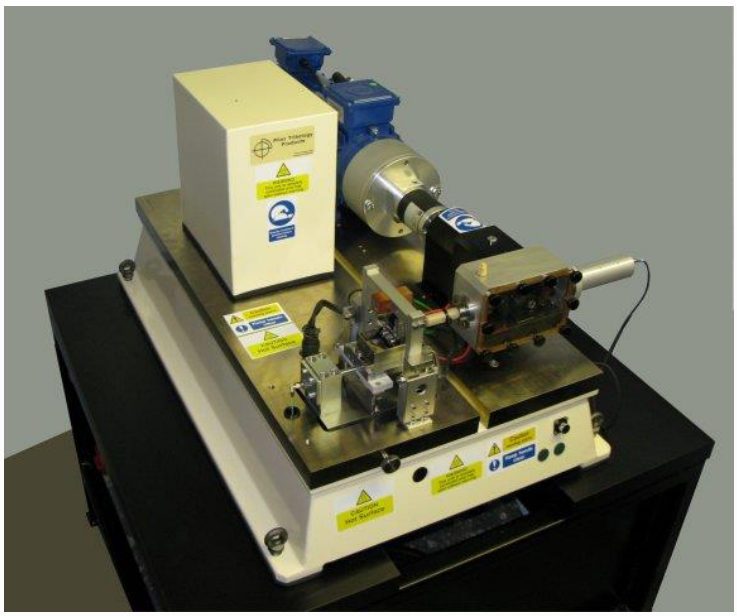
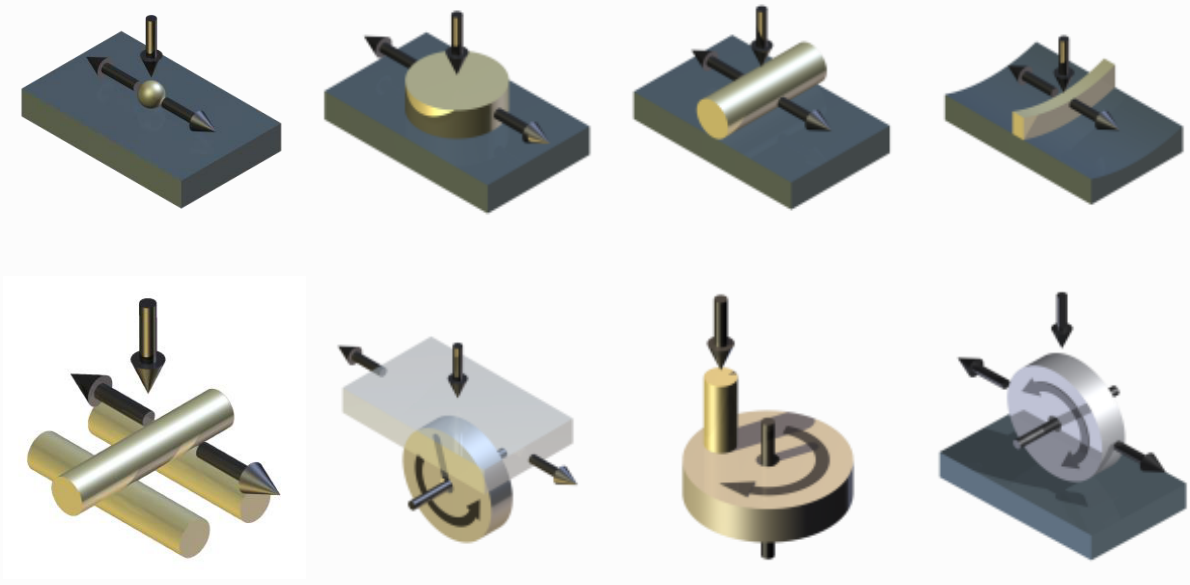
TE 77 HIGH FREQUENCY FRICTION MACHINE





Background

The TE 77 High Frequency Friction Machine is reciprocating tribometer with a maximum stroke of 25 mm and maximum load of 1,000 N. It is a well-established research and development tool for evaluation of lubricants, materials, coatings and surface treatments.

Specimens may either be of a standard format, or cut from real components, preserving surface finish and other properties.

The TE 77 was used for the inter laboratory tests for the development of ASTM G 133 "Standard Test Method for Linearly Reciprocating Ball on Flat Sliding Wear", which addresses the dry and lubricated wear of ceramics, metals and ceramic composites, and also for ASTM G 181 "Standard Practice for Conducting Friction Tests of Piston Ring and Cylinder Liner Materials Under Lubricated Conditions".

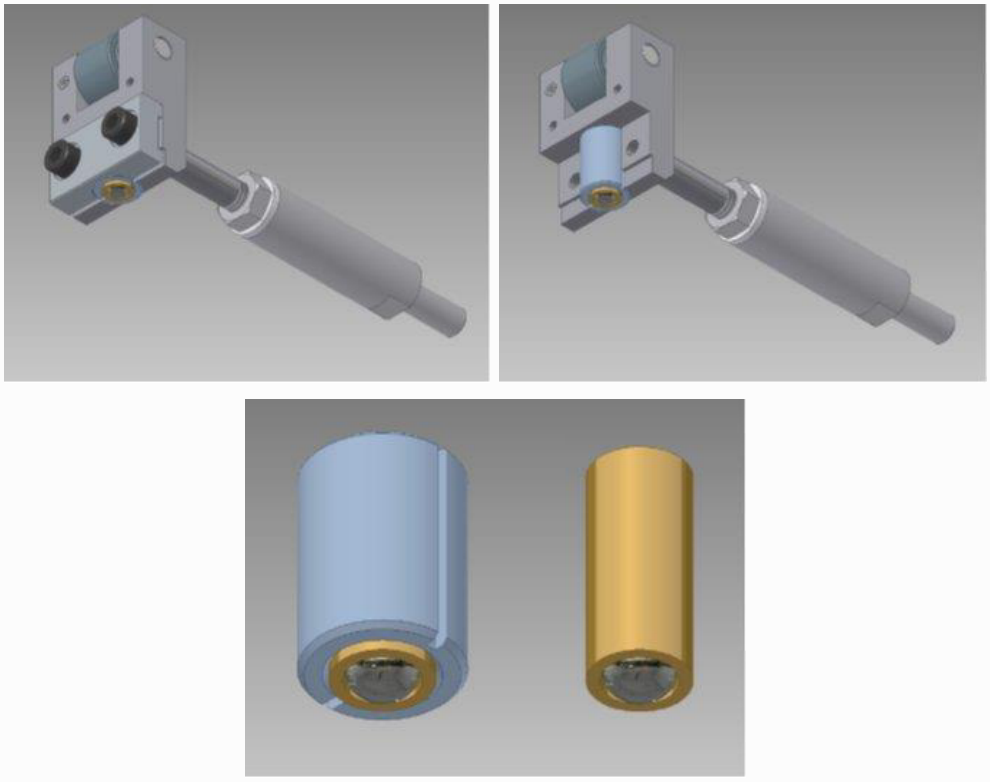
A large body of technical publications from existing users provides information on a wide range of research and development test procedures.

Description

The machine is floor standing with integral control unit incorporating a Phoenix Tribology USB Serial Link Interface Module. This is connected to a PC with COMPEND 2000 sequence control and data acquisition software installed. The system provides sequence control of load, frequency and temperature plus data acquisition of measured parameters, at both low and high speed.

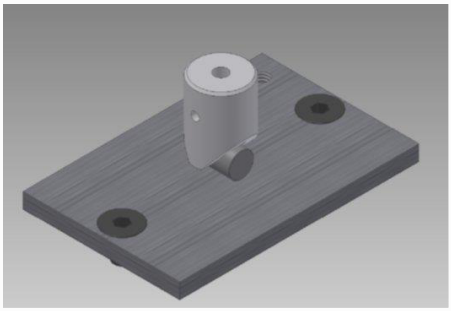
Moving Specimen

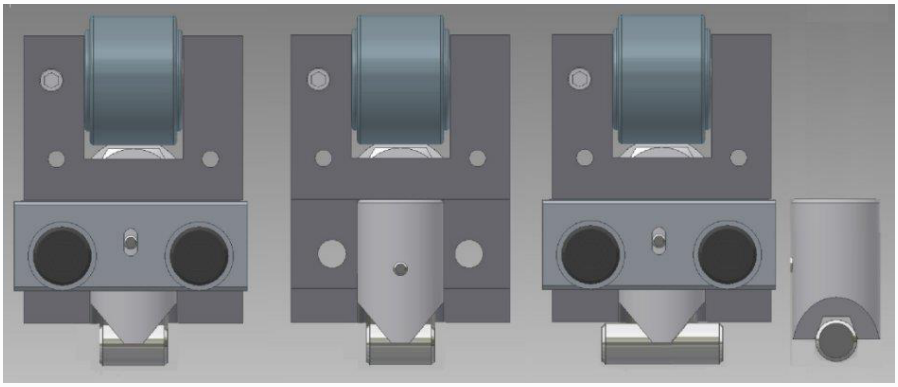
The moving specimen is mounted in a carrier. A number of different geometries can be accommodated by using a range of simple clamping fixtures.



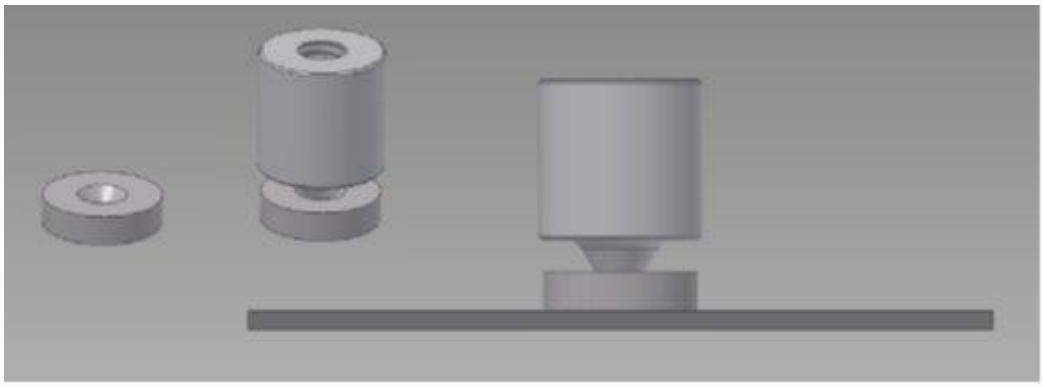
6 mm ball carrier in standard sleeve

10 mm ball carrier





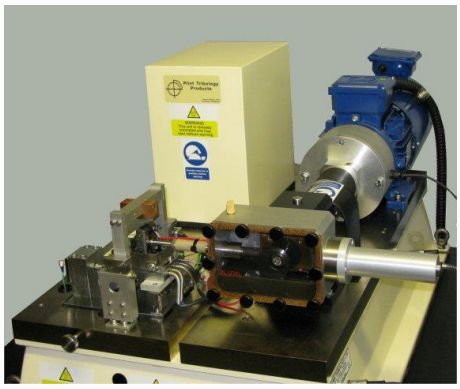
6 mm diameter line contact tooling



Self-aligning area contact tooling

The specimen is reciprocated mechanically against the fixed lower specimen. The mechanical drive comprises a motor driven scotch yoke assembly, providing pure sinusoidal motion.

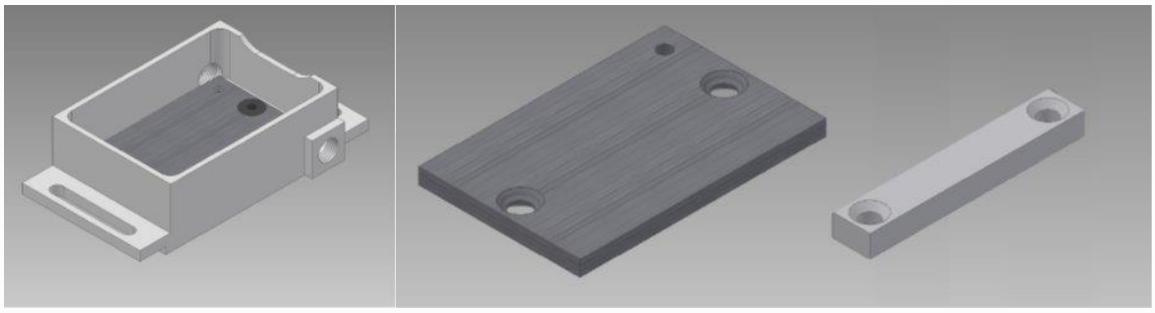
The stroke length is altered manually by adjusting eccentric cams on an eccentric shaft. Two fixed cams are provided allowing strokes to be set from 0 to 12.5 mm and 12.5 mm to 25 mm, with a total of eleven discrete positions per cam. A continuously variable double cam arrangement allows continuous variation of the stroke in the range 0 to 12.5 mm.



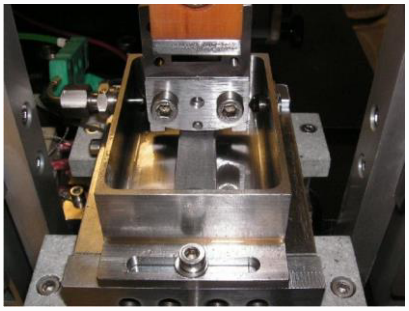
The load is applied to the moving specimen through a lever mechanism actuated by a servomotor and spring. The normal force is transmitted to the moving specimen by means of the needle roller cam follower and a loading yoke. A force transducer on the lever measures the applied load.

Fixed Specimen

The fixed specimen is located in a bath, which is clamped to a heater block. The bath can be moved sideways so that multiple tests can be performed on one fixed specimen.



The heater block is mounted on flexures, of minimal resistance to horizontal forces, resisted by a piezo force transducer, that senses the friction force.



The fixed specimen assembly is carried on a sub-base. This provides seismic isolation at high frequencies but also allows alternative sub-base assemblies to be used.

Friction Measurement

The piezo transducer has an output range which is set to match expected friction levels in the contact. The maximum friction level is +/- 500 N.

At reciprocating frequencies above 2.5 Hz, the charge amplifier is operated a.c. coupled. This eliminates d.c. drift. The signal is passed through a true rms/dc converter amplifier and the final output is the true mean friction force. The instantaneous friction signal may also be logged in bursts using the high-speed data acquisition interface.

For low frequency sliding at less than 2.5 Hz, stick-slip, single pass sliding, the charge amplifier is operated d.c. coupled mode. This gives signal decay times sufficiently long for the zero not to move significantly during the measurement.

Contact Resistance Measurement

The moving specimen carrier is electrically isolated from the drive shaft and from the fixed specimen. This allows a millivolt potential to be applied across the contact using a Lunn-Furey contact resistance circuit. The signal is taken to a true rms/dc converter amplifier to give a time-smoothed average. The measurement can be used to observe the formation of chemical films, the breakdown of non-conducting layers and coatings or the build-up of oxides. The instantaneous value of contact potential is also available for data logging as high-speed data.

Temperature Measurement

In the reciprocating contact the sliding velocities are low, minimising frictional heating and, in the case of lubricated tests, promoting boundary lubrication. Minimisation of frictional heating means that contact temperature can be controlled by controlling the bulk temperature of the fixed specimen. The temperature is measured with a thermocouple pressed against the fixed specimen.

Wear

Wear is not directly monitored on the basic machine, so assessments are made from post-test wear scar sizes.

The optional TE 77/WEAR provides continuous measurement of the wear displacement of the moving specimen relative to the fixed specimen. TE 77/PROFILE allows periodic in situ measurement of the fixed specimen wear.

Low Speed Data

Analogue input channels are sampled and data logged at a maximum rate of ten samples per second. Time smoothing and averaging functions are provided by in hardware and software.

High Speed Data

The high-speed data acquisition interface provides programmable burst data acquisition of friction, contact potential and stroke position, using a 16-bit six channel multi-function ADC, with programmable data acquisition rates up to 50 kHz. Data is buffered and stored direct to hard disc with a separate file automatically created for each acquisition cycle. The high speed data file names are automatically inserted as hyperlinks in the standard machine data file so that the high speed data may be viewed at the relevant place in the test.

Friction Noise

By rectifying the instantaneous friction force signal and subtracting the r.m.s. average, a resulting signal corresponding to the perturbations (friction noise) can be produced. If this signal is subsequently passed through a second true r.m.s. to d.c. converter, an r.m.s. signal of friction noise can be generated. This can be used as a measure of the orderliness or otherwise of the friction signal. By dividing the r.m.s. friction noise value by the r.m.s. friction signal value, a percentage friction noise value is generated.

Comparisons and Advantages

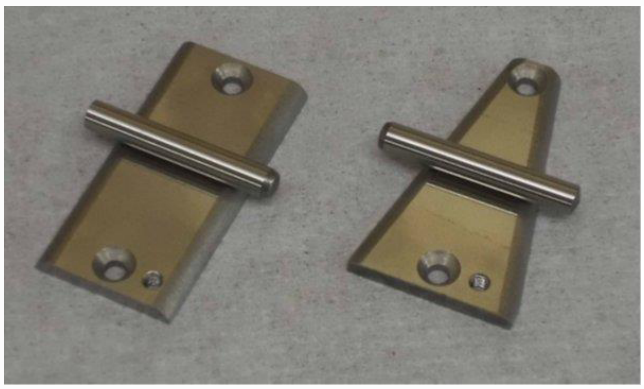
Generation of Wear

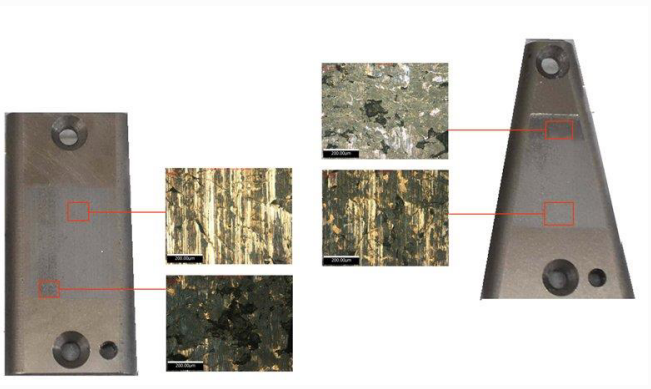
Wear is a direct function of sliding distance, hence, the rate of generation of wear is a direct function of the rate of accumulation of sliding distance.

- 25 mm Stroke at 20 Hz: 60 m per minute (TE 77)
- 15 mm Stroke at 30 Hz: 54 m per minute (TE 77)
- 5 mm Stroke at 50 Hz: 30 m per minute (TE 77)
- 4 mm Stroke at 50 Hz: 24 m per minute (Typical electro-magnetic machine performance)

- 1 mm Stroke at 100 Hz: 12 m per minute (Typical electro-magnetic machine performance)

The longer stroke capability of the TE 77 makes it a more effective wear generator than short stroke electro magnetically driven devices. It also allows tests to be performed using variable contact width, hence variable contact pressure, curved edge fixed specimens.





Entrainment and Wear Debris

The ability of the moving specimen to "expose" all parts of the fixed specimen depends on the contact length being not more than half the stroke length. This has serious implications for lubricant entrainment, for surface activation and for the discharge of wear debris from the contact. This favour long stroke over short stroke reciprocating devices.

Contact Scale

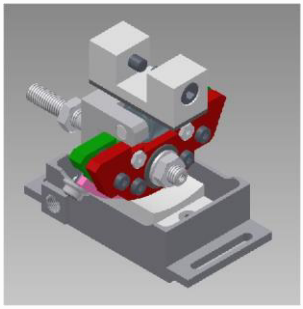
An important issue is how the wear is shared between the two contacting surfaces. Wear is a function of sliding distance. In the case of the moving specimen, the sliding distance is twice the stroke length x number of cycles. For a point on the fixed specimen, the linear wear is twice the contact length x number of cycles. In other words, the wear of the moving specimen is dependent on total sliding distance but the wear on the fixed specimen is dependent on the number of passes and the contact length. It follows that the ratio of wear between the two surfaces depends on both stroke and contact length. In order to model a real tribological contact, this contact scale parameter should be correctly modelled.

Very Low Frequencies

The TE 77 offers, by means of simple interchangeable gearboxes, a minimum frequency down to 0.01 Hz. Electro magnetically driven devices typically offer a minimum operating frequency of 1 Hz. This lower end speed range allows the TE 77 machine to be used for investigating stick-slip and low velocity sliding.

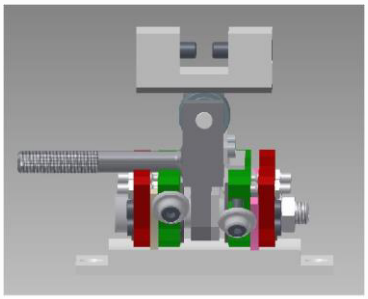
Optional Accessories

TE 77/SRC Adjustable Radius Piston Ring Clamp



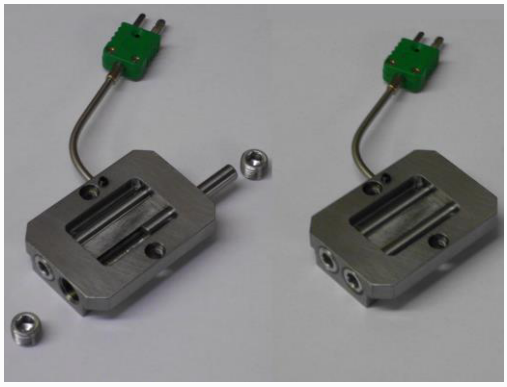
The clamp allows the ring curvature to be adjusted to allow ring samples to conform with liner samples. The standard clamp can accommodate rings of diameter 90 to 110 mm. A larger clamp has been designed to accommodate rings up to 200 mm diameter.

TE 77/TRC Adjustable Radius Twin Piston Ring Clamp



This arrangement allows two adjustable radius ring clamps to be mounted in series so that tests can be run with two ring samples on a common liner section sample.

TE 77/PT Pin on Twin Test Bath

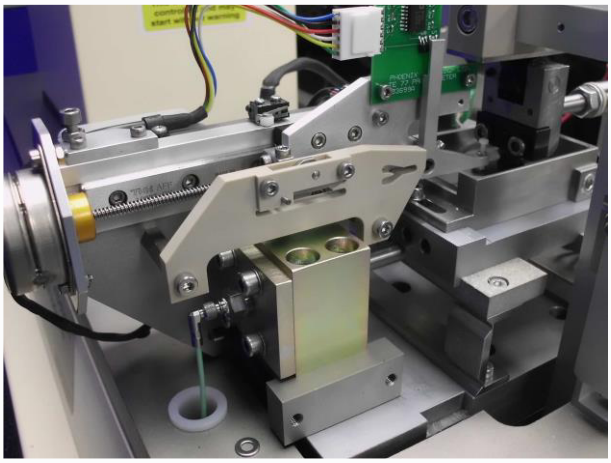


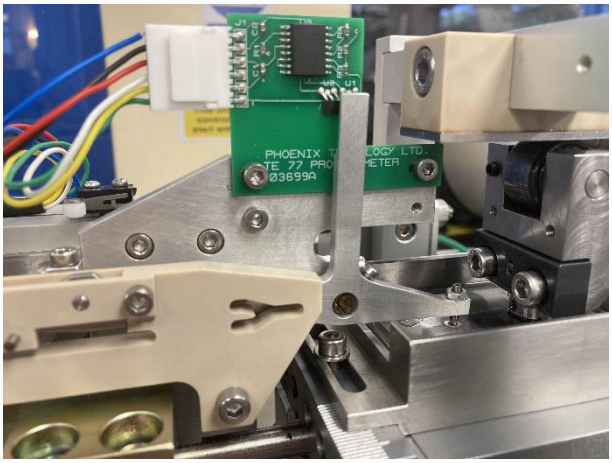
The pin on twin test bath allows tests to be performed with a self-locating crossed cylinder geometry. This is a technique originally developed by Dr Peter Blau at Oakridge National Laboratories.

TE 77/WEAR On-Line Wear Monitoring System

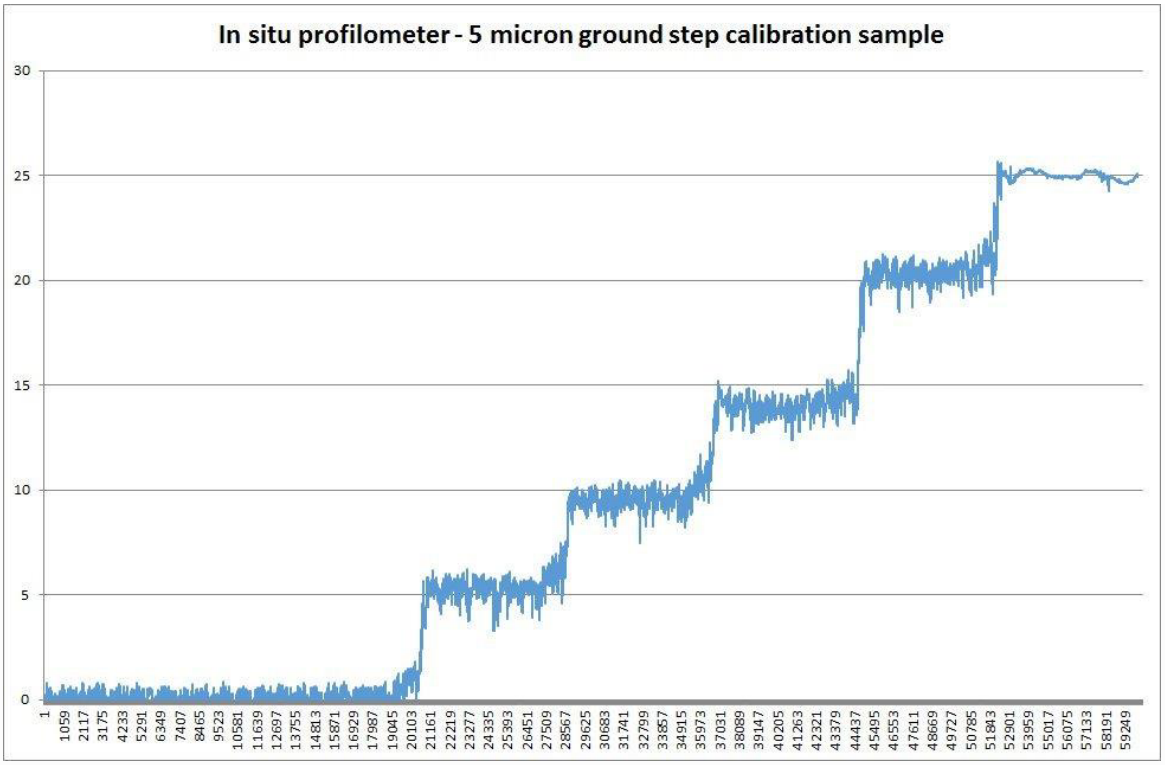
TE 77/WEAR is a non-contact measuring system. A capacitance probe is mounted in the moving specimen carrier, above a reference surface mounted on the edge of the specimen bath. The variations in the gap due to wear, lubricant film formation, thermal expansion or a combination of these are picked up by the system. The measuring resolution is greatest when the temperature of the fixed specimen is held constant.

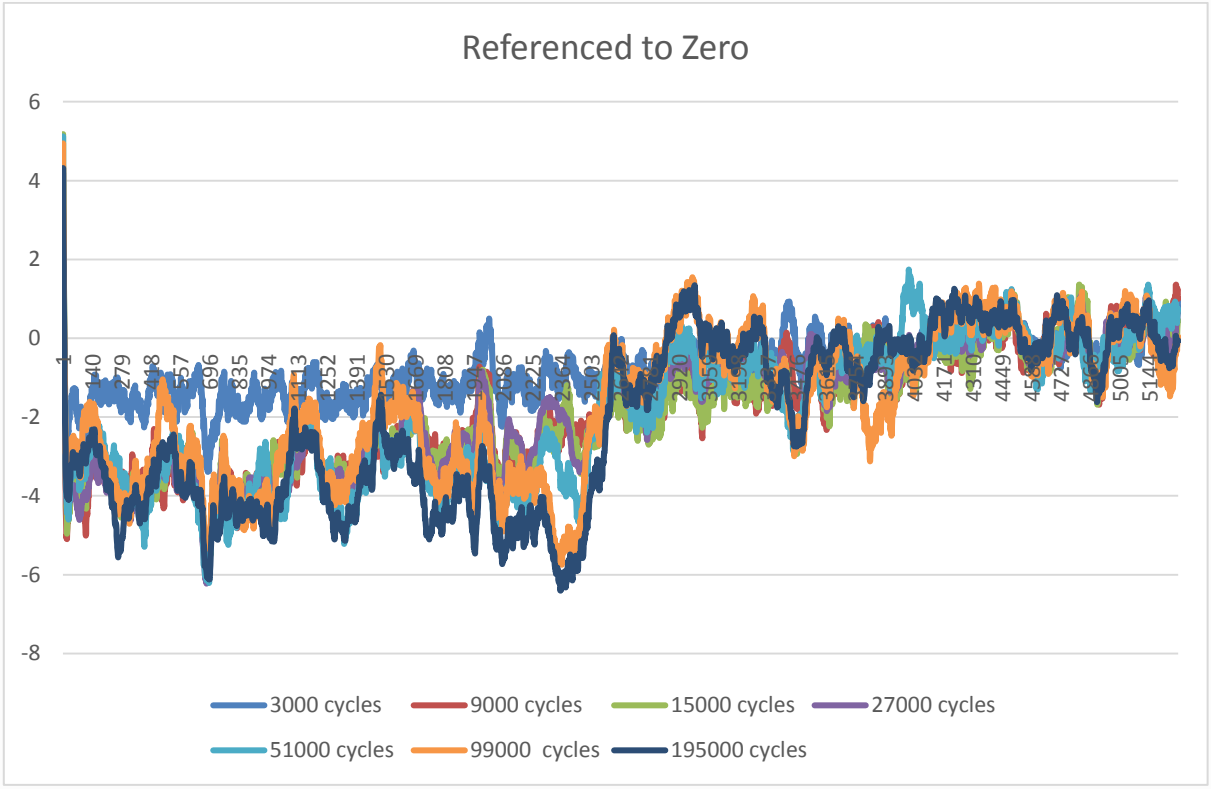
TE 77/PROFILE In situ Profilometer



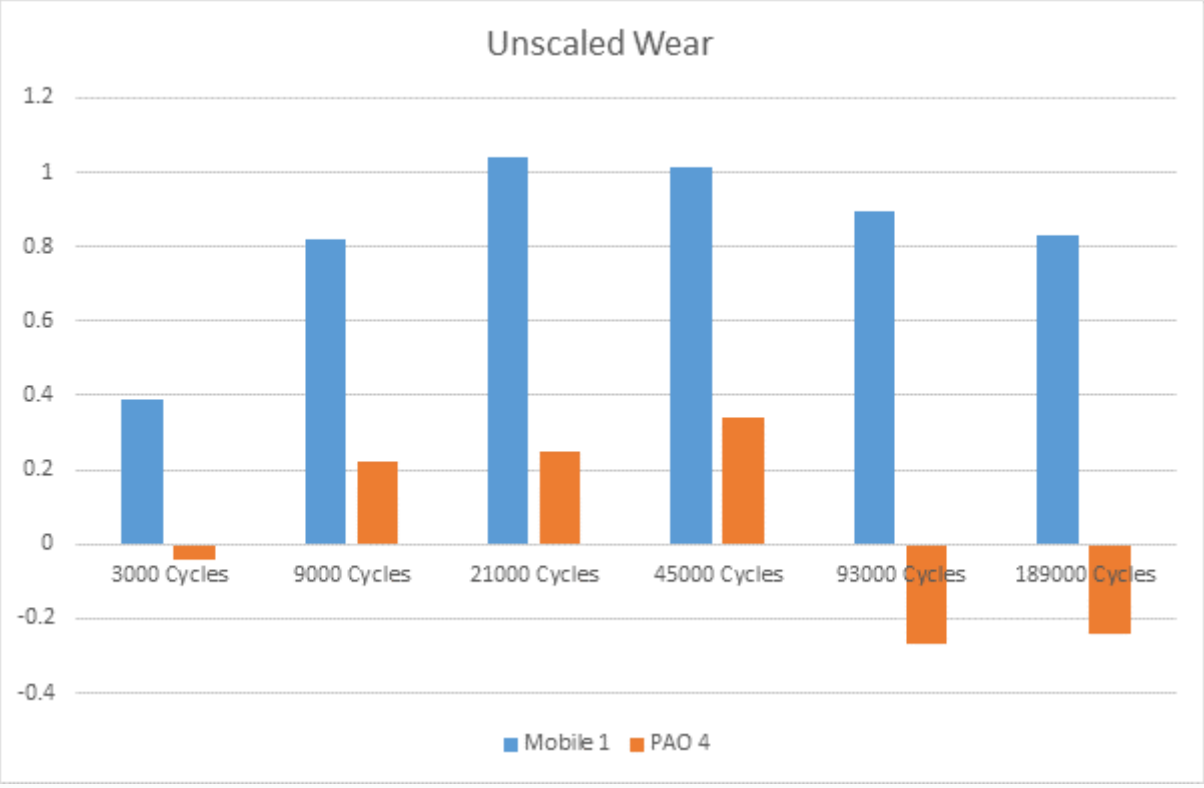


This is a tactile profilometer, which is used to make periodic measurements of just over half the fixed specimen wear scar. During a measurement cycle, reciprocating motion is stopped and the moving specimen moved to the opposite stroke end to the profilometer, which is then triggered to probe the fixed specimen surface, from just over the mid-stroke position to the stroke end nearest the profilometer.





At the start of a test, an initial surface profile is measured. Subsequent measurements are referenced to this value and recorded as: Current Measured Value – Initial Reference Value.



The measurements will show both wear of the fixed specimen and material transfer from the moving to fixed specimen.

TE 77/GB/20 Gearbox for 20:1

This gearbox mounts between the drive motor and camshaft, providing a 20:1 reduction in operating frequency.

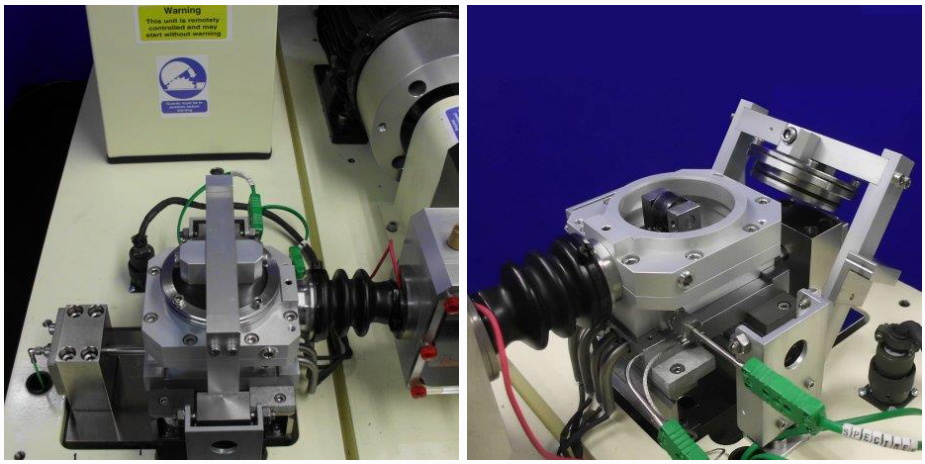
TE 77/GB/100 Gearbox for 100:1 Reduction

This gearbox mounts between the drive motor and camshaft, providing a 100:1 reduction in operating frequency.

TE 77/HR Heated Piston Ring Sample Carrier

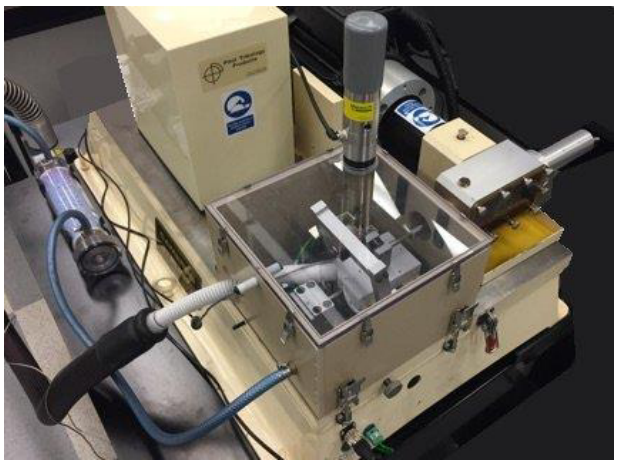
The TE 77/HR is a replacement reciprocating specimen carrier with integral heating, designed to allow tests to be run with a differential temperature between the moving ring specimen and the fixed liner specimen.

TE 77/INERT Gas Enclosure



The TE 77/INERT Gas Enclosure is a chamber that fits in place of the standard specimen bath and encloses the fixed and moving specimens. The reciprocating specimen carrier is sealed by a rubber bellows fitted between the reciprocating drive assembly and the chamber. Load is applied through a flexible membrane in the top of the chamber. This option is used for investigating the effects of ambient gas or moisture on friction and wear. Inert gases, water vapour and mildly corrosive gases may be used.

TE 77/COOLER



This replaces the standard fixed specimen heater block assembly with a cooler pad. A laboratory refrigeration unit delivers pressurised refrigerant direct to an expansion probe, embedded in the cooler pad, removing the requirement for an intermediate heat transfer fluid. This arrangement allows temperatures from ambient to -50°C to be achieved. To avoid ice formation, a test enclosure is included, fed with cool and dry air, delivered via a vortex cooler and a desiccant tube. A compressed air supply is required.

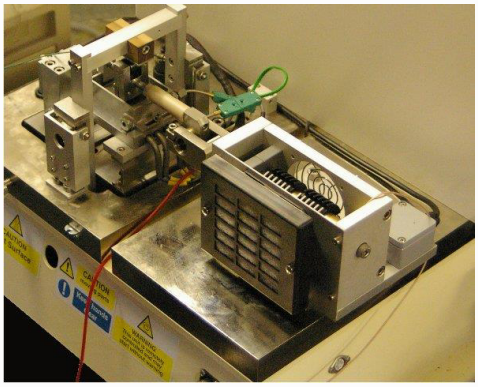
TE 77/800C High Temperature Heater

Key components of this assembly are made from Inconel (for high temperature performance) and a thermal barrier ensures that sensitive components are not exposed to excessive temperature. The standard reciprocating specimen carrier head is also replaced by a carrier made from Inconel. This has a “C” shape, permitting the specimens to be enclosed inside a shroud and the load to be transmitted through a roller bearing outside this enclosure.

TE 77/PUMP Peristaltic Pump and Drip Feed System

The TE 77/PUMP drip feed system uses a variable speed peristaltic pump. The package includes the pump controller and pump head, three sizes of pump tubing and universal pipe fittings.

TE 77/PIEZO Fretting Test Adapter



This adapter replaces the standard reciprocating drive assembly with a piezo actuator drive system. This is for performing fretting tests at strokes from 10 to 100 microns with frequencies up to 100 Hz with control of mid-stroke position and amplitude to +/-0.2 microns.

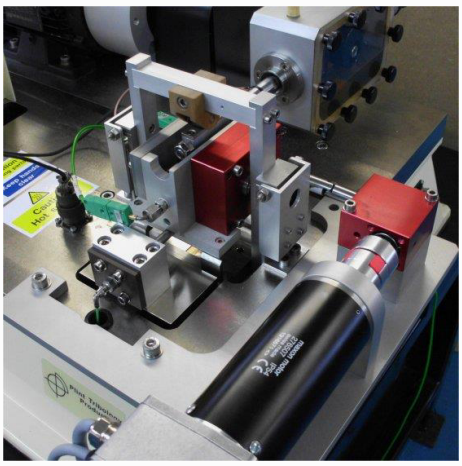
TE 77/PD Pin on Disc Test Adapter

The TE 77/PD Pin on Disc Adapter replaces the standard reciprocating head on the machine and allows the performance of conventional pin on disc tests, using the machines drive motor and automatic loading system.

TE 77 Slide/Roll Adapters

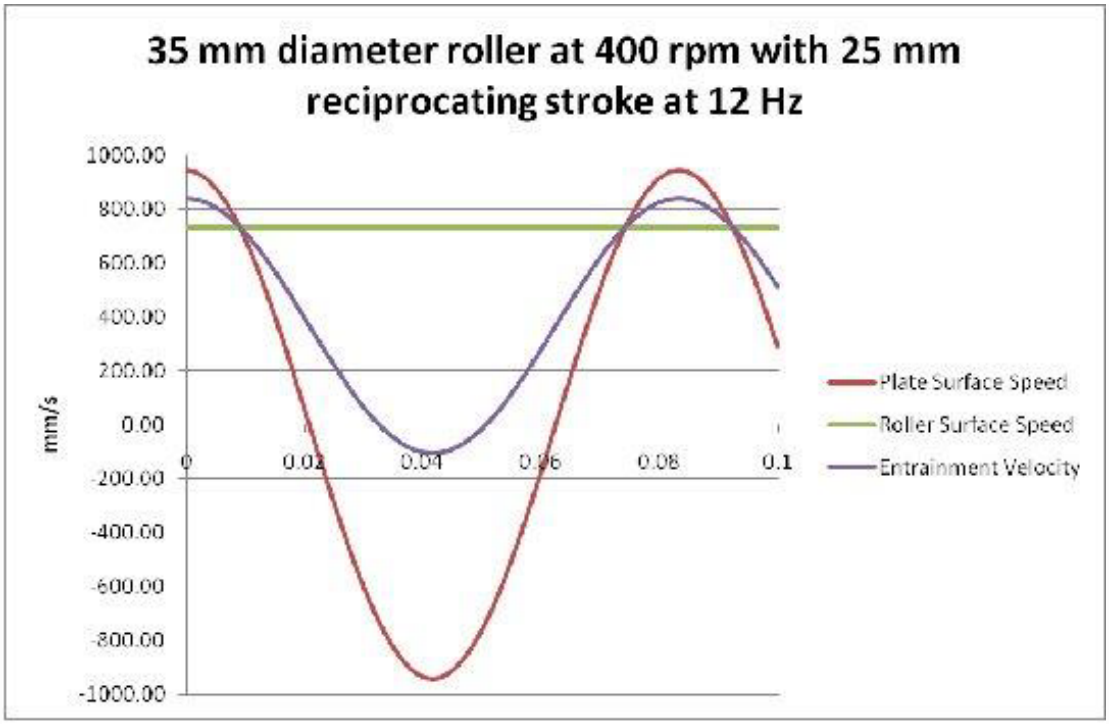
Many wear and failure mechanisms in gears and valve trains can be modelled with sliding-rolling contacts, in which the point of contact moves on both surfaces. The development of the "Energy Pulse" (EP) criterion led to the development of two slide-roll adapters for the TE 77.

TE 77 EP-CAM

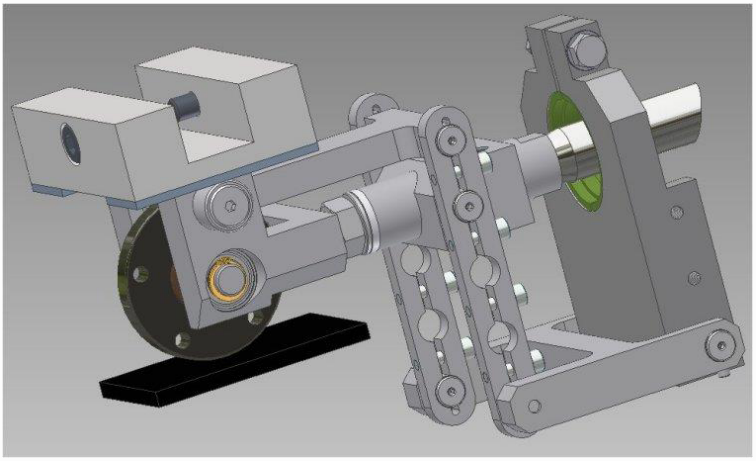


In this arrangement, a plate specimen is reciprocated against a rotating roller in what has been termed a "Reciprocating Amsler" test configuration. This produces asymmetrical lubricant entrainment: positive with the surface of the plate and roller moving in the same direction and, depending on relative speeds, negative when moving in opposite directions, hence a model for the kind of entrainment conditions occurring in a cam-follower contact. No point on either specimen remains in continuous contact.

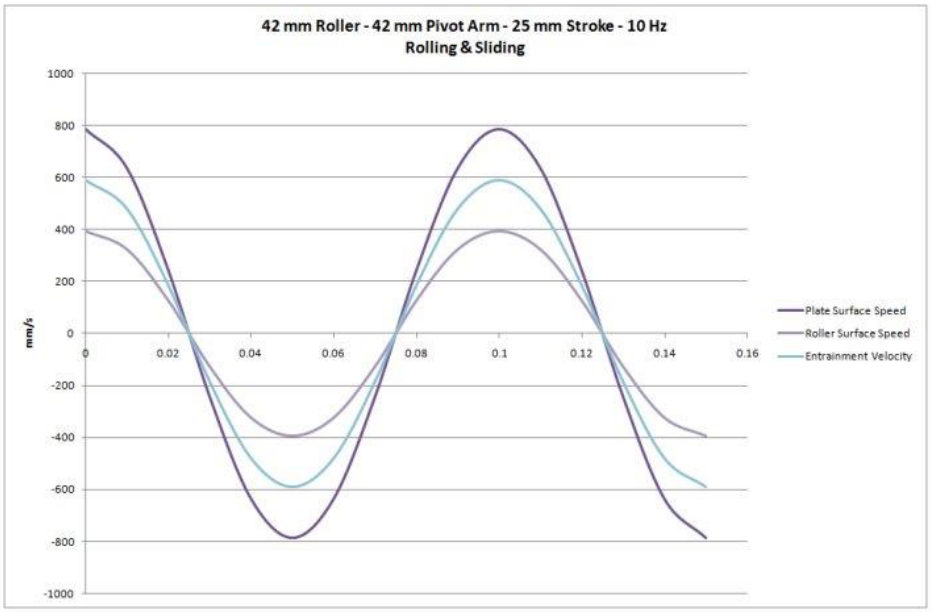
The rotational speed of the roller can be adjusted independently of the reciprocating rate of the plate, allowing a range of different varying entrainment velocities to be set. In addition to adjusting the varying slide/roll ratio by adjusting the rotational speed and reciprocating frequency, the stoke length can of course be adjusted.

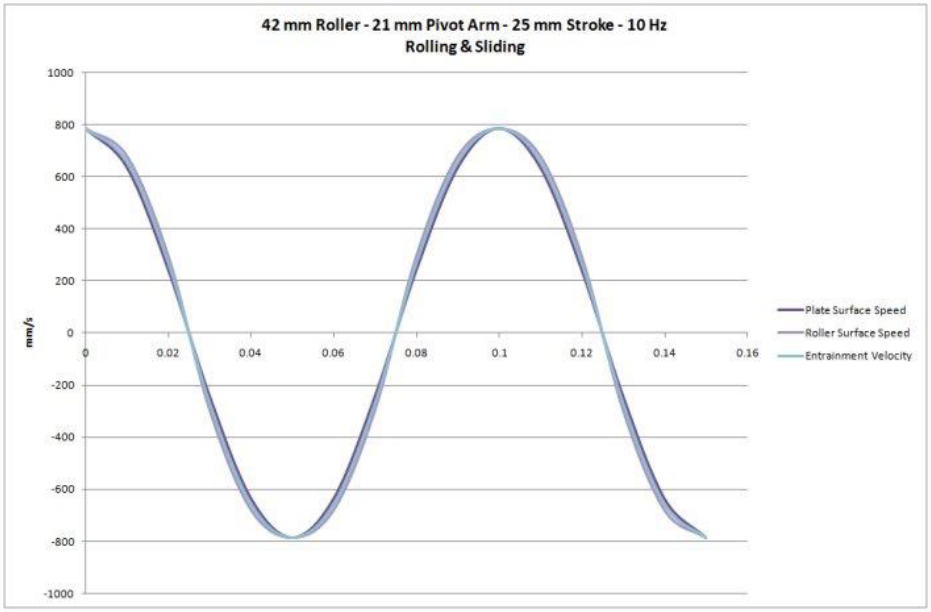


TE 77 EP-GEAR

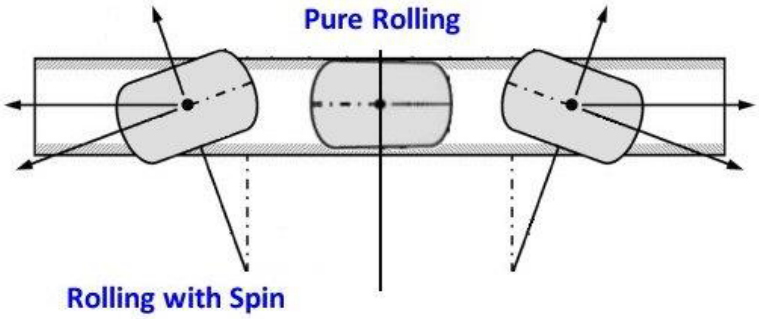


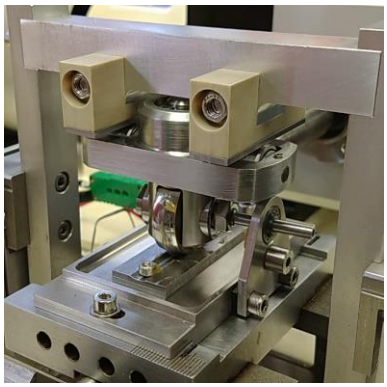
In this arrangement, a roller is reciprocated against a plate specimen and a rocking motion induced by a linkage mechanism. The entrainment velocity varies with stroke, symmetrically about the mid-stroke position. The result is that the point of contact moves on both specimens, similar to gear teeth sliding and rolling about the pitch point. No point on either specimen remains in continuous contact.





TE 77 Contact Spin Adapter





This adapter models sliding-rolling contacts with contact spin. This can be used for modelling, at longer strokes, the motion in a tripod CV joint, and at shorter strokes, amplitude rotational displacement in rolling element bearings.

TE 77/LLA Dead Weight Low Load Adapter

There are a number of test procedures requiring low levels of normal load. These include tests on coatings and soft layers, the evaluation of the lubricity of fluids and the ISO/DIS 12156-2 Fuel Lubricity Test. The standard automatic loading system has a loading threshold of 5 N. The Low Load Adapter can apply loads down to fractions of a Newton, although the minimum resolvable friction forces are at a level of 2 N normal load.

TE 77/TB ISO Test Bath

This test bath is for use in conjunction with TE 77/LLA for performing tests using standard ISO Fuel Lubricity Test specimens.

TE 77/D5706/7 Fixed Specimen Bath

TE 77/D5706/7 Fixed Specimen Bath, in conjunction with the standard reciprocating head, allows fixed and moving specimens as specified in ASTM D5706 and D5707to be accommodated.

TE 77/CAL Calibration Kit for Load and Friction

The two most important parameters to calibrate on the TE 77 are the normal load and the friction force. TE 77/CAL provides a pivoted beam with dead weights able to apply up to 1,000 N to the loading system and a pulley, cord and weights to apply a tangential force to the specimen bath to check the friction measurement.

TE 77 HIGH FREQUENCY FRICTION MACHINE

Technical Specifications

Contact Configurations:	Ball on Plate (Point Contact) Cylinder on Plate (Line Contact) Area Contact
Optional Configurations:	Piston-Ring and Cylinder Liner ISO Fuel Test Specimens
Load Range:	5 to 1000 N
Loading Rate:	50 N/s
Temperature Range:	Ambient to 600°C
Heating Power:	800 W
Temperature Sensor:	k-type thermocouple
Frequency Range:	2 to 50 Hz
Stroke Range:	See following tables
Contact Potential:	50 mV dc signal
Friction Transducer:	Piezo-Electric Type
Force Range:	- 500 to 500 N
Stroke Transducer:	Magneto Inductive
Maximum Stroke:	25 mm
Linearity:	0.50%
Low Speed Interface:	Serial Link Interface Module
Resolution:	12 bit
Number of Input Channels:	1 to 8
Number of Output Channels:	1 to 4
Maximum Data Rate:	10 Hz
High Speed Interface:	USB
Resolution:	16 bit
Number of Input Channels:	6
Maximum Data Rate:	Six channels at 50 kHz
Software:	COMPEND 2000
Motor:	1.1 kW a.c. vector motor with 2048 ppr encoder
Plate Specimen:	38 mm x 58 mm x 4 mm thick (typical)

Point Contact: 6 mm, 3/8 inch and 10 mm diameter ball
Line Contact: 6 mm diameter x 16 mm long pin
Area Contact: 12 mm diameter x 4 mm thick disc
Stroke Range:

Continuously Variable Cam - 0 to 12.5 mm

Angle - degrees:	Minimum - mm	Maximum - mm
0	0	2
18	1.04	3.04
36	2.65	4.65
54	4.25	6.25
72	5.75	7.75
90	7.09	9.09
108	8.24	10.24
126	9.17	11.17
144	9.85	11.85
162	10.26	12.26
180	10.4	12.4

Step Variable 0 to 12.5 mm:

Angle - degrees:	Nominal Stroke - mm
0	0
18	1.94
36	3.83
54	5.63
72	7.29
90	8.77
108	10.03
126	11.05
144	11.79
162	12.25
180	12.5

Step Variable 12.5 to 25 mm:

Angle - degrees:	Nominal Stroke - mm
0	12.5

18	13.05
36	14.26
54	15.97
72	17.89
90	19.8
108	21.54
126	23
144	24.09
162	24.77
180	25

Controlled Parameters

Frequency
Load
Temperature
Test Duration

Measured Parameters

Load	Low speed data
Friction (rms)	Low speed data
Friction (instantaneous)	High speed data
Friction Noise (time smoothed)	Low speed data
Contact Potential (time smoothed)	Low speed data
Contact Potential (instantaneous)	High speed data
Stroke Position (instantaneous)	High speed data
Temperature	Low speed data
Frequency	Low speed data
Number of Cycles	Low speed data
Wear (with TE 77/WEAR)	Low speed data

Derived Parameters

Friction Coefficient	Low speed data

Real-time Graphs

All low speed data (user selectable)
Burst high speed data (user selectable)

ACCESSORIES & ADAPTERS

TE 77/WEAR On-Line Wear Monitoring System

Contact Configurations:	Ball on Plate Cylinder on Plate Area Contact Piston Ring on Liner
Displacement Range:	0 to 1 mm
Resolution:	0.2µm
Accuracy:	within 3 %
Allowed Temperature:	- 20°C to 200°C
Output Range:	1 mV = 1µm

TE 77/GEAR/20 Gearbox for 20:1 Reduction

Frequency Range:	0.1 Hz to 2.5 Hz

TE 77/GEAR/100 Gearbox for 1001 Reduction

Frequency Range:	0.02 Hz to 0.5 Hz

TE 77/HR Heated Piston Ring Sample Carrier

Load Range:	5 to 1000 N
Self Heating Temperature:	200°C

TE 77/INERT Gas Enclosure

Maximum Pressure:	120 mm water
Maximum Temperature:	200°C

TE 77/COOLER Cooler Pad

Minimum Temperature:	-50°C

TE 77/800C High Temperature Heater

Contact Configurations:	Ball on Plate

	Cylinder on Plate
	Area Contact
Plate Size:	30 mm diameter x 4 mm thick
Temperature Range:	ambient to 800°C
Heating Power:	800 W
Temperature Sensor:	k-type thermocouple

TE 77/PUMP Peristaltic Pump and Drip Feed

Maximum Pump Speed:	55 rpm
Turn-Down Ratio:	110:01:00
Flow Rates:	0.02 to 2.3 ml/min with 0.5 mm bore tube
	0.06 to 6.7 ml/min with 0.8 mm bore tube
	0.22 to 24 ml/min with 1.6 mm bore tube
Tube Wall Thickness:	1 mm

TE 77/PIEZO Fretting Test Adapter

Type of Contact:	Ball/Flat
	Flat/Flat
	Line/Flat
Type of Movement:	Sine, Square and Triangular
Load:	5 to 1000 N
Friction Force:	+/-500 N Maximum
Stroke - continuously variable:	10 microns to 100 microns
Resolution:	+/-0.2 microns
Frequency – continuously variable:	1 Hz to 100 Hz
Maximum stroke at 100 Hz:	30 microns
Maximum stroke at 50 Hz:	60 microns
Maximum stroke at 20 Hz:	100 microns

TE 77/PD Pin on Disc Adapter

Contact Configurations:	Pin on Disc
	Ball on Disc
Specimen Holders:	8 mm and 5.5 mm diameter pins

	10 mm and 6 mm diameter balls
Disc Diameter:	75 mm
Track Radius:	0 to 35 mm
Fluid Temperature:	Ambient to 200°C
Heating Power:	800 W
Temperature sensor:	k-type thermocouple
Drive Ratio:	3:1 reduction
Rotation Speed:	20 to 1,000 rpm
Sliding Velocity:	0.08 to 3.6 m/s
Maximum Torque:	4.5 Nm
Normal Load:	50 to 1,000 N (with 500 N Autoloader)
Friction Force Range:	1,000 N
Signal Conditioning:	Strain Gauge Amplifier Module

TE 77/EP-CAM Slide/Roll Adapter

Contact Configuration:	Plate on Cylinder (Line Contact)
Roller Specimen Diameter:	35 mm
Roller Width:	10 mm
Plate Specimen:	50 mm x 12 mm x 3 mm
Load Range:	1000 N
Stroke Range:	25 mm
Maximum Frequency:	20 Hz
Maximum Rotational Speed:	1000 rpm
Servo Motor Power:	400 W
Temperature Range:	ambient to 100°C
Heating Power:	200 W
Temperature Sensor:	k-type thermocouple

TE 77/EP-GEAR Slide/Roll Adapter

Contact Configuration:	Plate on Cylinder (Line Contact)
Roller Specimen Diameter:	42 mm
Roller Width:	5 mm
Load Range:	1000 N

Stroke Range:	25 mm
Maximum Frequency:	10 Hz

TE 77/LLA Dead Weight Low Load Adapter

Contact Configuration:	Ball on Plate
Ball Diameter:	6 mm
Load Range:	2 to 20 N by dead weight
Allowed Stroke:	0 to 2 mm
Maximum Frequency:	50 Hz

TE 77/D5706/7 Specimen Bath

Specimen:	24 mm Diameter x 7.85 mm Specimen (ASTM D5706/7)

Services

Electricity:	220/240 V, single phase, 50/60 Hz, 3.2 kW

Installation

Floor-standing machine:	900 mm x 900 mm x 600 mm high, 250 kg
Packing Specifications:	1.33 m3, GW 410 kg, NW 310 kg