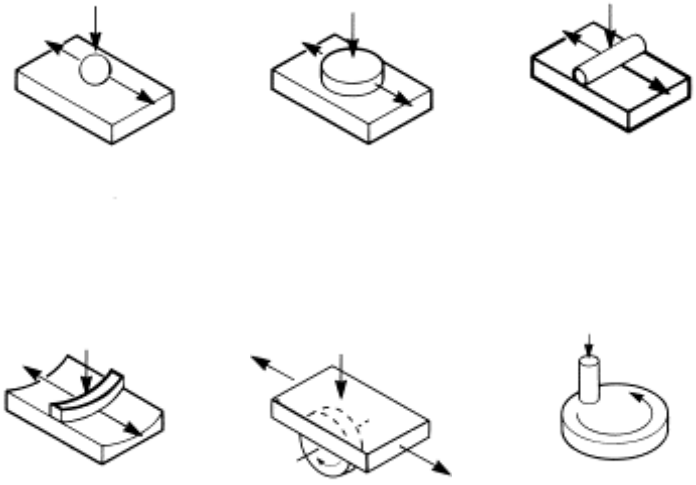
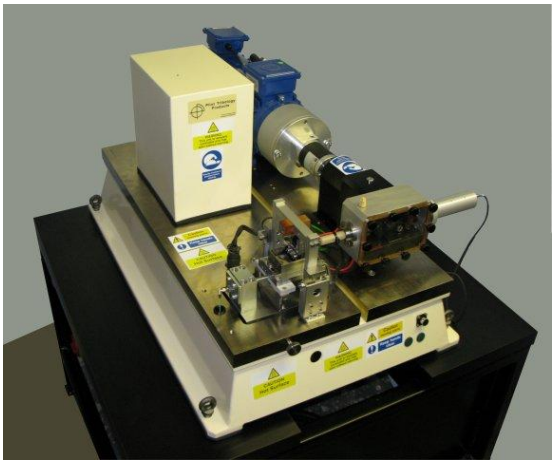
PLINT Tribology Products
from Phoenix Tribology Ltd

TE 77 HIGH FREQUENCY FRICTION MACHINE





Background:

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

With the TE 77, sliding contact conditions can be matched to a number of machine elements. 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".

Although not included in the inter laboratory test programs, the TE 77, in conjunction with selected adapters, can also accommodate tests specimens and provide test conditions as specified in the following standards:

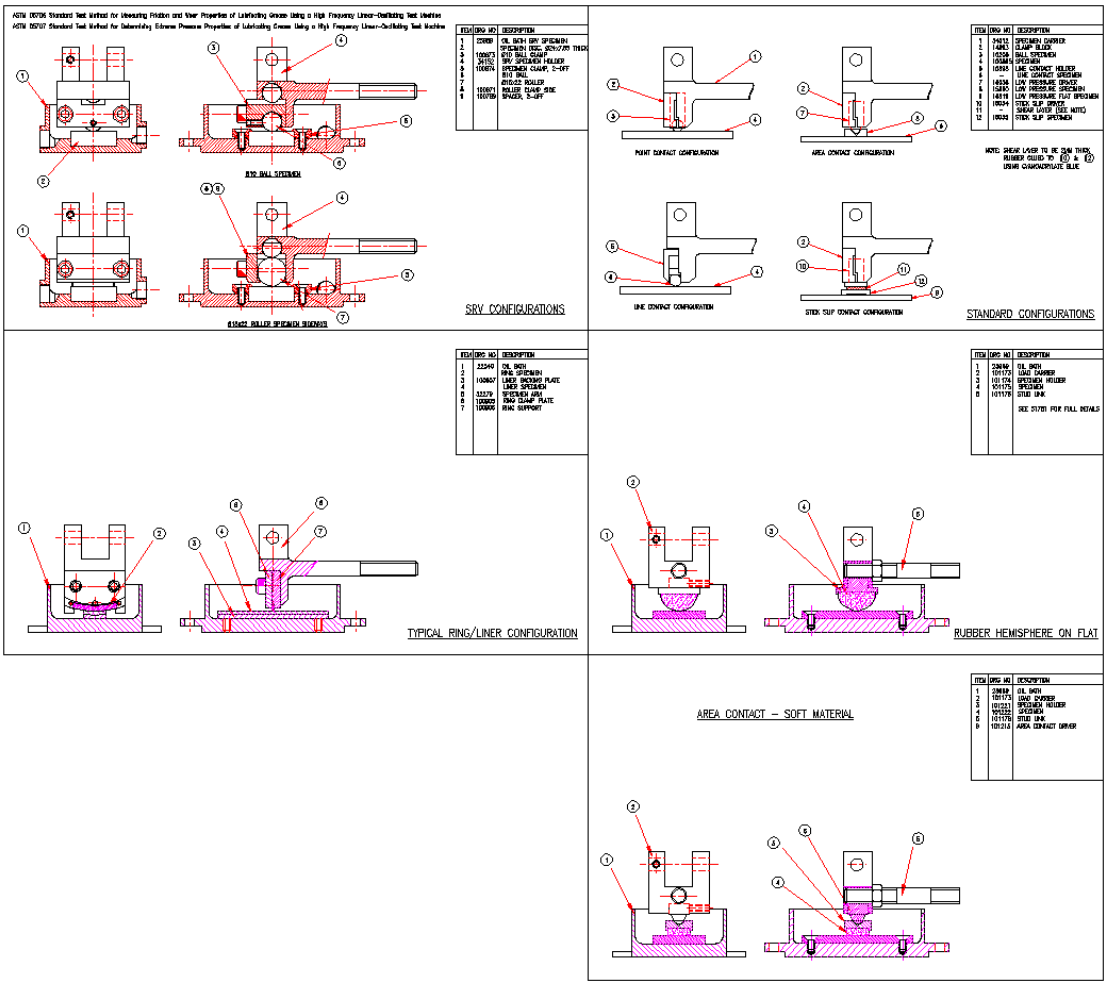
> ASTM D 5706 "Standard Test Method for Determining Extreme Pressure Properties of Lubricating Grease Using a High Frequency Linear-Oscillating Test Machine"
>
> ASTM D 5707 "Standard Test Method for Measuring Friction and Wear Properties of Lubricating Grease Using a High Frequency Linear-Oscillating Test Machine"
>
> ISO/DIN 12156-2 "Diesel Fuel Lubricity - Performance Requirement Test Method for Assessing Fuel Lubricity"
>
> ASTM D 6079 "Standard Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR)"

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

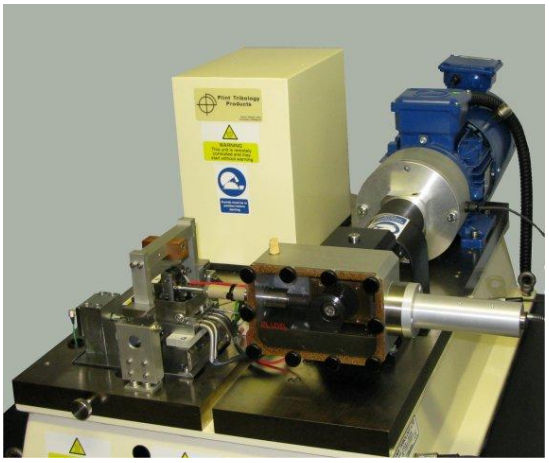
Description:

TE 77 High Frequency Friction Machine is supplied with its own floor standing bench and with a bench-top control unit incorporating a SUPERSLIM Serial Link Interface Module, which is connected to a host 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.

Moving Specimen:
The moving specimen is mounted in a carrier. A number of geometries can be accommodated by using a range of simple clamping fixtures. The specimen is oscillated mechanically against the fixed lower specimen. The mechanical drive comprises a motor driven cam and scotch yoke assembly, providing pure sinusoidal motion. The drive mechanism runs inside an oil bath.

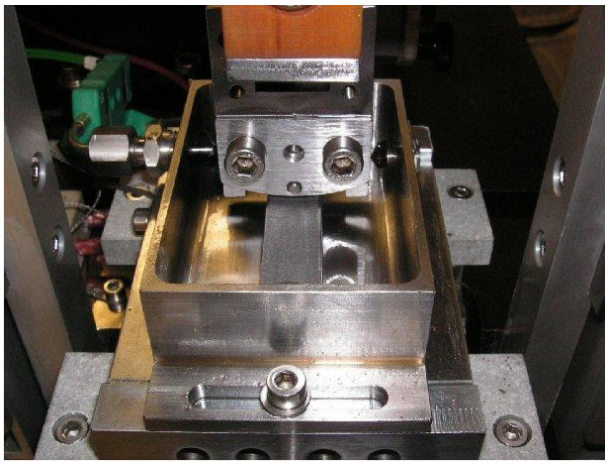


The stroke length is altered manually by adjusting splined eccentric cams on an splined eccentric shaft. Two fixed cams are provided as standard allowing strokes to be set from 0 to 12.5 mm and 12.5 mm to 25 mm, with a total of eleven discrete positions per cam. A continuously variable double cam arrangement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



The moving specimen is loaded against the fixed specimen through a lever mechanism actuated by a geared servomotor with in-line spring. The normal force is transmitted directly onto the moving specimen by means of the needle roller cam follower on the carrier head and the running plate on a loading stirrup. A strain gauge transducer is mounted on the lever at a point directly beneath the contact and this measures the applied load.

Fixed Specimen:
The fixed specimen is located in a stainless steel reservoir. Special inserts are available for mounting the ISO Fuel Lubricity Test specimens and other standard specimens. The reservoir is clamped to a block that is heated by four electrical resistance elements and the temperature is monitored by a thermocouple pressed against the side of the specimen or holder. The reservoir can be moved sideways on the heater block so that multiple tests can be performed on one fixed specimen.



The heater block is mounted on flexures, which are stiff in the vertical (loading) direction, but offer limited resistance to horizontal forces. Movement in the horizontal direction is resisted by a piezo-electric force transducer, which measures the friction forces in the oscillating contact.

The heated specimen carrier and piezo-electric force transducer are mounted on a common sub-base. This not only provides seismic isolation from machine vibrations at high frequencies but also permits other sub-base assemblies to be fitted to extend the operating range of the machine.

Friction Measurement:
The piezo electric transducer used to measure the friction force has a sensitivity of typically 43.5 pC/N and the output range is set to match expected friction levels in the contact. The maximum friction level is +/- 500 N.

A charge amplifier converts the measured force to a proportional voltage. This is followed by a low pass filter, which fixes the upper cut off frequency of the measuring system. This serves to suppress transducer resonance. Final scaling of the signal for voltage output takes place in a second stage amplifier.

During higher frequency (>1Hz) operation, the charge amplifier is operated a.c. coupled. This eliminates the effects of d.c. signal drift over long time periods. The signal is passed though a true rms/dc converter amplifier and the final output is the true mean friction force. The instantaneous friction signal is also made available for viewing on an oscilloscope or for data logging using the TE 77/HSD option.

For low frequency sliding (<1Hz), stick-slip, single pass sliding, work with the Energy Pulse Slide/Roll Adapter and also for calibration of the transducer, the charge amplifier is operated in Quasi-Static d.c. coupled mode. This gives signal decay times of up to 100,000s, sufficiently long when compared to typical measurement time scales for the zero not to have moved significantly during the measurement.

Electrical Contact Resistance Measurement:
The moving specimen carrier is electrically isolated from the drive shaft and therefore from the fixed specimen. This allows a millivolt potential to be applied across the contact using a Lunn-Furey Electrical Contact Resistance Circuit. The voltage signal is taken to a true rms/dc converter amplifier to give a time-smoothed average of the contact potential.

Variations in this voltage are indicative of the level of metallic contact, provided that both test specimens are conductors of electricity. This measurement may be used for observing the formation of chemical films from anti-wear and extreme pressure lubricants, the breakdown of non-conducting layers and coatings or the build-up of oxides.

The instantaneous value of contact potential is also available for display on an oscilloscope or for data logging using the TE 77/HSD option.

Temperature Measurement:
Many wear processes are driven by temperature, be they the formation of oxides on the surfaces, the transformation of microstructure, the formation or break-down of lubricant additive or other tribochemical films, the melting of the surface (the PV limit of the material) or thermal stress induced failure.

To be more specific wear occurs as the result of the dissipation of frictional energy in the contact and this is irresistibly accompanied by a rise in temperature. The frictional energy is generated by the combination of load and sliding speed and its distribution and dissipation is influenced by other contacting conditions such as size and relative velocity.

In the reciprocating contact of the TE 77, sliding velocities are deliberately maintained at low levels in order to minimise frictional heating and, in the case of lubricated tests, to promote boundary lubrication. Minimisation of frictional heating means that contact temperature can be controlled effectively by controlling the bulk temperature of the fixed specimen. The temperature is measured with a thermocouple pressed against the fixed specimen and control is by software PID with PWM output.

Wear:
This is not directly monitored on the TE 77 and assessments are made from wear scar sizes on the moving specimen and wear volumes on the stationary specimen. Specimen sizes are small enough to be placed in SEM and other surface analysis equipment for detailed chemical analysis of surface films.

With the optional TE 77/WEAR fitted, a continuous record can be made of the movement of the moving specimen relative to the fixed specimen. This measurement can be used as an indication of the combined wear of both surfaces and for identifying wear transitions.

Control and Data Acquisition:

The TE 77 has PC based sequence programmable control and data acquisition. This is provided by an integrated Serial Link Interface Module and COMPEND 2000 software running on a host PC, operating under Windows. Data is stored to hard disc in standard spread sheet compatible file formats (.csv or .tsv).

Tests are defined by a sequence of steps, each step containing set-point, data recording rates and alarm level information. Set-points may be adjusted by step change or ramp. The test sequence is followed unless interrupted by the operator or an alarm. Set-points may also be adjusted manually using on screen toggles.

Comparisons and Advantages:

Frequency Range:
The maximum frequency on the TE 77 is 50 Hz. It should be noted that the majority of standards relating to reciprocating tribometers call for a test frequency of 50 Hz or less. The frequency range of competing electro-magnetic oscillator driven reciprocating tribometers is often higher (up to 500 Hz), but the amplitude range is lower than the TE 77, with a maximum stroke range typically up to 4 mm (but not over the full frequency range). This is compared with 25 mm on the standard TE 77. The TE 77 will run at 50 Hz at 5 mm and 30 Hz at 15 mm stroke.

Whereas stroke length has no great significance for basic tests to evaluate the frictional and chemical film forming behaviour of lubricants, stroke length, hence sliding distance, are of great importance when it comes to wear generation. A stroke length of 10 mm is also specified in ASTM G 133.

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.

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. In other words, in the case of other devices, with a contact length greater than 2 mm and a maximum stroke of 4 mm, it is apparent that the centre portion of the fixed specimen will be in continuous contact with part of the moving specimen. This has serious implications for lubricant entrainment, for surface activation and for the discharge of wear debris from the contact. Debris can become entrapped and generate an unwanted third body wear mechanism. Because of this, the devices are not entirely satisfactory for adhesive wear tests with area contact specimens.

Contact Scale:
An important issue with regard to contact scale 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.

To get the model right, the contact length must be correctly scaled. Hence, running at 25 mm stroke modelling a contact length of 3 mm in an engine with 100 mm stroke, the ring specimen in the test machine should have a contact length of 0.75 mm. To model this at shorter stroke lengths would require a contact length of 0.09 mm, which is not practical.

The extra stroke length on the TE 77 means that quite a variety of large sliding specimens can be accommodated. This is particularly useful when working with test specimens cut from machine components. The test area is highly accessible and open to design of specialised specimen carriers.

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 friction-velocity (Stribeck) curve characteristics of lubricants and materials.

Optional Accessories:

TE 77/WEAR On-Line Wear Monitoring System:

TE 77/WEAR is a high-resolution capacitance proximity measuring system. Output from the device is in the form of a DC voltage proportional to displacement, suitable for data acquisition on a PC.

A capacitance non-contact probe is mounted in the moving specimen carrier. The probe is mounted approximately 0.5 mm away from a reference surface mounted on the edge of the specimen bath. The capacitance of the gap is converted to a dc voltage by a charge amplifier. The voltage is passed through a true rms/dc converter to provide the mean gap value over the length of the stroke.

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 fact that the gap is small ensures that temperature effects are limited to the thermal expansion over that length.

The measuring resolution is greatest when the temperature of the fixed specimen is held constant. The TE 77/WEAR system is ideal for establishing long-term wear rates and transition points.

TE 77/HSD High Speed Data Acquisition:

This additional hardware option has two main uses on the TE 77:

Storing and displaying snap-shots of friction and contact potential (in place of or in addition to the use of an oscilloscope) during higher frequency tests. Storing and displaying complete friction cycles during very low speed Stribeck Curve and stick-slip tests using the 200:1 reduction gearbox (in place of using a chart recorder).

High-speed data acquisition is implemented by means of a 16-bit sixteen channel multi-function ADC PCI bus card, with programmable data acquisition rates up to 250 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.

TE 77/LVDT Stroke Transducer:

This option provides positional feedback for the moving specimen and is best used in conjunction with the TE 77/HSD to allow long stroke force-displacement data to be generated.

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

This gearbox mounts between the drive motor and camshaft, providing a 20:1 reduction in operating frequency. The low sliding speeds generated encourage the contact to operate in boundary lubrication conditions. The option is therefore useful when testing additives and lubricant formulations.

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

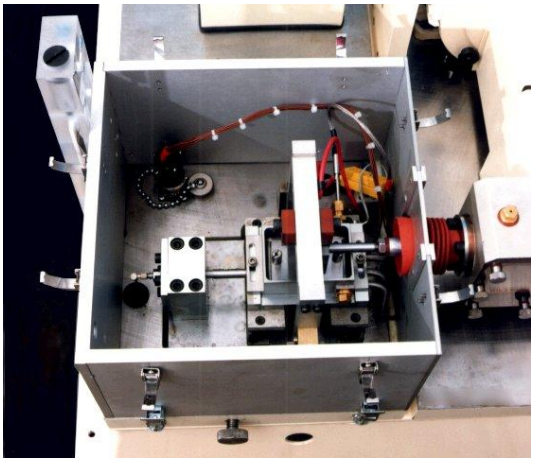
This gearbox mounts between the drive motor and camshaft, providing a 100:1 reduction in operating frequency. The very low sliding speeds generated ensure that the contact operates in boundary lubrication conditions. The option is used for studying static friction and stick-slip of lubricants for slide-ways, clutches and the like. Specimens are available for stick-slip testing.

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. The ring sample is self-heating to 200°C and is normally used in conjunction with liner sample temperature controlled by the fixed specimen heater block to less than this value.

TE 77/INERT Gas Enclosure:

The TE 77/INERT Gas Enclosure is an anodised aluminium chamber that encloses the fixed specimen/force measurement and load yoke assemblies. Fittings are provided to clamp the enclosure onto the machine base. The enclosure is sealed against the base using foam strip and a customised rubber gasket is provided to seal the gaps around the loading yoke verticals.



The reciprocating specimen carrier is also sealed by use of a customised rubber bellows secured to the moving arm and the enclosure. A transparent lid is provided so that the test can be observed.

Inlet and outlet pipe fittings and a length of pipe are provided for connection to a customer's inert gas supply. A water manometer is used to measure the gas pressure in the enclosure. Ambient temperatures in the chamber are limited to 250°C.

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 chiller circulates a water/glycol mixture, allowing temperatures from -30°C to ambient to be achieved. To avoid ice formation, this is best used in conjunction with the TE 77/INERT test enclosure with dry air.

TE 77/800C High Temperature Heater:

On the TE 77 the heated specimen carrier and piezo-electric force transducer are mounted on a common sub-base. To carry out high temperature experiments this is replaced with the separate TE 77/800C sub-base assembly. Key components of this assembly are made from Inconel (for high temperature performance) and a thermal barrier ensures that the flexures and piezo-electric force transducer 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.

Specimens can be mounted either in the standard sample bath for dry or lubricated tests up to 600°C or on a special platform for high temperature un-lubricated tests. A stainless steel shroud is provided to help reduce heat loss by radiation and convection at the high temperatures.

This option may be provided as a retrofit assembly comprising heater block and four 200 W heaters, flexures and piezo-electric force transducer all mounted on a separate sub-base. The heaters are wired into the same connector as the standard heaters once these have been removed.

TE 77/PUMP Peristaltic Pump and Drip Feed System:

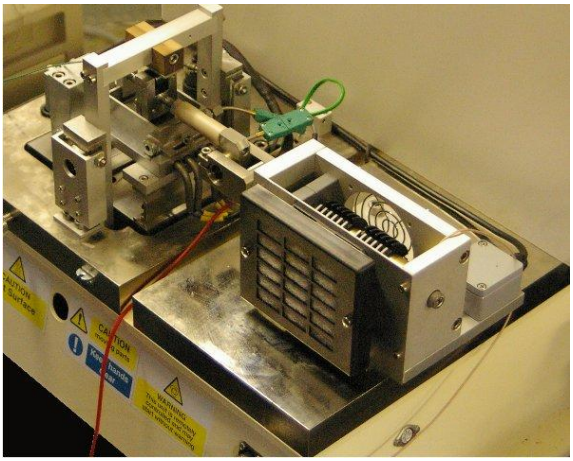
The TE 77/PUMP drip feed system uses a variable speed peristaltic pump. The advantages of this system are that there is no cross-contamination between pump and fluid, fluids are not exposed to high shear rates, it is self-priming and safe under dry running. By selecting a range of tube bore diameters a very wide range of flow rates are achievable. With a single size of tube the pump has a 110:1 turn ratio.

The package includes the peristaltic pump controller and pump head, three sizes of pump tubing and universal pipe fittings. An adaptor is provided for use with the standard moving specimen carrier clamps. This allows a PTFE tube to be mounted on the carrier to direct lubricant onto the contact zone.

This option is used in additives screening and lubricant development programs to provide fresh lubricant to the contact over long time periods. This is particularly important if tests are being carried out at temperatures where oxidation or evaporation of the sample is accelerated.

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.

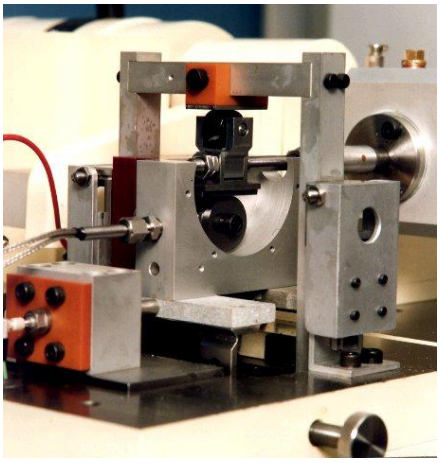


The system includes a high pre-load piezostack, servo amplifier and signal generator, capacitance displacement gauge, 250 kHz 16-bit 16 channel multi-function ADC (not required if TE 77/HSD is already installed) and C-flex mounted moving specimen carrier. Simultaneous high speed data acquisition of friction force and displacement allows force-displacement curves to be plotted.

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/EP Energy Pulse Slide/Roll Adapter:



The TE 77/EP Energy Pulse Adapter converts the sliding contact into a combined sliding/rolling contact. This recognises that it is the cyclic nature of the energy input into the contact that contributes to wear and permits lubricated contacts to withstand higher levels of energy dissipation than in a pure sliding case (where the energy pulse is continuous). The Energy Pulse is the product of the Friction Power Intensity and the contact time. The conditions of slide/roll can provide a close simulation of machine contacts such as cam/follower and meshing gear teeth.

The Energy Pulse Adapter uses the standard 15 mm stroke cam drive and loading system. It is supplied on an sub-base, interchangeable with the standard TE 77 heated specimen carrier and piezo-electric force transducer sub-base. The TE 77/EP test roller is mounted on the output shaft of a worm gearbox and runs in a heated lubricant reservoir. The reservoir is supported on flexures and a piezo-electric force transducer measures the horizontal (traction) forces in the contact. The enclosure is provided with an integral electric heater and thermocouple to enable tests with bulk fluid temperatures up to 100°C.

The worm gearbox with has a 2:1 speed reduction and the input shaft is connected via a timing belt drive of 1:2 ratio to the TE 77 motor output shaft. The rotation of the roller is synchronised therefore with the reciprocation of the upper plate and the drive does not interfere with the standard loading arrangement.

The upper plate specimen is secured to a pivoted yoke on the reciprocating drive. This ensures that the plate aligns with the roller with an even load distribution across the contact width. The load is transferred to the reciprocating arm by the usual method of the needle roller cam follower running against a plate on the lower side of the loading yoke. The ratio of slide to roll is varied simply by adjusting the stroke of the reciprocating arm.

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.

The Low Load Adapter applies dead weight loading to a ball (point contact) moving test specimen. The adapter uses a balanced beam and a push rod running through a linear bearing in a modified specimen carrier. This ensures that the load remains vertically above the ball across the whole stroke. The design limits the stroke to 2 mm with this adapter.

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/PLA Pressurized Lubricity Test Adapter:

The adapter is designed for lubricity tests under conditions as specified in ASTM D 6079 Standard Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR), but under pressurized conditions. This allows wear tests to be performed on volatile fluids and fluids that are not liquid at atmospheris temperature and pressure.

TE 77/MW Piston Ring/Groove Micro Welding Test Adapter:

The contact between the ring and the piston groove can give rise to problems of wear, scuffing, micro-welding and, in severe cases, seizure. The TE 77/MW adapter may be used for simulating this contact. The adapter uses the drive motor and control system of the standard TE 77. When in use, the normal reciprocating test system is disabled, the reciprocating drive mechanism removed from the machine and replaced with a vertical axis cam drive with a stroke of 3 mm. This provides the vertical reciprocation of the Ring Specimen Holder. The Piston Specimen Holder is placed above the Ring Holder and locates on two linear shafts, restrained by springs.

When the Ring Specimen strikes the Piston Specimen, the springs compress to provide the loading on the interface. The peak load is adjusted by pre-setting the spring compression. The Upper Piston Specimen Holder is connected to the motor drive shaft via timing belts and two gearboxes. This system imposes a +/- 90 degrees rotation on the Piston Specimen, at 10 rpm when the motor shaft is running at 1,200 rpm (20 Hz). The specimens are thus subjected to a combination of impact and relative rotary motion.

Both the Holders incorporate heaters to permit the temperature of the specimens to be controlled, with thermocouples for feedback to PID controllers. A test oil catching reservoir is provided underneath the Ring Sample Holder. Means of feeding the lubricant into the contact is not included, however, access is provided for either drip feed or oil mist delivery of lubricant samples.

TE 77/SRV SRV Test Adapters:

TE 77/SRVF Fixed Specimen Bath, TE 77/SRVB Reciprocating Head for Ball Specimens and TE 77/SRVC Reciprocating Head for Cylinder Specimens, are three adapters allowing standard SRV fixed and moving specimens to be accommodated.

Options Guide:

The following table provides a summary of the uses of the various optional accessories and adapter:

TE 77/WEAR:	For dry or lubricated tests with on-line wear measurements Used with standard specimen bath and heater block Replaces standard specimen head
TE 77/HSD:	For data logging instantaneous friction force and contact resistance signals
TE 77/LVDT:	For positional feedback for moving specimen
TE 77/HSD+TE 77/GB/20	For Stribeck Curve (low speed sliding) and stick-slip experiments Used with standard specimen head and bath
TE 77/HSD+TE 77/GB/100	For Stribeck Curve (low speed sliding) and stick-slip experiments Used with standard specimen head and bath
TE 77/HR:	For piston ring on cylinder liner tests where differential ring/liner temperatures are considered important Replaces standard specimen head
TE 77/INERT:	Primarily for dry tests where control of test atmosphere is important Used with standard specimen head and bath and TE 77/PELTIER
TE 77/COOLER:	For tests at reduced temperatures Replaces standard heater pad and best used in conjunction with TE 77/INERT

TE 77/800C:	For dry or lubricated high temperature tests Replaces standard specimen bath and heater block
TE 77/PUMP:	For controlled lubricant feed to test specimens Used with standard specimen arrangement
TE 77/PIEZO:	For fretting tests with continuously variable stroke Replaces standard specimen head and reciprocating drive assembly
TE 77/PD:	For converting from reciprocating sliding to pin on disc configuration Replaces standard specimen head, specimen bath and heater block
TE 77/EP:	For lubricated tests involving combined sliding and rolling with variable lubricant entrainment Replaces standard specimen head, specimen bath and heater block
TE 77/LLA + TE 77/TB:	For performing diesel fuel lubricity tests Replaces standard reciprocating head and best used in conjunction with TE 77/CAM/1
TE 77/PLA	For pressurized lubricity tests
TE 77/MW:	For evaluation of ring/groove interface Replaces standard specimen head, specimen bath and heater block
TE 77/SRVF+B+C:	For tests with standard Optimol SRV size specimens Replaces standard specimen head and bath

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.

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

Plate Specimen:	38 mm x 58 mm x 4 mm thick (typical)
Point Contact:	6 mm 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
Interface:	SLIM 2000 Serial Link Interface Module
Software:	COMPEND 2000
Motor:	1.1 kW a.c. vector motor, 2048 ppr encoder, force vent,

Stroke Range:

Continuously Variable Cam - 0 to 12.5 mm

Angle - degrees:	Minimum - mm	Maximum - mm
0	0.00	2.00
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	10.40	12.40

Step Variable 0 to 12.5 mm:

Angle - degrees:	Nominal Stroke - mm
0	0.00
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	12.50

Step Variable 12.5 to 25 mm:

Angle - degrees:	Nominal Stroke - mm
0	12.50
18	13.05
36	14.26
54	15.97
72	17.89
90	19.80
108	21.54
126	23.00

144	24.09
162	24.77
180	25.00

Controlled Parameters

Frequency
Load
Temperature
Test Duration

Measured Parameters

Load
Friction
Temperature
Contact Potential
Frequency
Wear (with TE 77/WEAR)
Friction Coefficient

ACCESSORIES & ADAPTERS

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 System:

Maximum Pump Speed:	55 rpm
Turn-Down Ratio:	110:1
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 Energy Pulse Slide/Roll Adapter:

Contact Configuration:	Plate on Cylinder (Line Contact)
Roller Specimen Diameter:	28 mm
Roller Width:	4 mm
Plate Specimen:	40 mm x 10 mm x 2.5 mm
Load Range:	500 N
Stroke Range:	25 mm
Frequency Range:	10 Hz
Rolling Velocity Ratio:	0 to 0.5
Temperature Range:	ambient to 100°C
Heating Power:	200 W
Temperature Sensor:	k-type thermocouple

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/PLA Pressurized Lubricity Test Adapter:

Contact Configuration:	Ball on Plate
Test Samples:	6 mm diameter ball
Load:	Dead Weight
Load Measurement:	Not available
Friction Force:	Not available
Pressure:	7 bar maximum
Load:	2 N
Stroke:	1 mm
Maximum Frequency:	50 Hz
Temperature:	Ambient to 100 C

TE 77/MW Piston Ring/Groove Micro Welding Test Adapter:

Ring Diameter:	Up to 99 mm
Peak Applied Load:	300 N (adjustable)
Ring Sample Stroke:	3 mm
Maximum Operating Frequency:	20 Hz (1,200 rpm)
Piston Oscillation:	+/- 90° at 10 rpm
Ring Sample Temperature:	Up to 200°C
Piston Sample Temperature:	Up to 350°C

TE 77/SRVF Fixed Specimen Bath for SRV Specimens:

Specimen:	24 mm Dia x 7.85 mm Fixed Specimen (SRV)

TE 77/SRVB Reciprocating Head for SRV Ball Specimens:

Contact Configuration:	Ball on Plate
Specimen:	10 mm Diameter Ball

TE 77/SRVC Reciprocating Head for SRV Cylinder Specimens:

Contact Configuration:	Cylinder on Plate - Axial Oscillation
Specimen:	15 mm Diameter x 22 mm Long

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
Bench-mounting cabinet:	530 mm x 420 mm x 400 mm, 40 kg
Packing Specifications:	1.33 m^3, GW 410 kg, NW 310 kg

Order As:

TE 77/1000 High Frequency Friction Machine - 1000N - with automatic loading and bench-top control unit with serial interface for sequence control of load, frequency and temperature and data acquisition on host PC, Windows based software included. PC hardware not included.

Options:

TE 77/HSD	High Speed Data Acquisition Option
TE 77/LVDT	Stroke Sensor
TE 77/GB/20	Gearbox for 20:1 Reduction Ratio
TE 77/GB/100	Gearbox for 100:1 Reduction Ratio
TE 77/INERT	Inert Gas Enclosure
TE 77/PUMP	Peristaltic Pump with Drip Feed System
TE 77/SRVF	Specimen Bath for 24 mm Diameter x 7.85 mm Thick Fixed Specimen
TE 77/SRVB	Reciprocating Head for 10 mm Diameter Ball Specimen
TE 77/SRVC	Reciprocating Head for 15 mm Diameter x 22 mm Long Specimen
TE 77/SRVBC	Reciprocating Head for 10 mm Diameter Ball Specimen and 15 mm Diameter x 22 mm Long Cylinder Specimen
TE 77/800C	High Temperature Electrically Heated Assembly
TE 77/LLA	Dead Weight Low Load Adapter
TE 77/TB	Test Bath for ISO Fuel Lubricity Test
TE 77/PIEZO	Piezo Actuator Drive System
TE 77/COOLER	Cooler Pad
TE 77/WEAR	Capacitance Displacement Gauge for Wear Measurement
TE 77/RC	Self Aligning Clamp for Piston Ring Samples
TE 77/EP	Energy Pulse Slide/Roll Adapter
TE 77/MW	Piston Ring/Groove Micro Welding Test Adaptor
TE 77/HR	Heated Piston Ring Sample Carrier
TE 77/PD	Pin on Disc Test Adapter
TE 77/CAL	Calibration Kit for Load and Friction
TE 77/SCOPE	Microscope for Wear Scar Measurement

Consumables:

TE 77/P	Qty 100 : 6mm Diameter Ball Specimens in Carrier
TE 77/L	Qty 100 : 6mm Diameter x 16mm long Nitrided Steel Pin
TE 77/AS	Qty 5 : 12 mm Diameter Mild Steel Area Specimens
TE 77/AB	Qty 5 : 12 mm Diameter Phosphor Bronze Area Specimens
TE 77/SG	Qty 5 : Gauge Plate Stick-Slip Specimens
TE 77/SB	Qty 5 : Phosphor Bronze Stick-Slip Specimens
TE 77/FG	Qty 5 : Annealed Ground Gauge Plate Specimens
TE 77/FC	Qty 5 : Ground Cast Iron Specimens
TE 77/FH	Qty 5 : Hardened Ground Gauge Plate Specimens

TE 77/EPR	Qty 5 : Energy Pulse Adapter Rolling Specimens	
TE 77/EPP	Qty 5 : Energy Pulse Adapter Hardened Plate Specimens	
TE 77/ISOP/B	Qty 100 : Test Plates/Test Balls for ISO Fuel Lubricity Test	
TE 77/C41	Qty 10 : Cylindrical Pin 4 mm Diameter	SS 304 (Annealed)
TE 77/C42	Qty 10 : Cylindrical Pin 4 mm Diameter	Aluminium Bronze (Annealed)
TE 77/C43	Qty 10 : Cylindrical Pin 4 mm Diameter	SS 440C (Hardened and tempered)
TE 77/C44	Qty 10 : Cylindrical Pin 4 mm Diameter	SS 410 (Hardened and tempered)
TE 77/C45	Qty 10 : Cylindrical Pin 4 mm Diameter	AISI 52100 (Hardened and tempered)
TE 77/C46	Qty 10 : Cylindrical Pin 4 mm Diameter	Natural PEEK
TE 77/C47	Qty 10 : Cylindrical Pin 4 mm Diameter	PTFE
TE 77/C61	Qty 10 : Cylindrical Pin 6 mm Diameter	SS 304 (Annealed)
TE 77/C62	Qty 10 : Cylindrical Pin 6 mm Diameter	Aluminium Bronze (Annealed)
TE 77/C63	Qty 10 : Cylindrical Pin 6 mm Diameter	SS 440C (Hardened and tempered)
TE 77/C66	Qty 10 : Cylindrical Pin 6 mm Diameter	SS 410 (Hardened and tempered)
TE 77/C65	Qty 10 : Cylindrical Pin 6 mm Diameter	AISI 52100 (Hardened and tempered)
TE 77/C66	Qty 10 : Cylindrical Pin 6 mm Diameter	Natural PEEK
TE 77/C67	Qty 10 : Cylindrical Pin 6 mm Diameter	PTFE
TE 77/C81	Qty 10 : Cylindrical Pin 8 mm Diameter	SS 304 (Annealed)
TE 77/C82	Qty 10 : Cylindrical Pin 8 mm Diameter	Aluminium Bronze (Annealed)
TE 77/C83	Qty 10 : Cylindrical Pin 8 mm Diameter	SS 440C (Hardened and tempered)
TE 77/C88	Qty 10 : Cylindrical Pin 8 mm Diameter	SS 410 (Hardened and tempered)
TE 77/C85	Qty 10 : Cylindrical Pin 8 mm Diameter	AISI 52100 (Hardened and tempered)
TE 77/C86	Qty 10 : Cylindrical Pin 8 mm Diameter	Natural PEEK
TE 77/C87	Qty 10 : Cylindrical Pin 8 mm Diameter	PTFE
TE 77/B1	Qty 100 : Balls 6mm (Grade 25)	SS 440C (Hardened and tempered)
TE 77/B2	Qty 100 : Balls 6mm (Grade 25)	AISI 52100 (Hardened and tempered)
TE 77/B3	Qty 100 : Balls 6mm (Grade 25)	Al2O3
TE 77/B4	Qty 100 : Balls 3/8” (Grade 25)	SS 440C (Hardened and tempered)
TE 77/B5	Qty 100 : Balls 3/8” (Grade 25)	AISI 52100 (Hardened and tempered)
TE 77/B6	Qty 100 : Balls 3/8” (Grade 25)	Al2O3
TE 77/B7	Qty 100 : Balls 1/2” (Grade 25)	SS 440C (Hardened and tempered)
TE 77/B8	Qty 100 : Balls 1/2” (Grade 25)	AISI 52100 (Hardened and tempered)
TE 77/B9	Qty 100 : Balls 1/2” (Grade 25)	Al2O3
TE 77/F1	Qty 10 : Flat Plate Specimen 58 x 38 x 4	SS 440C (Hardened and tempered)
TE 77/F2	Qty 10 : Flat Plate Specimen 58 x 38 x 4	SS 410 (Hardened and tempered)
TE 77/F3	Qty 10 : Flat Plate Specimen 58 x 38 x 4	AISI 52100 (Hardened and tempered)
TE 77/RG	Qty 5 : Rubber & Glass Specimens	Materials to be specified
TE 77/RL	Qty 5 : Piston Ring and Liner Specimens	Materials to be specified