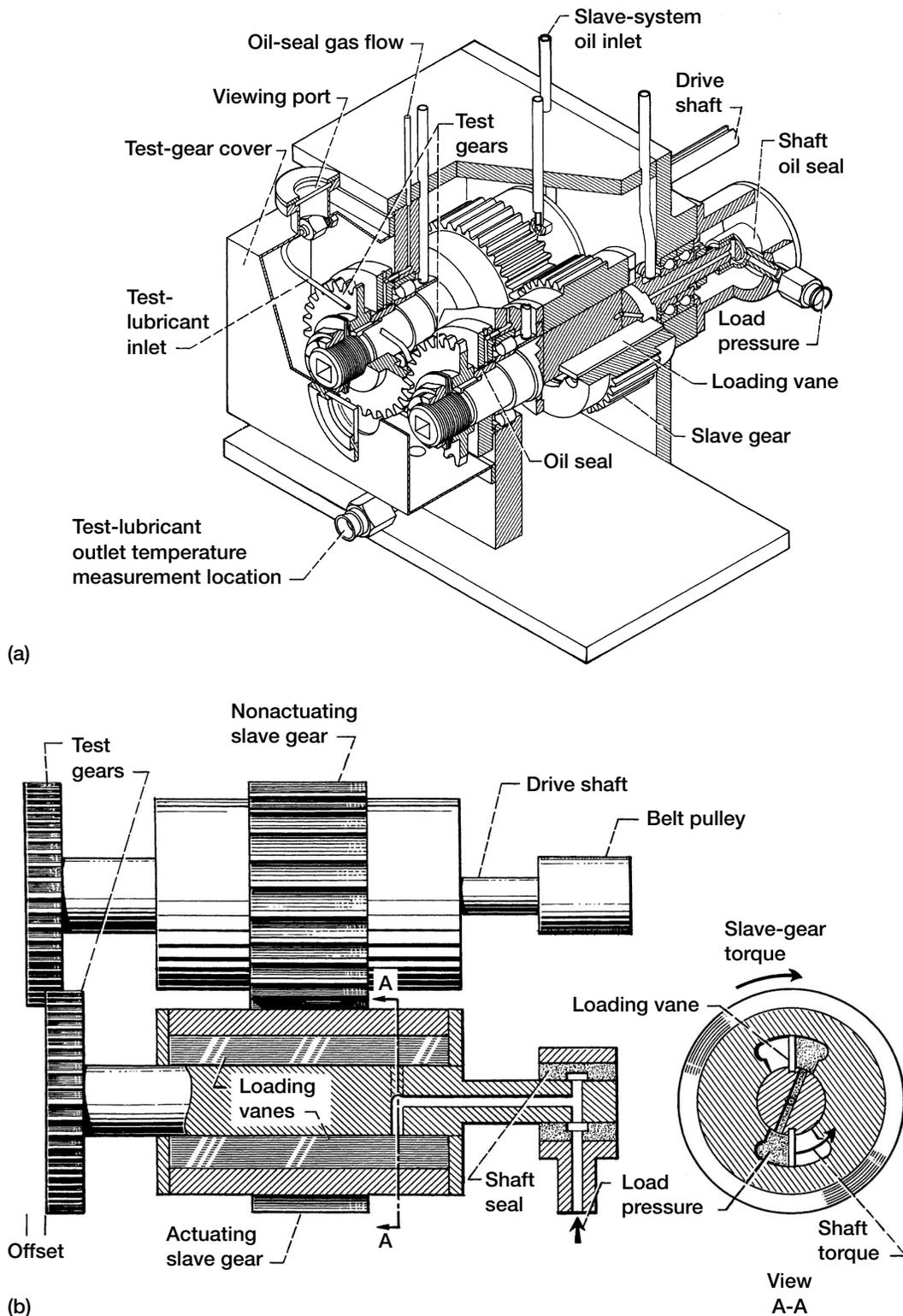


Figure 1.—NASA Glenn Research Center gear fatigue test apparatus. (a) Cutaway view. (b) Schematic view.

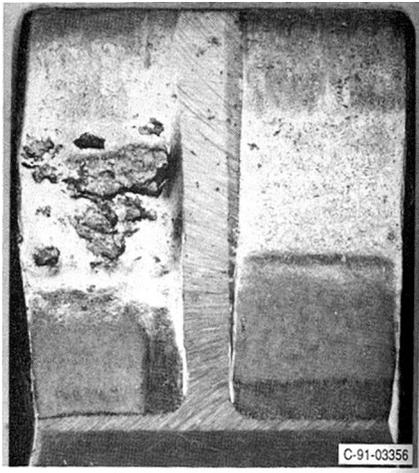


Figure 2.—Typical fatigue failure on left half of test gear tooth. The right half did not fail. Original grinding marks are still visible on the untested area at tooth middle.

The facility is normally used for fatigue testing at a Hertzian contact stress of 1.7 GPa (250 ksi). This requires 75 kW (100 hp) in the loop at the 10 000 rpm rotation speed. Test conditions monitored and recorded during the test include the hydraulic pressure supplied to the load device and the oil fling-off temperature via a thermocouple at the out of mesh position. Other indicators such as oil debris, vibration and noise levels may also be recorded.

Spiral Bevel and Face Gear Rigs

A spiral bevel gear rig has been dedicated to fatigue testing since 1993. The primary purpose of this rig is to study the effects of gear tooth design, gear materials, and lubrication on the fatigue strength of aircraft quality spiral bevel gears. The standard 12-tooth test pinion and 36-tooth gear have a 25.4 mm (1 in.) face width, and a 90 degree shaft angle. The maximum power condition is 560 kW (750 hp) at 20 000 rpm pinion speed. The same facility is also used for testing face gears.

The facility operates in a closed-loop arrangement where the drive motor only needs to provide the power to overcome the system losses. An overall sketch of the facility is shown in figure 3 and the facility in the face gear arrangement is shown in figure 4. Two sets of test gears (either spiral bevel or face gears) are tested simultaneously. The left side of the test section in operates in the speed reducer mode as would be used in a helicopter main rotor transmission application. The right side operates in a speed increaser mode, in which the gear drives the pinion. The two pinions are connected via a cross-shaft.

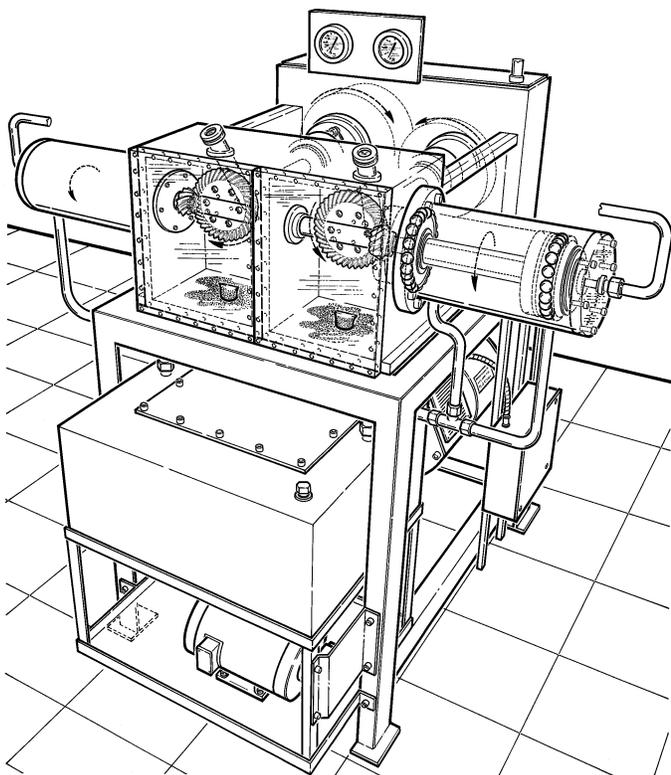


Figure 3.—Spiral bevel and face gear test rig.

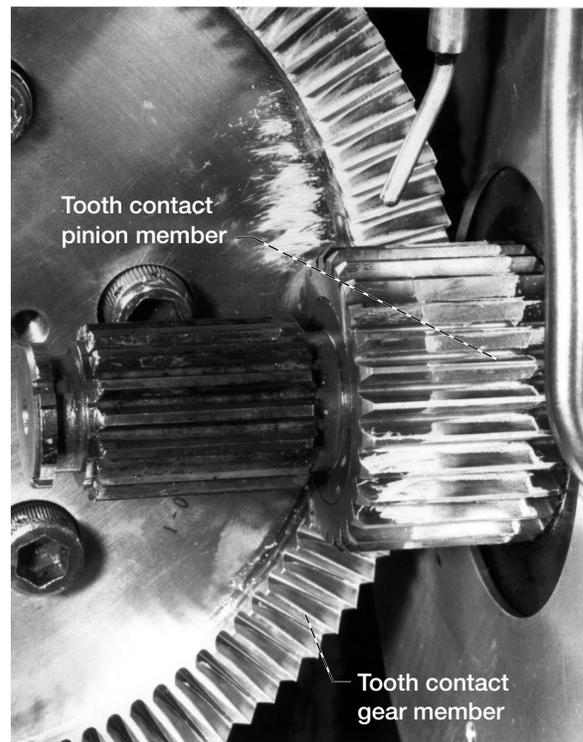


Figure 4.—Face gears.

The facility can be preloaded via a split coupling located on the slave gear shaft. The rest of the load is applied using a floating helical gear that is forced into mesh via a thrust piston. The loop torque is measured by a strain-gage type torque meter within the loop. Facility operational parameters are measured and recorded via a laboratory computer.

Helicopter Transmission Test Stand

The NASA Helicopter Transmission Test Stand (fig. 5) is used for dynamic testing of a full-scale single-engine helicopter main-rotor transmission. Research performed with this rig includes gear stress measurement, deflection of components, mechanical efficiency, gear noise and vibration, transmission diagnostics and condition monitoring. Various transmission configurations have been tested, including variants of the U.S. Army OH-58 helicopter transmission, hybrid (gear and traction drive) transmission and a bearingless planetary transmission design.

The rig can simulate transmission mast lift and bending loads, in addition to main rotor torque loading. In the actual OH-58D helicopter, the transmission at no-load is misaligned with respect to the input shaft. At the mast lift load of 18 309 N (4116 lb), the elastomeric corner mounts of the OH-58D transmission housing deflect such that the transmission is then properly aligned with the input shaft. (In the actual helicopter, this feature serves to isolate the airframe from rotor vibration.)

The rig can reach power levels of 400 kW (500 hp), at input speeds of 6200 to 36 000 rpm and output speeds of 350 rpm. The rig employs a closed-loop arrangement with a differential torque loading mechanism and therefore it can operate with a 150 kW variable speed D.C. electric motor. A smaller 11 kW motor operates through a magnetic particle clutch to provide torque in the loop through the differential.

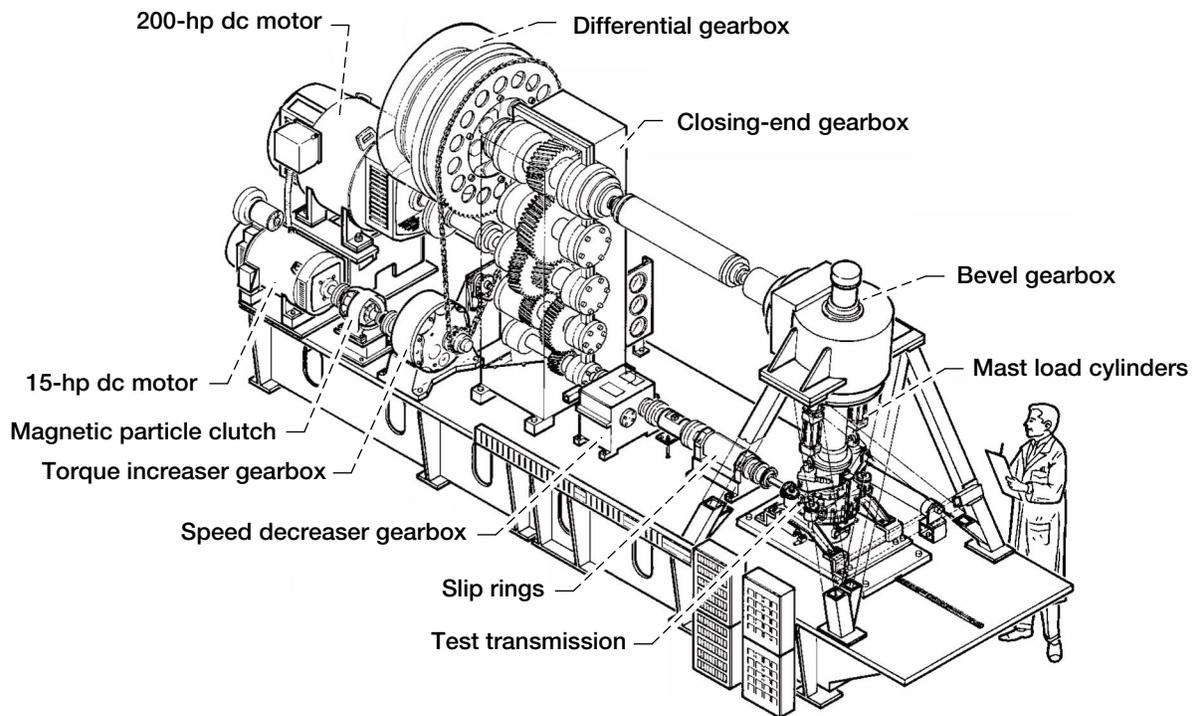


Figure 5.—Helicopter transmission test stand.

Instrumentation on the test transmission includes speed sensors, torquemeters, and slip rings at input and output shafts. Both load cylinders on the mast yoke are mounted to load cells. An external oil-water heat exchanger cools the test transmission oil to allow measurement of heat generation from transmission energy losses. A facility oil-pumping and cooling system lubricates the differential, closing-end, speed increaser, and bevel gearboxes. The facility gearboxes include accelerometers, thermocouples, and chip detectors for health and condition monitoring.

Gear Noise/Dynamics Rig

The NASA gear noise rig (fig. 6) is used for dynamic testing of parallel axis (spur and helical) gears. The rig includes a simple gearbox powered by a 150 kW variable speed electric motor connected through a poly-v-belt drive connected to the input (high speed) shaft. Typical input gear speeds range from 500 to 7200 rpm. Power absorption on the output is provided by an eddy current dynamometer.

The rig can measure vibration and noise, gear tooth strain and other parameters. A special transmission error measurement system (fig. 7) was added in 2000. This unique instrument can detect the actual error between a pair of meshing spur or helical gears to within a resolution in the time domain of better than 0.1 micrometer, and discrimination in the frequency domain of better than 0.01 μm .

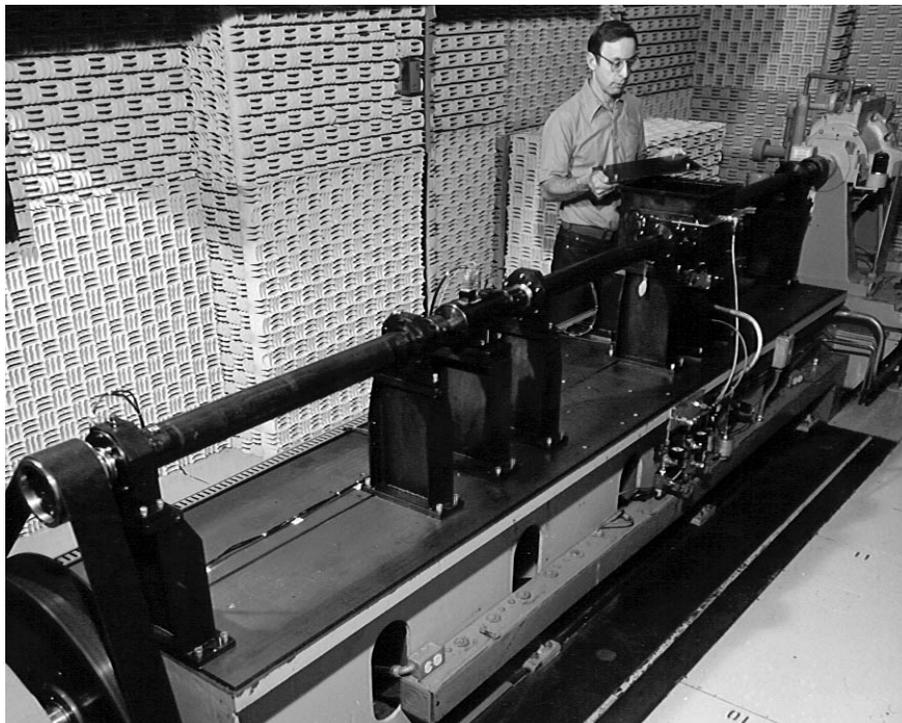


Figure 6.—Gear noise rig.

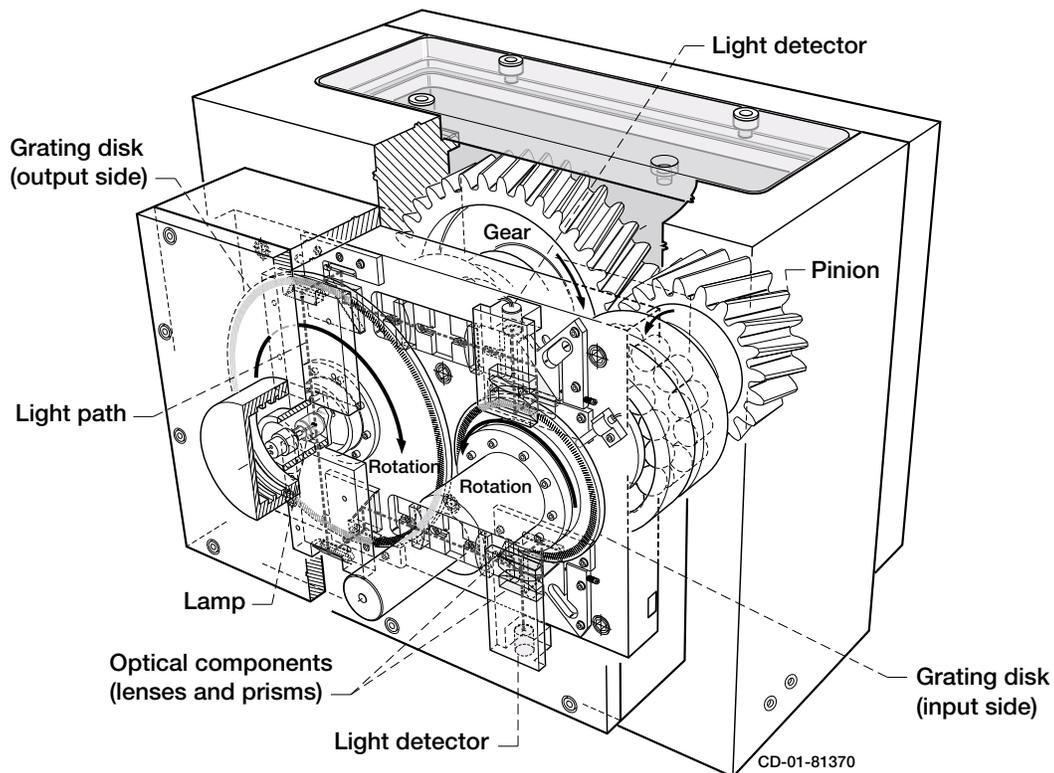


Figure 7.—Gear transmission error measurement system.

High-Speed Helical Gear Test Facility

The test facility for the study of thermal behavior of high-speed helical gear trains is shown in figure 8. The facility is a closed-loop, torque-regenerative testing system. There is a test gearbox and slave gearbox that are basically mirror images of each other. Each gearbox has an input gear, three idlers, and one bull gear. The gearboxes are joined together through the input gears and bull gears via shafting.

The facility is powered by a 400 kW (500 hp) DC drive motor through a speed-increasing gearbox. The output of the speed-increasing gearbox then passes through a torque and speed sensor before connecting to the slave gearbox at the first idler gear.

Because power is recirculated within the system, the drive motor needs only to accelerate the system to operating speed and to overcome friction losses. A rotating torque actuator inside the slave gearbox loads the system by rotating the bull gear relative to the shafting from the test gearbox. This permits adjusting loop torque during operation.

Each gearbox has separate supply and scavenge pumps and reservoirs. Lubrication system flow rate is controlled by adjusting the oil supply pressure. Temperature is controlled via immersion heaters in the reservoir and heat exchangers that cool the lubricant returned from the gearboxes. Each lubrication system has a very fine 3-micron filtration. Nominal flow rate into the test or slave gearboxes at 0.55 MPa (80 psi) is approximately 57 l/min (15 gpm).

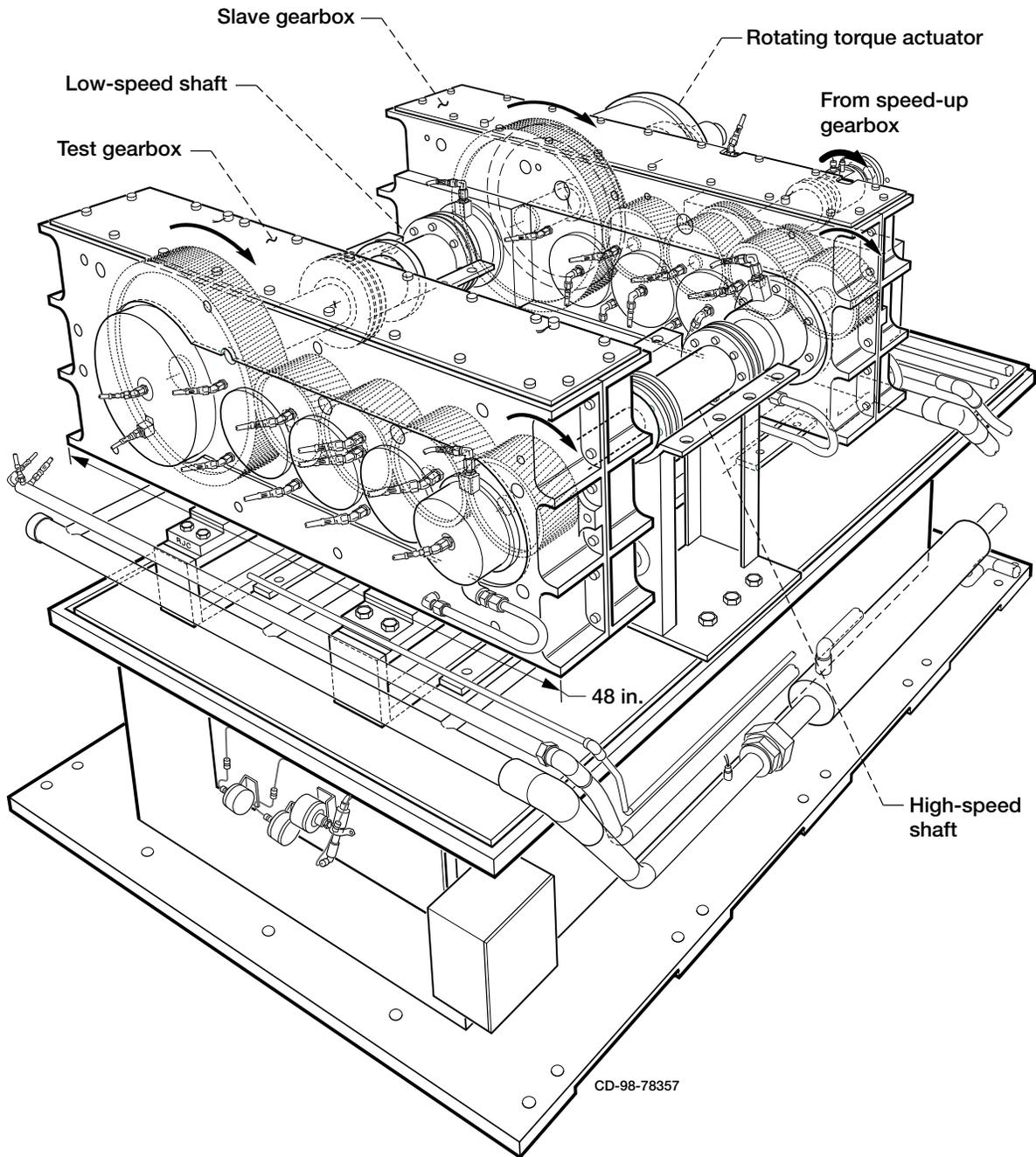


Figure 8.—High-speed helical gear test facility.

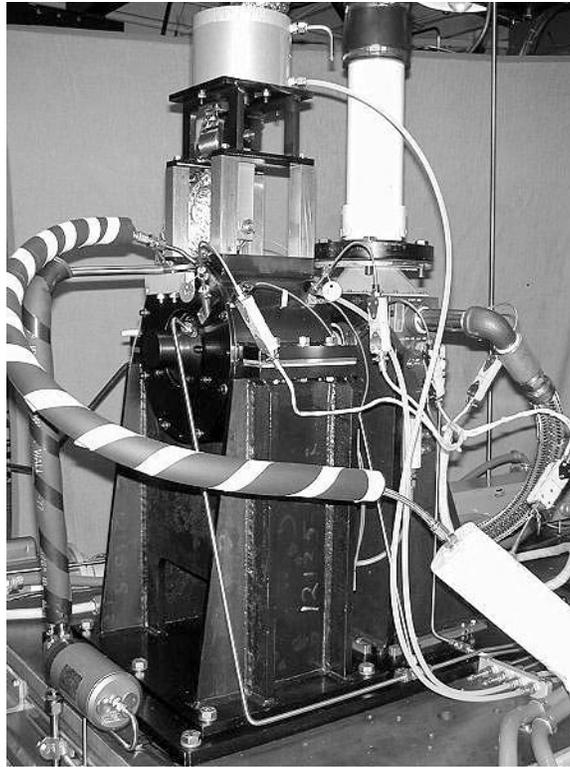


Figure 9.—Oil journal and thrust bearing rig.

Oil Journal and Thrust Bearing Rig

This facility (fig. 9) tests fluid film journal and thrust bearings up to 100 mm (4 in.) diameter and 50 mm (2 in.) length under controlled conditions. The speed capability extends to 25 000 rpm at radial loads to 13 kN (3000 lbs) and axial loads to 1300 N (300 lbs). Lubricant can be supplied to the bearing at pressures to 0.55 MPa (80 psi) and temperatures to 370 °C (700 °F). The rig can apply both steady-state and dynamic loading with arbitrary start-stop cycles and under various oil supply conditions, including normal, starvation, and start-stop.

The measurement capability includes shaft speed, radial and axial loads, oil flow rate, temperature and pressure of the bearing inlet and exit and the temperature of the bearing sleeve. We also track the relative position of the shaft to the bearing and determine dynamic shaft orbits inside the sleeve. Accelerometers are fixed on the rig housing and turbine to monitor noise and vibration.

Turbine and Structural Seals Team Facilities

The Seals Team conceives, develops and tests advanced turbine seal concepts to increase efficiency and durability of turbine engines. Current projects include developing non-contacting seals for near-infinite life. The Seals Team also performs experimental and analytical research to develop advanced structural seals. This includes propulsion system and control surface seals for next generation launch vehicles and thermal barrier seals for solid rocket motor nozzle joints



Figure 10.—High-temperature, high-speed turbine seal rig.

High Temperature, High Speed Turbine Seal Test Rig

The turbine seal test rig (fig. 10) is used to investigate the performance of aircraft engine air seals. The rig can accommodate the current labyrinth, brush, and finger seals as well as advanced concepts in non-contacting seals.

Measurement capability includes seal leakage rate, pressure differential, hot air flow rates, shaft torque and seal power loss. The seal leakage rate is used to calculate the flow factor to an accuracy of ± 1.5 percent. The flow factor is used to compare the leakage performance of seals with different diameters and under various operating conditions. The rig is also used to investigate seal hysteresis and endurance, rotor runout, and seal offset.

The rig consists of a 215 mm (8.5 in.) diameter test rotor mounted overhung on a shaft and driven by an air turbine. The rig has been operated at seal surface speeds to 370 m/s (1200 f/s). Pressure differentials range to 1700 kPa (250 psi). Seal inlet air temperatures can be controlled from ambient to 650 °C (1200 °F). A planned heater upgrade will extend the temperature capacity to 800 °C (1500 °F).

Proximity probes measure the change in clearance between the seal holder and the rotor and monitor the rotordynamic behavior of the test rotor. Temperatures are measured on the seal both upstream and at the back face. Air flow temperatures are taken at seal inlet and exit.

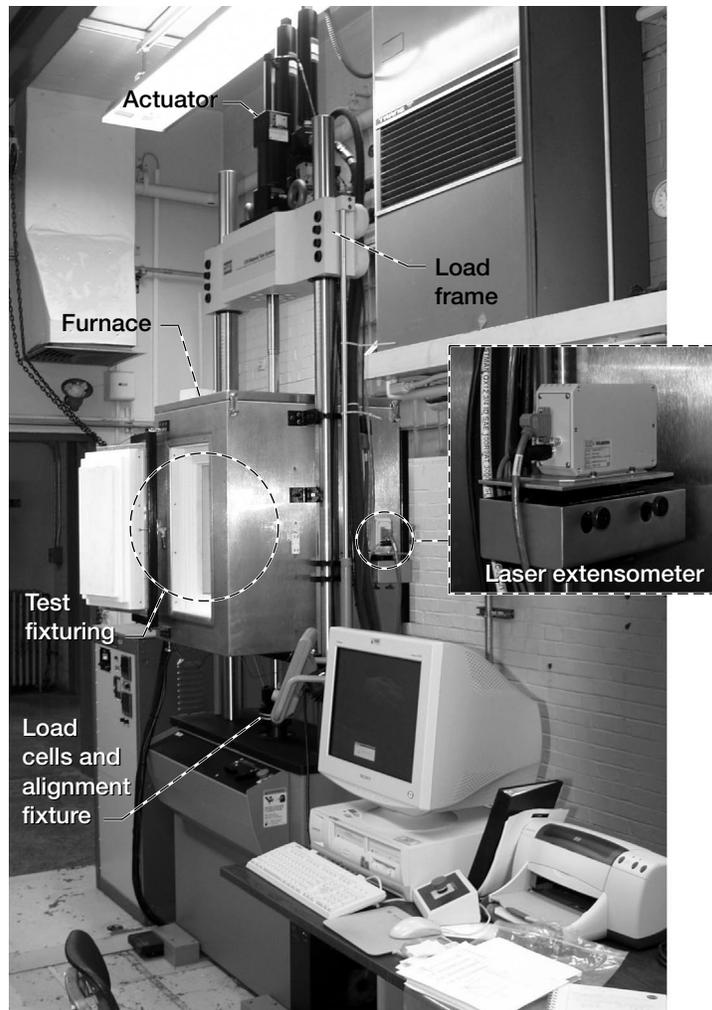


Figure 11.—Hot compression and scrub test rig.

Hot Compression and Scrub Test Rig

The hot compression and scrub test rig (fig. 11) is used to evaluate advanced structural seals such as braided rope seals and thermal barriers. The main components of this test rig are a servohydraulic load frame, an air furnace, and a non-contact laser extensometer. High temperature seal compression tests and scrub tests can be performed at temperatures up to 1650 °C (3000 °F) by using different combinations of test fixtures made of silicon carbide. The furnace has a working volume 23 cm wide by 35 cm deep by 46 cm high (9 by 14 by 18 in.). The rig can accommodate seal lengths to 100 mm and diameters to 50 mm.

The load frame has a top-mounted actuator capable of generating a load of 15 kN (3300 lb) over a 150 mm (6 in.) stroke. The actuator can be moved at rates of 0.3 to 200 mm/s (0.001 to 8.0 in./s). Low stroke rates are typically used for compression tests and higher rates for scrub tests. Computer control of the hydraulic system permits a mission-simulated duty or scrub cycle to be used during testing.

Hot compression tests are performed inside the furnace using the fixture shown in figure 12. These tests evaluate seal resiliency and stiffness and generate data relating seal load to amount of compression at temperatures to 1650 °C. Test specimens are installed into a seal holder that rests on a stationary base at the bottom of the furnace. A movable platen loads and unloads the specimens via the loading rod at the top of the furnace.

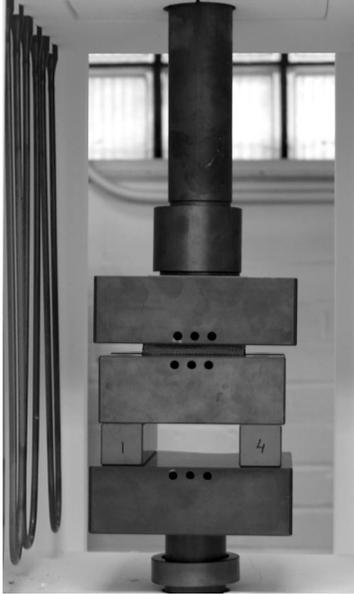


Figure 12.—Hot compression fixture.

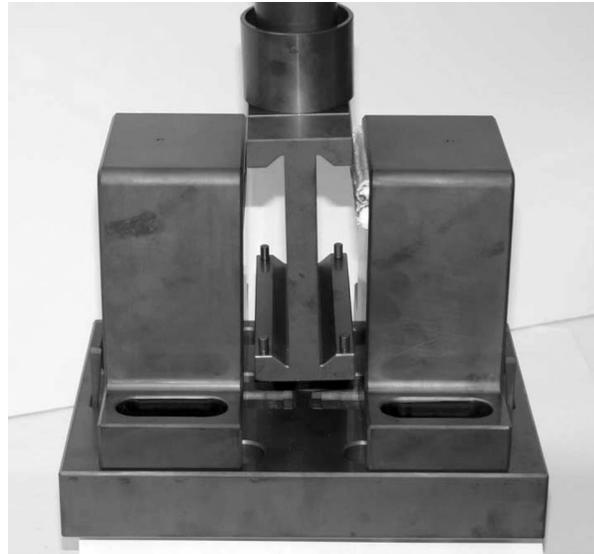


Figure 13.—Hot scrub fixture (with rub surfaces not installed).

The laser extensometer measures the linear compression of the specimens during testing (fig. 11). A “sheet” of light produced by the laser passes through slots in the furnace walls and is detected by a receiver on the opposite side of the furnace. This system has a measurement range up to 50 mm (2 in.) and an accuracy of $\pm 6.4 \mu\text{m}$ (0.00025 in.).

Variables that can be adjusted for these tests include the compression applied to a specimen, the loading rate, and the temperature. Test specimens can be loaded and unloaded repeatedly for cyclic loading tests, or stress relaxation tests can be performed in which a specimen is put under a specified amount of compression and then held in that state for a period of time. Tests can be performed using either load control or displacement control.

High temperature seal scrub tests can also be performed in this rig by using different test fixtures (fig. 13). These tests evaluate seal wear rates and frictional loads for a variety of test conditions. Seals are held in place in two stationary seal holders on either side of a pair of movable rub surfaces. The rub surfaces are installed in a holder that is connected through the loading rod to the actuator. The gaps between the rub surfaces and the seals are varied by spacer shims. The largest gap size that can be tested is 16 mm (0.625 in.). The amount of compression on the seals is varied by use of shims behind the seals.

Room Temperature Flow Testing

Room temperature flow tests are performed on seal specimens before and after they have been scrub tested using the test fixture shown in figure 14. The seal holders used for the scrub tests are flipped over and inserted into this test fixture. A cover plate is then bolted over the seal holder. O-ring seals are used to block parasitic leakage around the perimeter of the seal holder. A section is cut out of the center of the cover plate where the seal is located. Different sealing surfaces can be inserted into this cavity and compressed against the seal during a flow test. These sealing surfaces can be made of different materials or have different surface roughness or profiles to determine how these changes affect the amount of flow that passes through and around the test seals. A transparent sealing surface can be used to allow visual inspection of the seal under pressure loads.

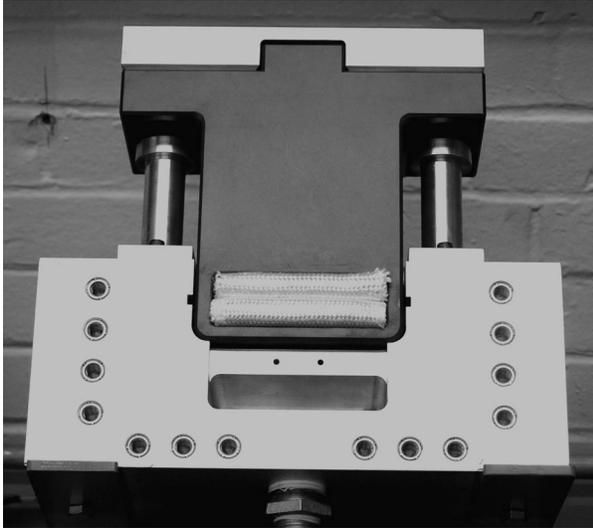


Figure 14.—Room temperature flow test fixture with cover plate removed.

During testing, pressurized air enters through an opening in the base of the fixture and passes through a plenum chamber before reaching the test seal. Flow meters upstream of the flow fixture measure the amount of flow that passes through the seal. Four flow meters cover a flow range of 0 to 3000 standard liters per minute (0 to 0.135 lbfm/sec). A pressure transducer upstream of the test seal measures the differential pressure across the seal with respect to ambient conditions for pressures up to 700 kPa (100 psi), while a thermocouple measures the upstream temperature.

A typical sequence of tests begins with a flow test on a seal specimen before scrub testing to establish the baseline flow rates for the seal. The seal holder is then removed from the flow fixture and placed into the hot scrub test rig for scrub testing. After the seal has been subjected to a specific number of scrub cycles, the seal holder is removed

from the scrub fixture and inserted into the flow fixture for another flow test. The results of this flow test are then compared to the original flow test results to determine what effect scrubbing damage has on seal flow blocking ability.

Ambient Cold Flow and Scrub Test Rig



Figure 15.—Ambient flow and scrub rig with carriage in open position for seal installation.

The ambient flow and scrub test rig (fig. 15) permits simultaneous flow and scrub testing of structural seals at room temperature. The rig is used to investigate seal performance as a function of scrub cycling, seal gap size, and compression level. The rig accommodates a variety of seal configurations in lengths of 200 mm (8 in.) or longer. Different rub surfaces can be provided to simulate various end use conditions.

In this rig, the seals are installed in a race-track-shaped groove in a cartridge. Different seal cartridges are used for seals of various sizes. The assembly can be rotated to different positions to scrub the rub surface across the seals in different directions. The amount of compressive load on the test seal is controlled using one of the following approaches: (a) Bellville springs acting through push rods from behind, (b) shims inserted behind the seals or (c) pneumatic pressure applied behind the seals.

As with the hot scrub tests, rub surfaces can be made of a variety of materials, surface roughness conditions, and surface profiles. These rub

surfaces include Space Shuttle-type thermal tiles and Inconel 625 plates. The rub surfaces are attached to a carrier plate that is scrubbed back and forth across the seals by an actuator. The actuator is capable of forces up to 45 kN (10 kip) with a 30 cm (12 in.) stroke at up to 30 cm/sec (12 in./sec). A computer controlled hydraulic system permits mission-simulated duty cycles. Load cells in line with the actuator measure frictional loads between the seals and the rub surface. As seal damage accumulates during testing, any changes in frictional loads are measured by these load cells.

During tests, the actuator moves the rub surface back and forth across the stationary seals while flow passes out of the port in the center of the seal cartridge and through the seals. Flow meters upstream of the test rig measure the amount of flow that passes through the seal in the range of 0 to 3000 standard liters per minute (0 to 0.135 lbm/sec). Two pressure transducers upstream of the test seal measure the differential pressure across the seal with respect to ambient conditions. Differential pressures up to 700 kPa (100 psi) can be achieved. A thermocouple upstream of the seal measures the upstream temperature.

Acoustic Seal Test Stand

The acoustic seal test rig (fig. 16) is used to investigate the application of shaped acoustic resonators to sealing devices used for rotating machinery. By oscillating specially shaped resonating cavities at frequencies equivalent to the resonant frequency of the fluid contained by the cavity, high-amplitude standing pressure waves have been demonstrated. The acoustic pressure waves generated on the rig are being used to develop the innovative Acoustic-Based Seal that shows the potential of operating with zero-leakage and zero-wear.

The primary component of the rig is a 15 cm diameter shaker table. The shaker table can produce a sine force up to 2200 N (500 lbf) peak-to-peak, a shock force up to 4400 N (1000 lbf), and a random force up to 1550 N (350 lbf). The frequency range of the shaker system is DC to 4500Hz with a displacement stroke length of 2.5 cm. The maximum payload that can be oscillated on the system is 28 kg (62 lbf). The instruments used during testing on the rig include thermocouples, static and dynamic pressure transducers, and accelerometers. Simultaneous measurements of flow rates through the acoustic resonator assembly can be made up to 1500 SLPM.

Several acoustic resonators have been fabricated for sealing application evaluation. The resonator shapes include cylindrical, conical (fig. 16), half-cosine, and two horn-cones. The measurements recorded on the acoustic seal test rig are used to evaluate characteristics of the acoustic resonators such as hardening, softening, and hysteresis as well as their applicability to a sealing device.

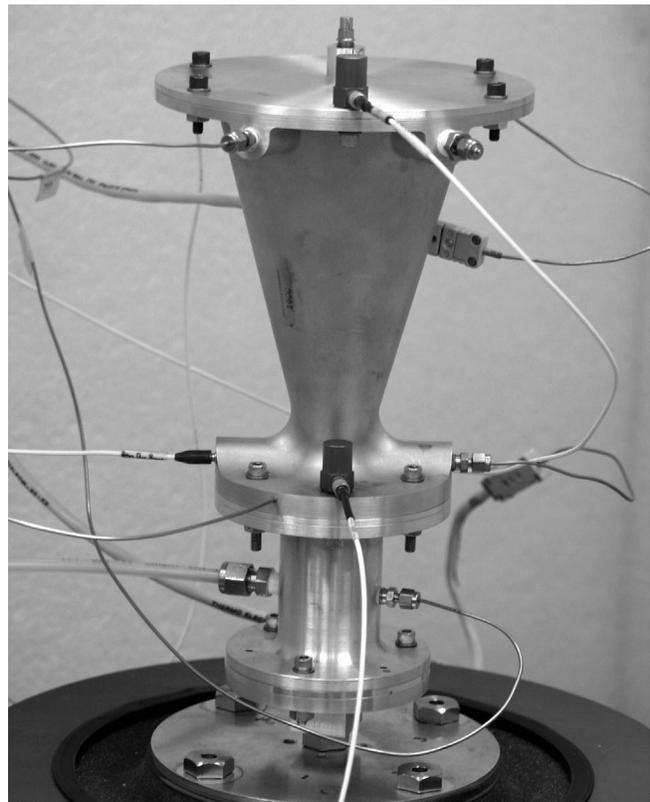


Figure 16.—Acoustic seal rig with conical resonator.

Space Mechanisms Test Facilities

The Space Mechanisms Team employs several devices for accelerated tribological testing of space mechanisms and components. These devices are used to investigate the effect of solid or liquid lubricants and coatings on the friction, variation of friction force, wear and life of specimens under simulated conditions. Often the condition simulated is high vacuum, but some tests can be made using a controlled atmosphere, such as dry nitrogen or argon. Some tests are also conducted in dry or humid air as well. Testing in humid air can simulate problems caused by a delayed spacecraft launch.

Pin-on-Disk Tribometer

Pin-on-disk test devices employ a pin with hemispherical tip (or a ball clamped in a holder) pressed against a 50.8 mm diameter flat disk that is rotated relative to the pin. A schematic of the device is shown in figure 17 and a photograph in figure 18. The load (typically 9.8 N) is applied by a dead weight through a lever arm system. A plastic housing around the apparatus allows control of the atmosphere (by purging the housing with dry nitrogen, etc.). The device allows sliding speeds up to approximately 0.5 m/s at a rotation speed of 200 rpm.

For solid lubrication testing, a film or coating is applied to the disk or the disk is made from a polymer or composite material and then a metallic or ceramic pin is slid against the disk. For testing liquid lubricants, the disk must be immersed in an oil reservoir or a vertically mounted disk can be dipped into the lubricant.

Wear of the pin is determined by measuring the change in diameter of a circular wear scar on the pin and then calculating the volume of material removed or by measuring the weight loss of the pin. Wear of the disk is determined by measuring the wear track cross-sectional area using a surface profilometer and then calculating the volume removed or by measuring the weight change. Wear should always be reported as a volume change (for a disk, the cross-sectional-area of the scar multiplied by the disk track length or for a ball or pin, the volume of the material removed from the tip) because adhesive wear is a volume phenomenon.

We generally rely on optical and surface profilometry measurements for wear data rather than weight-loss measurements, since material transfer from one surface to another can provide an erroneous weight change. Pin-on-disk testing offers an advantage that it produces flat wear surfaces that are very easy to analyze using surface measurement techniques.

Block-on-Ring Tribometer

A block-on-ring tribometer (fig. 19) is used to evaluate tribological materials for aircraft and spacecraft. This device employs a stationary rectangular block pressed against the periphery of a rotating or oscillating ring that slides against the block. The block can be flat (for line contact) or conforming (area contact). For area contact, the same radius of curvature is given to the contacting block face and to the ring to produce a large area of contact.

The block-on-ring tribometer is capable of speeds to 1300 rpm, which produces 2.4 m/s (468 ft/min) sliding speed at the periphery of the 35 mm (1 $\frac{3}{8}$ in.) diameter ring. The block is 6.3 mm ($\frac{1}{4}$ in.) wide. A dead weight produces up to 2800 N (630 lb) contact force between the block and the ring. This will generate a Hertz stress up to 760 MPa (110 000 psi). The device can test at elevated temperatures up to 230 °C (450 °F). The atmosphere may be controlled by purging the test chamber with dry or humid air or with gasses such as nitrogen and argon.

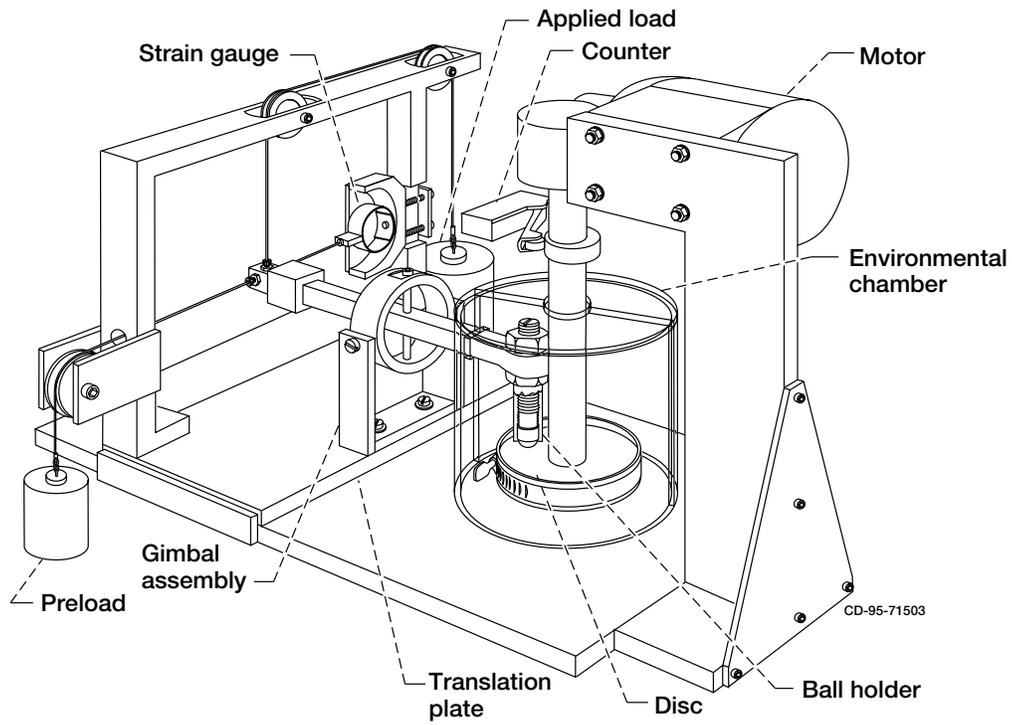


Figure 17.—Pin-on-disk tribometer schematic.

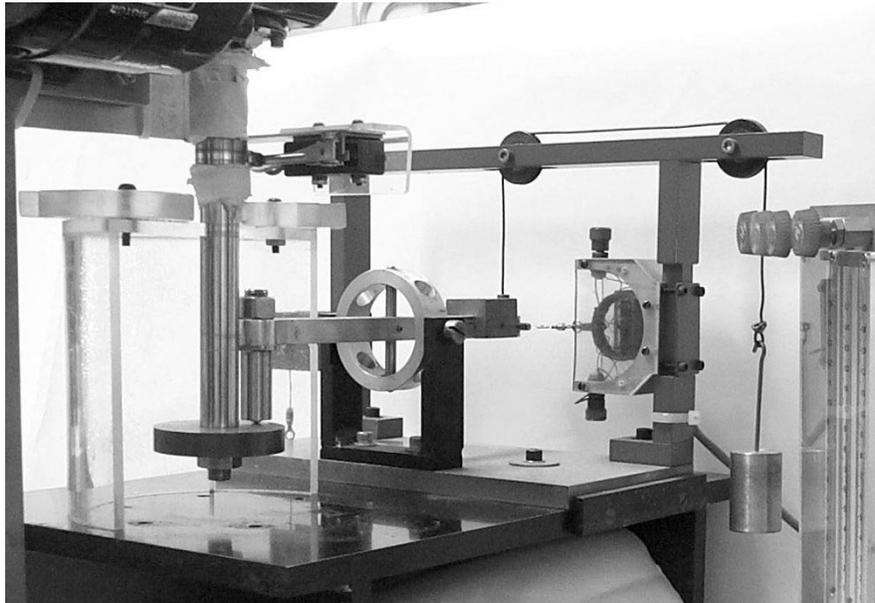


Figure 18.—Pin-on-disk tribometer.

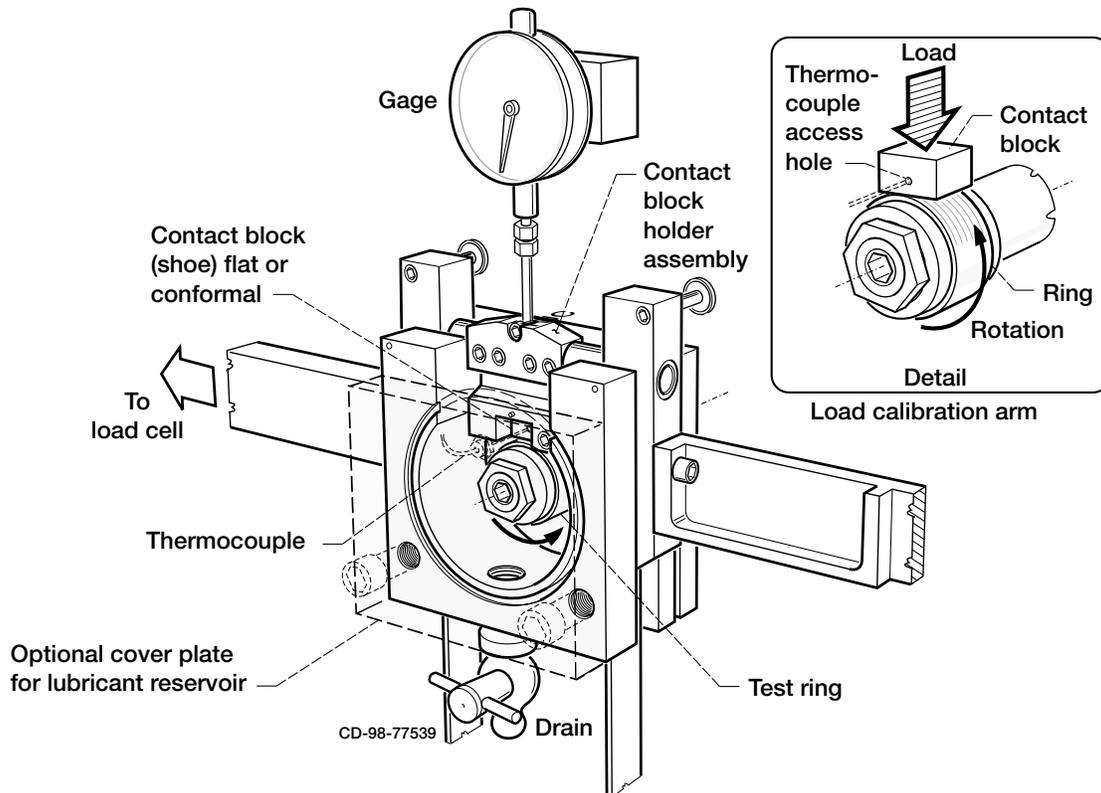


Figure 19.—Block-on-ring tribometer schematic.

A load transducer attached to the block holder measures the frictional force between the block and the rotating ring. A thermocouple imbedded near the contact area of the block measures the block temperature. Also when testing a liquid lubricant, a thermocouple is immersed in the lubricant supply cup to measure the lubricant temperature.

If liquid lubricants are tested, a lubricant reservoir (cup) is filled so that the ring dips into the lubricant. If a solid lubricant film is tested, the film is applied to the contact area around the diameter of the ring. The block can also be made from a composite material slid against a metallic or composite ring. In all cases, the surface roughness of the ring is very important and can influence the results. Generally speaking, the wear rate for a block is inversely related to the roughness of the ring. To most closely reproduce the end-use application, the roughness should closely match that of the end-use application. ASTM standard tests for this machine are: D-2714-94 for calibration and operation with liquid lubricants and D-2981-94 for wear life of bonded solid lubricants in an oscillating motion.

Vacuum Roller Contact Rig

The vacuum roller rig (fig. 20 to 21) was built to evaluate materials and coatings for use in traction drives or bearings for space applications. The rig can simulate combined rolling and sliding conditions under vacuum to 10^{-4} Pa (10^{-7} torr) or in a controlled atmosphere to evaluate roller traction and wear under spin, creep and sliding conditions. Roller specimens can be metallic, polymeric, or ceramic and they may be coated with a variety of protective materials. Rollers are nominally 35.6 mm diameter.

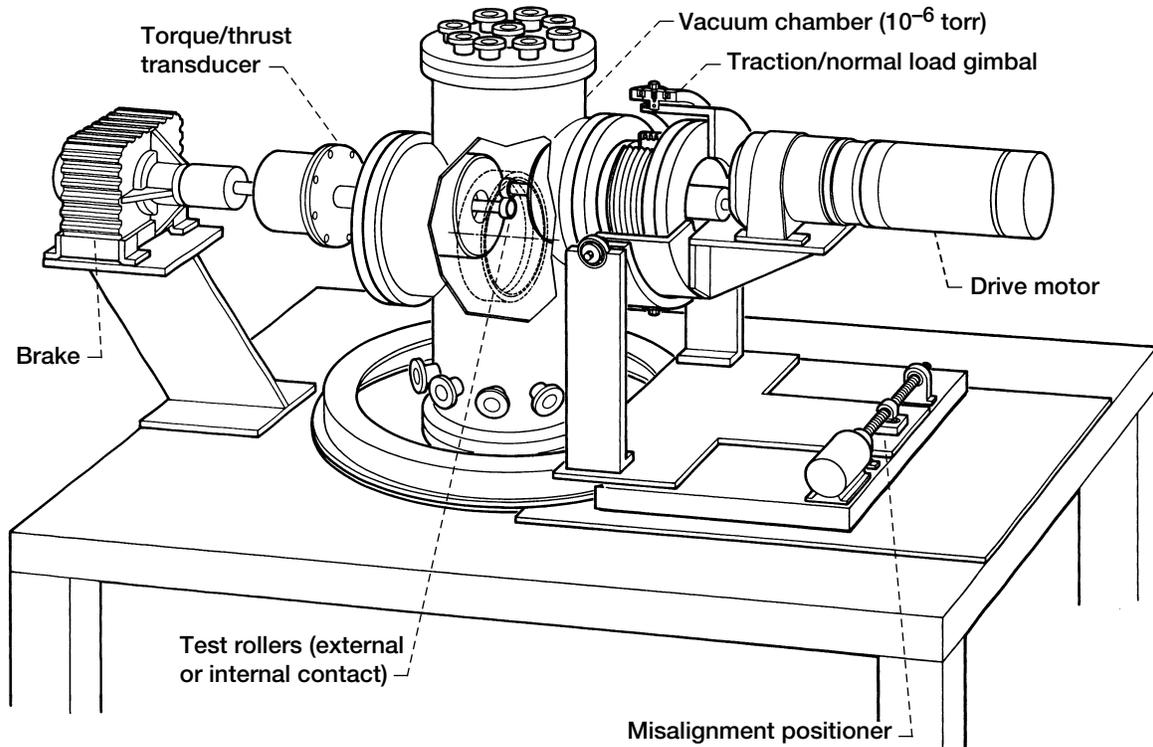


Figure 20.—Vacuum roller rig schematic.

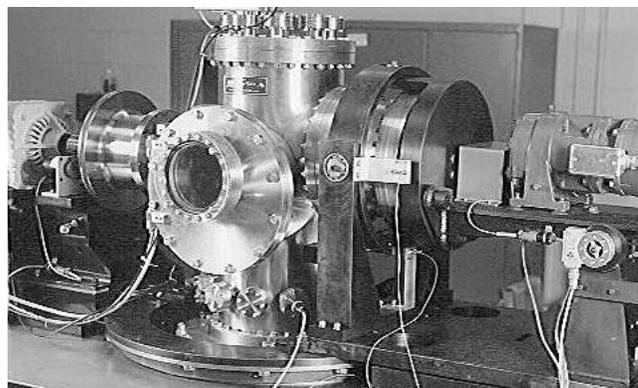


Figure 21.—Vacuum roller rig.

The motor drives a crowned roller up to 480 rpm loaded against a cylindrical roller. Surface speeds reach 0.9 m/s (180 ft/min). The maximum normal load of 900 N (200 lb) produces a contact stress of 2800 MPa (400 000 psi) with steel specimens. Torque capacity is 23 N-m (200 in.-lb) and we can apply an axial thrust load to 900 N (200 lb). The device is capable of misalignment up to ± 1.7 deg.

Various solid lubricants can be applied to the cylindrical roller or to both rollers if desired. Slip between the crowned roller and the cylindrical roller is controlled by a magnetic particle brake applied to the cylindrical roller. Friction coefficients can be measured and traction coefficients can be calculated. Wear to the coatings can be determined either at the end of a test or by stopping the test at preset intervals to measure the wear.

Vacuum Bearing Rig

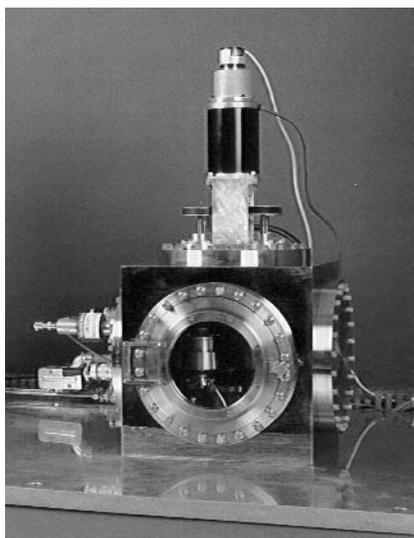


Figure 22.—Multiple bearing test rig.

The vacuum bearing rig was designed for long duration tests of multiple angular contact instrument bearings in a simulated space environment. The device, shown in figure 22 can test one to four preloaded pairs of bearings simultaneously. The tester is contained in a cubical vacuum chamber capable of vacuum levels to 10^{-5} Pa (10^{-8} torr). RGA mass spectrometry can be used to evaluate outgassing. Bearings can be solid or grease lubricated and can be heated or cooled (-40 to $+50$ °C).

The tester is driven by an external micro-step motor through a ferro-fluidic feed-through. The computer-controlled motor can provide either a precise dither motion or continuous rotation to 4800 rpm.

Bearing torque is measured with a flex pivot assembly instrumented with micro-strain gages. The device can test size 1219 angular contact bearings (O.D. of 30.16-mm, a bore of 19.05-mm, and eighteen 3.275-mm balls). Other bearings of similar size can be tested by changing the mounting canisters.

Space Mechanisms Accelerated Test Chamber

The space mechanisms accelerated test chamber (fig. 23) provides for testing spacecraft mechanisms in vacuum or simulated atmosphere. This chamber was used to calibrate hardware for Mars Pathfinder Abrasive Wheel Experiment.

The chamber size is 60 cm (24 in.) outside diameter by 60 cm long. Mechanisms may be driven internally or via ferrofluidic feedthrough. The chamber can reach a vacuum level to 10^{-4} Pa (10^{-7} torr). Low temperatures testing can be provided through liquid nitrogen cooling. Mass spectroscopy provides capability for measuring outgassing products.

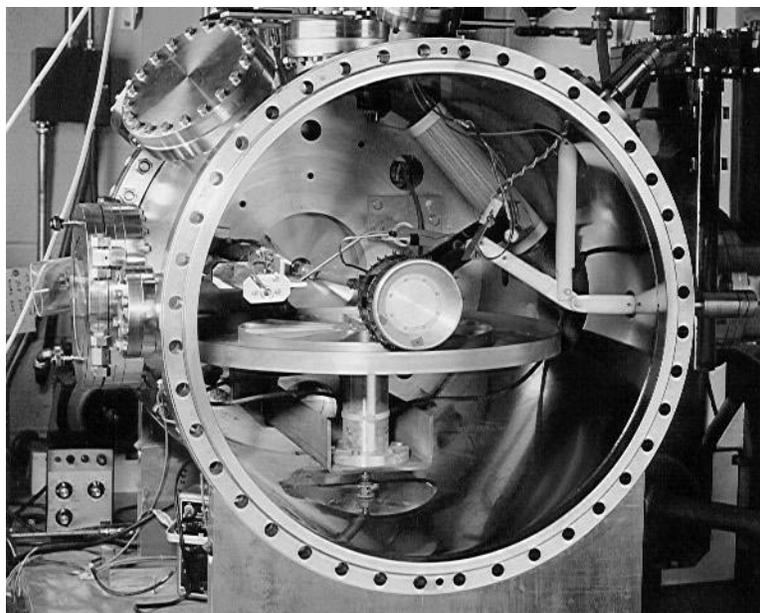


Figure 23.—Space mechanisms accelerated test chamber with Mars Pathfinder wheel inside.

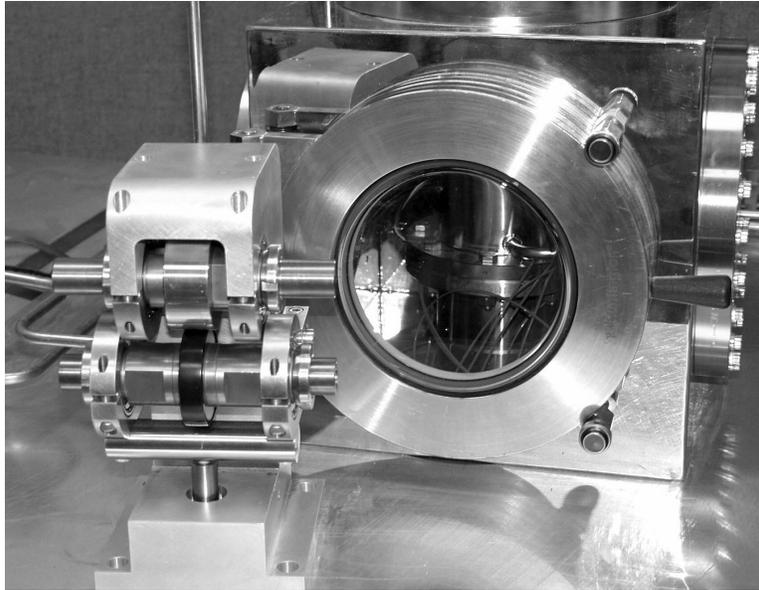


Figure 24.—Simple traction test device with vacuum cube.

Traction Drive Test Device

A simple test device (fig. 24) is being developed for testing solid coatings and traction roller materials under controlled torque and normal load. The device will provide for measuring traction coefficient, torque capacity, torque ripple, roller durability, creep or slip and temperature capability for different traction materials and coatings.

The device will be capable of vacuum levels to 10^{-5} Pa (10^{-8} torr) or a controlled atmosphere. It will test rollers at room temperature or cooled to -45 °C (or colder if liquid nitrogen is used for cooling). The device will also be able to simulate dust contamination.

Auxiliary Instruments

Several instruments are used to measure tribological performance in conjunction with the rigs described above. These include a surface profilometer, optical microscope (with magnifications from 50 to $500\times$) and a scanning electron microscope.

Summary

This overview of test facilities shows the unique facilities for testing aerospace hardware and concepts of the Mechanical Components Branch at NASA Glenn Research Center. The branch is organized into three research teams that perform basic research on mechanical drives, aerospace seals and space mechanisms. Each team conducts research with its area of specialty to advance the technology for propulsion systems used in aeronautical and space vehicles.

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13. ABSTRACT (Maximum 200 words) The Mechanical Components Branch at NASA Glenn Research Center formulates, conducts, and manages research focused on propulsion systems for both present and advanced aeronautical and space vehicles. The branch is comprised of research teams that perform basic research in three areas: mechanical drives, aerospace seals, and space mechanisms. Each team has unique facilities for testing aerospace hardware and concepts. This report presents an overview of the Mechanical Components Branch test facilities.				
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