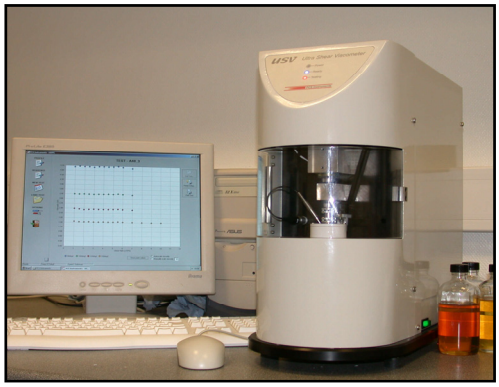
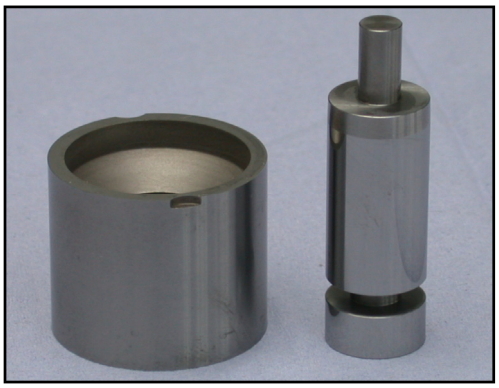
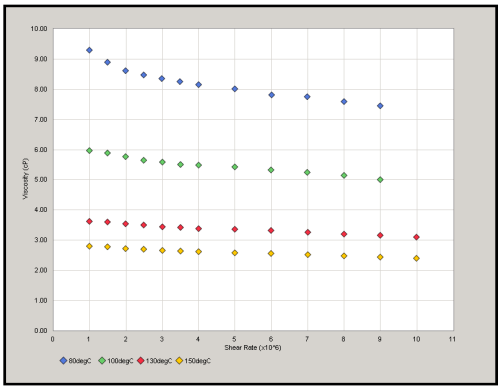
PCS Instruments

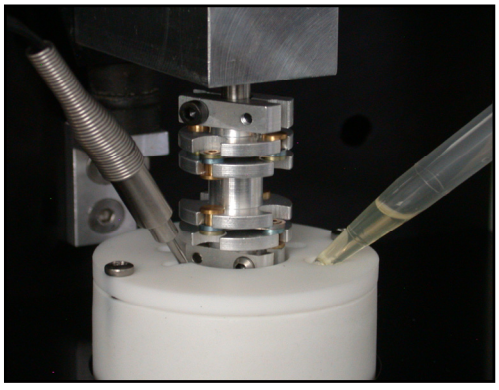
USV

Ultra Shear Viscometer









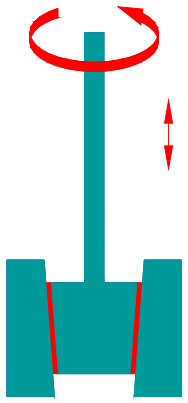
A computer controlled instrument capable of fully automatic viscosity measurements at 10,000,000 reciprocal seconds

Viscosity measurement background

Accurate measurement of dynamic viscosity at very high shear rates is of particular concern in the automotive industry. Lubricants developed for motor vehicle applications are typically non-Newtonian making it necessary to reproduce the shear rate found in engines when measuring the viscosity.
Several international standards (ASTM, CEC) define procedures to measure the High Temperature High Shear (HTHS) viscosity at 150°C and 10^6 s^{-1}.

Existing instruments

At present most instruments for measuring HTHS viscosity employ the same technique. The shear stress is generated between a tapered steel plug & copper stator. The gap between the plug and stator is set by adjusting the vertical position of the plug. In order to minimize the effects of thermal expansion, test results have to be compared with those for a calibration oil at the same temperature. Time-consuming calibration procedures have to be carried out each time the instrument is used. This considerably slows down the test turn around and increases uncertainty in the results.



THE GAP VARIES BY RAISING OR LOWERING THE PLUG

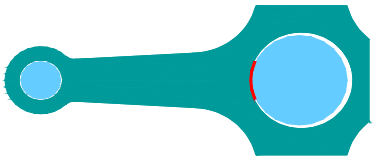
The temperature challenge

Extending the measuring range on existing instruments is not feasible due to the temperature rise caused by shear heating of the lubricant. As the shear rate rises, the heat dissipated in the film increases. This leads to both a distortion in the film shape and a drop in the test oil viscosity.
Consequently, the maximum shear rate is limited at approximately 3 x 10^6 s^{-1}.

HEAT GRADIENT CREATED BY THE SHEAR RATE IN A TAPERED PLUG & STATOR

New needs

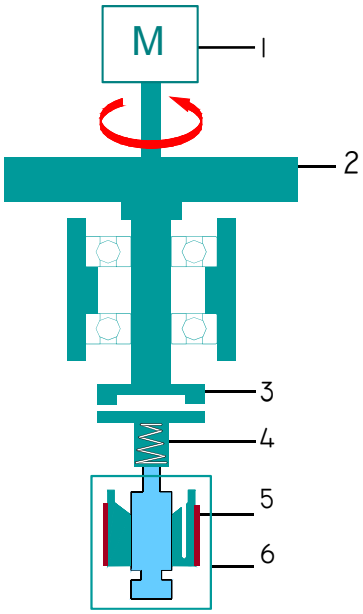
Lubricant formulators have long been aware of the shortcomings of existing high shear viscometers. Whilst the state of the art in high shear rate viscometry has remained around the 1,000,000 s^{-1} mark for many years, developments in engine and lubricant technology mean that in-service conditions are closer to 10,000,000 s^{-1}.
These new conditions generate a great demand to measure engine oil viscosity at more realistic shear rates, i.e. shear rates greater than 1,000,000 s^{-1}.



IN NEW ENGINES THE JOURNAL BEARING SHEAR RATE CAN EXCEED 10^7 s^{-1}

USV: the ultimate solution

The Ultra Shear Viscometer can carry out fully automated viscosity measurements over a shear rate range from 1,000,000 s^{-1} to 10,000,000 s^{-1} and temperatures between 40 and 150°C. All test parameters are controlled by a built-in microprocessor. These capacities are enhanced by the simple to use software and a rapid turnaround: a complete temperature / shear rate map for a lubricant can be completed in under 1 hour.



USV Main parts:

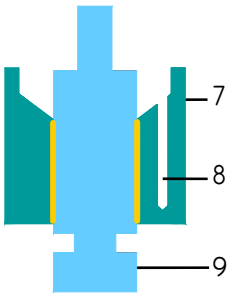
1. DC servo motor
2. Flywheel
3. Electromagnetic Clutch
4. Flexible coupling
5. Heaters
6. PTFE Test chamber
7. Stator
8. Temperature probe slot
9. Rotor

Novel measurement technique

The USV can measure at exceptionally high shear rates thanks to its unique measurement technique. The USV is fitted with a DC servo motor capable of speeds of over 20,000 rpm and an electromagnetic clutch which engages the rotor for only a very short period of time (typically 100ms). This brief shearing interval minimizes the shear heating in the lubricant.
The motor and clutch are controlled by the built-in micro-processor which also logs torque data from a piezo force transducer coupled to the stator.
The radial gap between the rotor and stator is one micron, making shear rates as high as 10^7 s^{-1} achievable.

Temperature under control

The temperature is constantly monitored by an independent temperature control micro-processor. Two Platinum RTD probes are used in the instrument. The main probe slides into the stator, in close proximity to the test sample. The probe is supplied with an internal chip programmed with its own calibration data. The second probe cross-checks temperature at the bottom of the test chamber for safety purposes.



No re-calibration

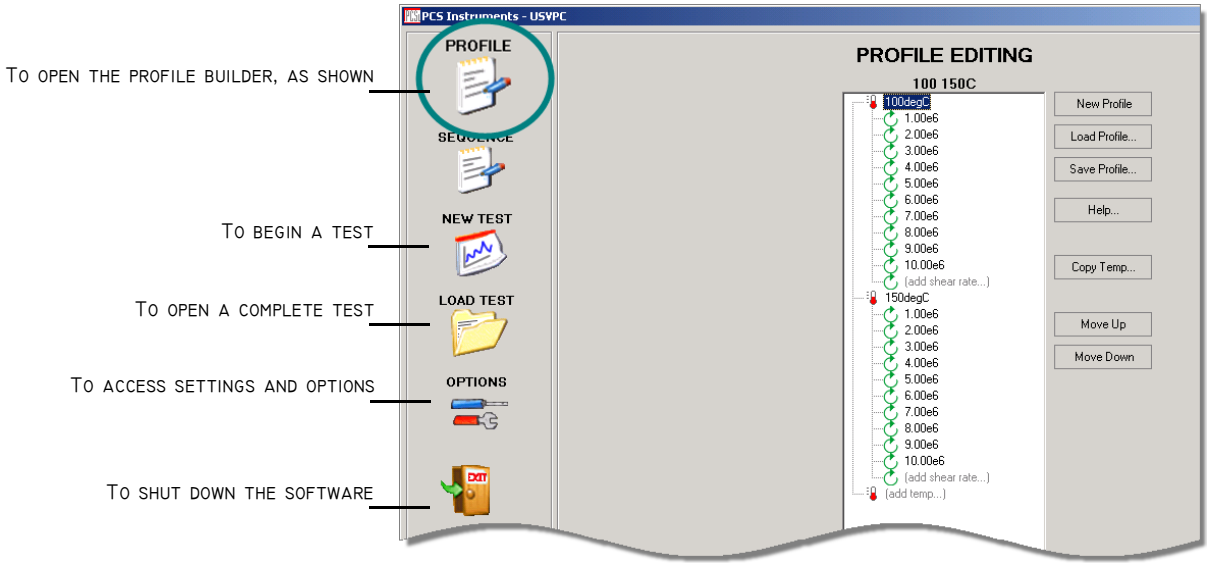
The rotor and stator are both made from the same material which is heated uniformly to the test temperature. The uniform expansion means that the gap change with temperature is negligible. More importantly, because the shear heating is minimal, thermal distortion of the gap is insignificant so the rotor can have a cylindrical form. As a result, the radial gap is constant and there is no need for a calibration procedure at each change of lubricant. The rotor position is set and the gap value is fixed for a particular rotor and stator pair. This constant gap allows to the USV to run multi-temperature tests over a wide range of shear rates.

Running a test with the USV

The USV software turns test preparation into a simple and fast procedure. Once the user has chosen the desired shear rate(s) and temperature(s), it takes only a few minutes to flush the current sample with the new one. The test is then ready to begin, with no user intervention required. As the measurements are logged, the viscosity results are plotted onto a graph with a series of smart options. From selecting the measurements to analysing them, the procedure can be divided into 5 steps:

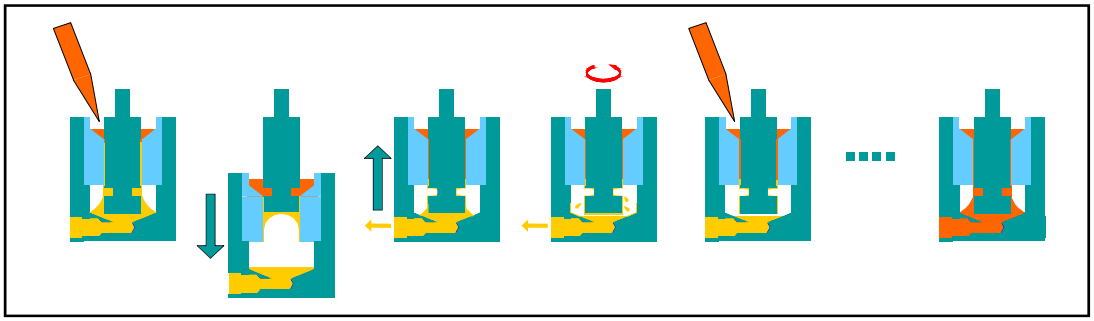
1 . Building a profile

A profile is the list of temperatures and shear rates at which the user wants to take measurements. With the user-friendly profile builder integrated to the software, it takes a few seconds to create a new profile. Profiles can be saved and re-loaded for modification. The view below shows an example of a profile comprising 20 measurements: 10 shear rates at two temperatures.



2 . Flushing the test sample

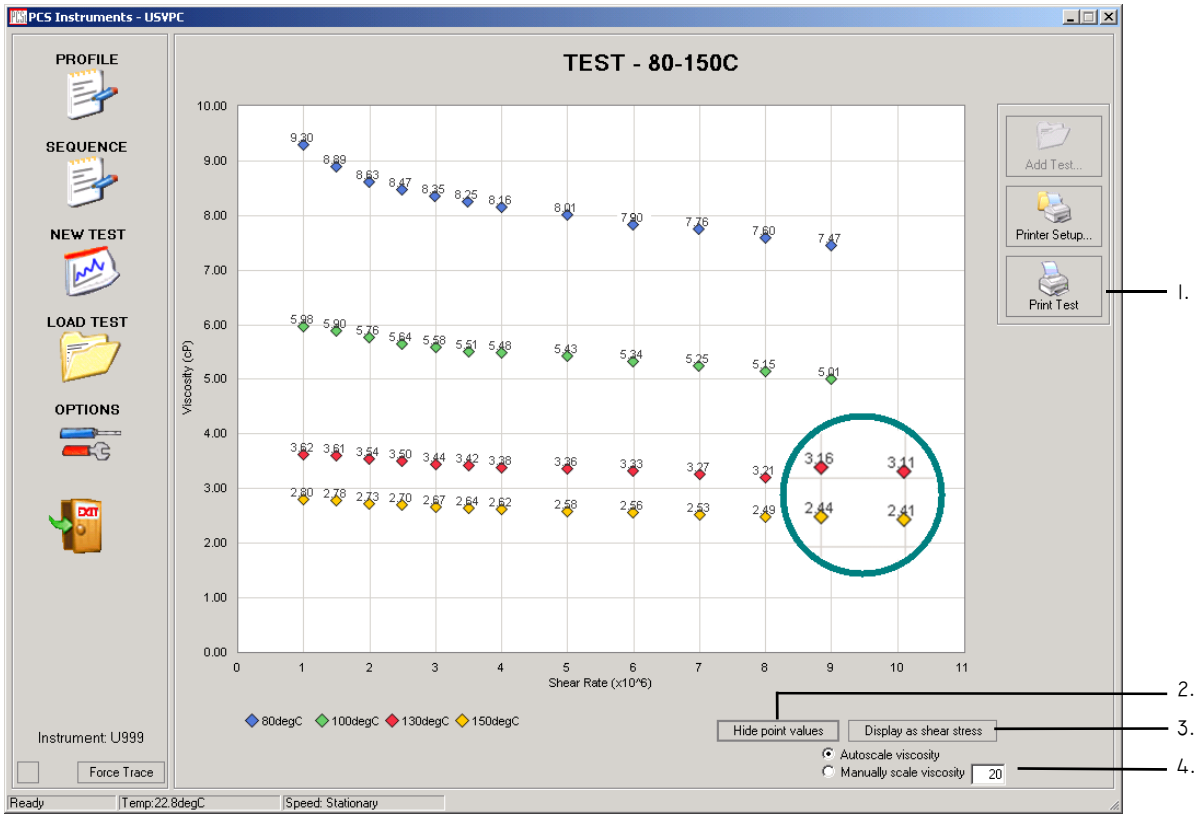
During the flushing procedure, the test chamber is heated up and the user is asked to pipette 0.5 ml of oil into the chamber. The oil is flushed automatically by oscillating the stator up and down and spinning the rotor. The procedure is repeated a number times to ensure complete flushing of the test sample.



STATOR MOVING UP AND DOWN TO FLUSH THE TEST SAMPLE

3 . Starting the test

To start a test, the user chooses a profile and a name for the test and clicks the Start Test button. The test chamber is then heated up to the first temperature selected in the profile. When the target temperature is reached the fly wheel speeds up to generate the first pre-defined shear rate.



1. To print the graph
2. To hide or show the values on the graph
3. To toggle the Y-axis from viscosity to shear stress
4. To manually scale the graph

4 . Test running

There is no user intervention required during a test. The results are plotted into a viscosity vs. shear rate graph as the measurements are logged. The user can choose to toggle the display to a shear stress vs. shear rate graph. The viscosity values can be shown or hidden with a simple click.

5 . Test complete: using the data

The test results can be viewed in two different ways: from the USV software or via an exported test data file (.txt). From the software interface, the graph can be re-scaled and printed by simply clicking the ‘Print Test’ button, see view above. From the data file, the results can be easily imported into a spreadsheet package to be viewed and analysed off-line.

USV results

The very high shear rate range and automated testing ability of the USV has attracted the interest of many companies and research centres since its release. Typical USV users are lubricant developers, additives designers, research departments of automotive manufacturers and universities.

Data accuracy and repeatability

When measuring viscosity, accurate temperature control and measurement is a key parameter. The USV temperature control constantly controls the test sample to within 0.1°C of the target temperature.
Each result is the average of 5 measurements to ensure consistency.

As a result, the USV achieves a repeatability of 2% of the viscosity value. For high shear rates at high temperature, the repeatability is as good as 0.03 mPas, see table on the right.

Shear rate /s	Repeatability cP (mPas)	Reproducibility cP (mPas)
1 x 10^6	0.05	0.09
2 x 10^6	0.05	0.09
3 x 10^6	0.04	0.07
4 x 10^6	0.04	0.07
5 x 10^6	0.04	0.06
6 x 10^6	0.04	0.06
7 x 10^6	0.03	0.05
8 x 10^6	0.03	0.05
9 x 10^6	0.03	0.05
10 x 10^6	0.03	0.05

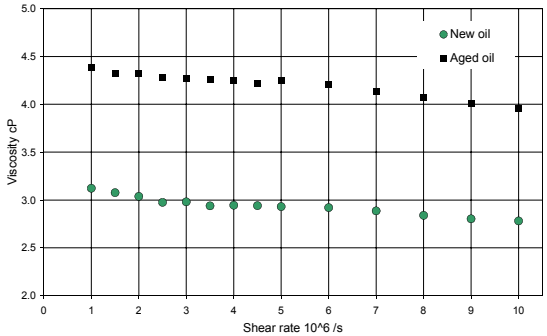
REPEATABILITY AND REPRODUCIBILITY
TESTING AT 150°C OILS HAVING A VISCOSITY OF 3 TO 5 CP

Testing time

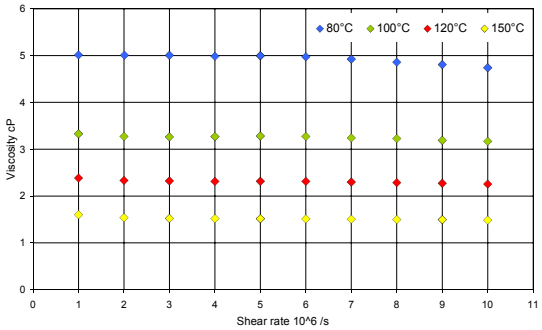
The USV is fully automated: there is no user intervention required during testing. Once the Start button has been pressed, the user can leave the rig unattended and will find all the results logged in a data file at the end of the test.
It takes 2 minutes to measure the viscosity at one shear rate and the temperature stabilization requires on average 10 minutes.
Therefore testing a sample at 10 shear rates for 3 different temperatures would take 3 x (10 x 2 min + 10 min) = 1h30.

Testing degraded oils

The viscosity of a lubricant changes - sometimes dramatically - as it ages. Therefore testing degraded oils is a key issue in some applications. It is possible to carry out tests on used oil with the USV as long as the oil has been filtered down to 1 micron, the size of the radial gap. It is also recommended to use a spare rotor and stator couple dedicated to the testing of used oils.



COMPARISON OF VISCOSITY BETWEEN NEW AND USED OIL:
VISCOSITY INCREASE OF 40 %
TESTING AT 150°C FROM 10^6 TO 10^7 /S



NEWTONIAN OIL TESTED AT 80, 100, 120 & 150°C
SHEAR HEATING EFFECT IS VISIBLE FROM 7X10^6 /S AT 80°C

Viscosity range

The USV can measure viscosities as high as 20 mPas over a temperature range of 40 to 150°C. However, at very high shear rates and low temperatures, shear heating in the film inevitably causes a slight drop in viscosity.

a - Measure viscosity at Target Temperature **T**

b - Calculate temperature rise **ΔT**

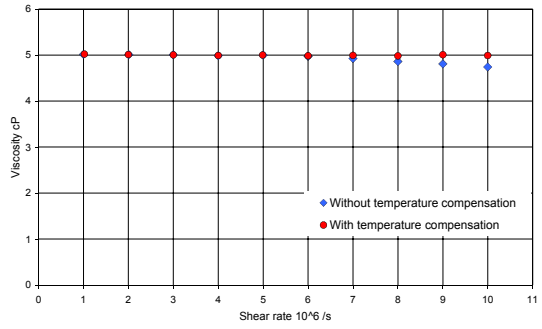
c - Control temperature down to (**T** - **ΔT**)

d - Measure viscosity at (**T** - **ΔT**)

STAGES OF THE TEMPERATURE COMPENSATION PROCEDURE
PERFORMED AT EACH SHEAR RATE

Temperature compensation

The oil temperature rise due to shear heating is a function of viscosity, gap value, shear duration and material properties of the lubricant and the stator & rotor (thermal conductivity, density, specific heat capacity).
The viscosity is measured for the given shear rate. The material properties are pre-programmed in the software (but can be accessed and modified by the user). Gap and shear duration are known values.
Therefore the temperature rise can be calculated at each measurement and used to compensate for shear heating.

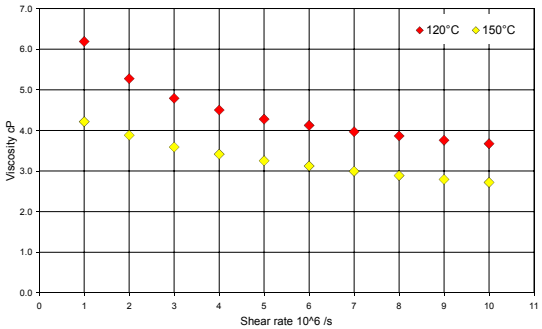


NEWTONIAN OIL TESTED AT 80°C
WITH AND WITHOUT THE TEMPERATURE COMPENSATION

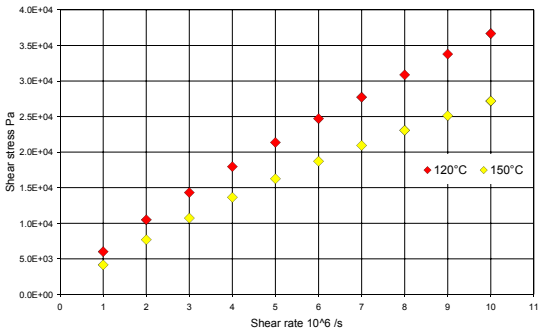
Research key tool

Rapid turn around testing facilities, reliability and simplicity of use are the key features of the USV. These qualities make it ideal for research and development on new additives and lubricants as well as studying the effect of ageing.

Currently under development, the optional autosampler will automate up to 42 tests, expanding the USV testing capabilities.



NON NEWTONIAN OIL TEST AT 120 & 150 °C
VISCOSITY VS. SHEAR RATE



NON NEWTONIAN OIL TEST AT 120 & 150 °C
SHEAR STRESS VS. SHEAR RATE

Technical Specification

The USV system comprises of:

Mechanical unit	PC with data logging software
User manual	Tool set
Variable displacement laboratory pipette	

Mechanical

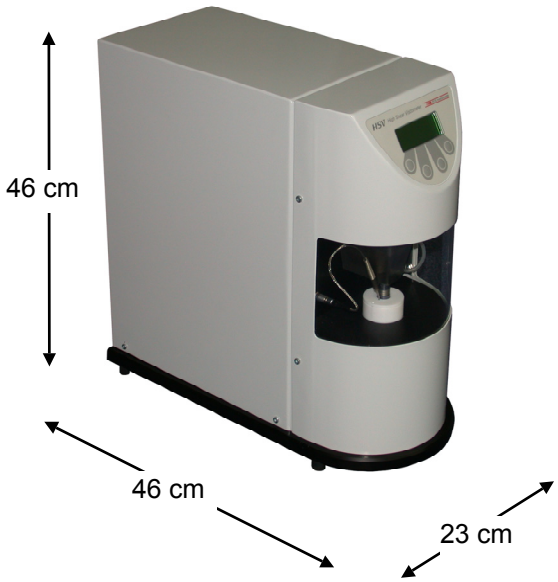
Shear rate range	1,000,000 s^{-1} to 10,000,000 s^{-1}
Testing temperature	40°C to 150°C
Test sample volume	< 5 ml
Flushing procedure duration	10 min
Number of pre-set measurements	unlimited

Temperature control

Temperature target window	+/- 0.1°C
Main sensor type	Platinum RTD
Safety sensor type	Platinum RTD

Dimensions & Weight

Weight Mechanical Unit	22 kg
Weight PC	7.15 kg
Dimensions PC	19 (w) x 30 (d) x 31 (h) cm



Options

Autosampler	for up to 42 automated tests
Printer for PC	

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