

COMMENTARY TO AG:PT/T121 – SHEAR PROPERTIES OF POLYMER MODIFIED BINDERS (ARRB ELASTOMETER)

PREFACE

This test method was prepared by the Bituminous Surfacing Research Reference Group working on behalf of the Austroads Pavement Technology Review Panel. Representatives of Austroads, ARRB Group and the Australian Asphalt Pavement Association have been involved in the development and review of this test method.

Polymer Modified Binders (PMBs) exhibit complex rheological behaviour and, consequently, simple viscometers do not provide a satisfactory measure of their viscous and elastic behaviour. ARRB Group's Elastometer determines several performance related properties on PMBs and other complex binders.

The instrument operates by axially shearing an annular sample of material between two concentric cylinders at a controlled strain rate, and to a preset strain level (loading phase). At this point, the load is removed and the amount of strain recovery is measured with time (recovery phase).

During the loading phase, both displacement and force are measured. The rapid force increase recorded at the beginning of the loading phase is used to calculate the Underlying Viscosity (UV). The maximum force achieved at the end of the loading phase is used to obtain a measure of the Consistency and Stiffness of the material. During the recovery phase, the Elastic Recovery (recovered strain, as a percentage of the original strain) is obtained for various times of recovery (e.g. 100 s and 300 s).

In addition to measures of UV, Consistency and Stiffness on concentric cylinder samples, the Elastometer can be used to obtain measures of low temperature tensile modulus, elastic response and other related properties on standard prism samples prepared for testing in accordance with the procedures described in AG:PT/T124 ARRB Extensiometer. A computer program is provided to make the necessary calculations for these properties. The program also provides analysis tools for determining viscosity, Consistency and Elastic Recovery on soft binders, including soft sealing grades of PMB, Class 320 (AS2008) and multigrade bitumens (Austroads AP-T41/06). These data analysis tools are described in Appendix A.

SCOPE

This test method sets out the procedures for the determination of UV, Consistency, Stiffness and Elastic Recovery of polymer modified binders (ARRB Elastometer), under specific conditions of deformation, using the Elastometer developed by ARRB Group.

Further Development

This test method is under development and some changes in the test parameters may occur in the future.

SHEAR PROPERTIES OF POLYMER MODIFIED BINDERS (ARRB ELASTOMETER)

1 REFERENCED DOCUMENTS

The following documents are referred to in this method:

AUSTROADS

AG:PT/T101	Method of sampling polymer modified binders, polymers and crumb rubber
AG:PT/T102	Protocol for handling polymer modified binders in the laboratory
AG:PT/T124	Toughness of polymer modified binders (ARRB Extensiometer)

ARRB Group

ATM No.13	The ARRB Elastic Recovery rheometer
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2 APPARATUS

The required apparatus are as follows:

- a. ARRB Elastometer – This exists in two versions; the manually-controlled version, or the PC-controlled version (see Note 1). The Elastometer is shown in Figure 1.
- b. Recording device:

For manually controlled instrument: 2-pen Chart recorder, such as a Pantos Model U228-2P-500, or alternatively a suitable PC based data acquisition system.

For PC controlled instrument: A PC with minimum requirements of a 486/33 with 8 Mb RAM, 540 Mb hard disk and operating under Windows 3.1.
- c. Constant temperature bath - Capable of maintaining the temperature to within $\pm 0.1^{\circ}\text{C}$, such as a LAUDA Model MS 20, or equivalent. The water bath must be of suitable dimensions to satisfactorily accommodate the Elastometer and provide a water depth of 135 mm for immersion of the sample. The bath must be fitted with a perforated baffle to minimise water turbulence around the sample.
- d. Sample moulds - Consisting of an inner and an outer cylinder, assembly base, Teflon sheet gasket and locknut. The cylinders are accurately machined with the inner cylinder trimmed to an exact mass, so that it can be used interchangeably with replacements without the need for rebalancing the instrument. Figure 2 shows the types of mould configurations.

Moulds designated A, B and C have been developed to cover a range of testing requirements. Mould A is the standard mould routinely used for testing UV and Consistency (at 60°C) and Mould C is used for testing Stiffness (at 15 and 25°C). Mould B can be used when 60°C test results are required on softer binders, such as S10E, S35E, A25E grade PMBs. Details of the moulds are given in Table 1.

Table 1 Concentric Cylinder Moulds geometry

Item		Unit	Mould A	Mould B	Mould C
Inner cylinder	d1	mm	25.0 ± 0.02	35.0 ± 0.02	12.0 ± 0.02
Outer cylinder	d2	mm	45.0 ± 0.02	45.0 ± 0.02	22.0 ± 0.02
Height	h	mm	40.0 ± 0.02	40.0 ± 0.02	20.0 ± 0.02
Inner cylinder mass	M	g	54.5 ± 0.05	105.5 ± 0.05	18.8 ± 0.2
Gap	G	mm	10	5	5
Stress factor	K	(m ²) ⁻¹	227.36	198.94	936.21

- e. Forced convection oven - Conforming to the requirements of AG:PT/T102.
- f. Thermometer - Calibrated for measuring the temperature of the water bath to ± 0.1°C at the required test temperature.
- g. Pouring containers - 100 mL beakers, or small cans, with a pouring lip (other sizes may be required).
- h. Safety razor blade
- i. Broad blade spatula
- j. Freeze spray or silicone grease

3 CALIBRATION

The operational dimensions of the instrument must be periodically checked, as follows:

3.1 General

- a. Sample moulds - Regularly check for damage. Check the mass of the inner cylinder. Replace it if it is not within the range specified in Table 1.
- b. Balance wheel - Check the wheel for free movement after removal of the counterweight cable. There should be negligible friction.
- c. Level - Regularly check the level of the instrument to ensure that the pullrod hangs centrally and clears the hole in the load cell.

3.2 Electronics

The instrument control unit, including chart recorder or PC, must be switched on at least half an hour before use to allow the electronics to stabilise. The instrument must be operated in a stable temperature environment, as substantial temperature changes can influence the accuracy of the system. The calibration procedures are as follows:

3.2.1 *Manually controlled instruments:*

- a. Force - The accuracy of the load cell can be checked regularly using the built-in calibration function (cal). This simulates a full scale load application and provides a calibrated reference output as shown on the meter.

Elastometers were originally fitted with lower capacity load cells, and initially calibrated to 10 kg full scale, then later to 100.00 N. Some instruments have been upgraded to a higher capacity load and calibrated to 200.00 N full scale. The reference output has been set accordingly to 10 kg, 100.00 N or 190.00 N, depending on the instrument calibration. The following calibration steps should be followed:

1. Zero the output, with the load cell unloaded.
2. Press the cal button and check the output as shown on the meter.

If the reading is within 0.1% of the appropriate reference output, then the functioning of the load cell can be regarded as correct.

The load cell accuracy should be checked at six month intervals, by applying a known load. This is done by hanging an accurately known mass (5 to 10 kg) from the load cell and checking the output. It should be within 0.1%. It may be convenient to remove the sample holder assembly for this operation.

- b. Speed - This should be checked on a regular basis by analysing the displacement versus time chart during the loading phase.
- c. Displacement - The calibration of the displacement transducer (LVDT) is checked using a 5 mm and a 10 mm spacer. Attach an inner cylinder to the pullrod and allow the assembly to settle on the base of the sample holder. Check the displacement output on the meter and adjust it to zero. Then raise the cylinder and insert the spacer under it and check the output. The displacement output as shown on the meter should agree with the measured dimension of the spacer to within ± 0.1 mm.

3.2.2 *PC controlled instruments:*

The calibration of Force, Speed and Displacement is automated, with minimal actions required by the operator. The procedures are self-contained, with full instructions on the PC screen via the control software.

The calibration routines are selected under "Calibration" in the ARRB PMB Test System main menu. They are carried out quickly, and it is recommended that a check of the calibration be performed at least at the beginning of each day of testing.

4 PREPARATION OF SAMPLES

4.1 *General*

Modified binders can be complex mixtures of polymers and a variety of petroleum products and are handled at elevated temperatures (refer to handling precautions below). It is recommended that notices, describing the action to be taken in the event of hot binder burns, should be displayed in the laboratory in the areas where bitumen, multigrade and PMBs are handled. A suitable warning could be as follows:

WARNING: HOT BITUMEN, MULTIGRADE & PMBs CAN CAUSE BURNS

The following precautions should be taken when handling hot bituminous binders, such as bitumens, multigrade bitumens, polymer modified bitumens and crumb rubber modified bitumens:

- a. Eye protection, such as safety glasses and/or face shields, shall be worn when handling hot bituminous binders.
- b. Heat-resistant gloves with close-fitting cuffs, and other suitable protective clothing, shall be worn when handling hot bituminous binders.
- c. There shall be no smoking or the presence of other ignition sources in close proximity while handling hot bituminous binders.
- d. Bituminous binders heated in the presence of small quantities of water may foam excessively and spatter or overflow the sample containers. Thus samples should always be checked for the presence of water while still cold by examining whether a layer of condensate is evident, either on the surface of the sample or on the underside of the container lid, or if the binder surface exhibits a pitted appearance. In such cases where water is found to be present, drain off as much as possible and dry the sample at room temperature or blow-dry with clean compressed air. However, should moisture contamination have occurred while binder was cooling, resulting in water entrapment within the binder which becomes evident on gentle heating, an additional precautionary treatment (as described in AG:PT/T102) is recommended.

4.2 Sample Preparation

Samples for testing shall be provided in accordance with AG:PT/T101 and AG:PT/T102.

4.3 Pouring Containers

These are smaller containers, with a pouring lip to facilitate pouring of the binder into the moulds. Small beakers (100 mL) are recommended. For higher Consistency binders, a larger number of smaller containers may be needed. For more fluid binders, a larger container may be used to fill more moulds, before the material becomes too viscous to pour easily. (Note 2)

5 PROCEDURES**5.1 Preparation of Moulds**

The procedure for preparation of concentric moulds shall be as follows:

- a. Assemble the mould(s) with Teflon gasket in place. The Teflon gasket may be lightly coated with silicone grease. Precoat the inner cylinders with polymer (optional, see Note 3).
- b. Preheat the moulds in the oven to the sample handling temperature (180°C, unless otherwise specified).

- c. Remove the mould(s) from the oven.
- d. Take the heated sub-sample in the pouring container from the oven. Then stir thoroughly, but gently, for 30 seconds to assure uniformity of the binder. Avoid trapping air.
- e. Pour the binder into the annular gap of the mould until it is just over-filled, as evidenced by the formation of a slight meniscus. Pour from one point only to avoid trapping pockets of air within the sample. Return the unused sub-sample to the oven to keep hot for topping up later.
- f. Allow the mould(s) to cool in air for 20 minutes. Re-stir the unused sub-sample briefly and top up the mould so that a distinct meniscus forms on top of the binder in the annular gap. On cooling, the binder will contract to just fill the mould. Sample trimming can be achieved without damaging the surfaces of the mould.
- g. Cool the mould(s) in air (at $23 \pm 3^\circ\text{C}$) for a further 2 hours from the time of addition of the top-up binder.
- h. Remove any excess binder protruding above the mould using a safety razor blade. Warming, or lightly coating the blade with oil, may be helpful to prevent it sticking to the binder.
- i. Clean up the mould by sliding it over a paper towel, dampened with kerosene, and placed on a flat surface. The base of the mould (inner cylinder in particular) must be free of binder otherwise it may stick to the sample holder and interfere with the operation of the test. For the same reason, the centre of the sample holder (i.e. the 'stop' for the inner cylinder) should be kept clean.

5.2 Loading Samples into the Elastometer

The procedure for loading samples into the Elastometer shall be as follows:

- a. Maintain the water bath at the required test temperature, within $\pm 0.1^\circ\text{C}$. Check the temperature near the sample with the thermometer, taking into account any necessary calibration corrections. If testing is required at different temperatures on the same day, it is preferable to start with the lower temperatures first, as only heating is then subsequently required.
- b. Ensure that the water level is to the top of the perforated baffle and is maintained during testing. Any significant change of level will affect the buoyancy of the submerged parts and thus the balance of the system.
- c. Before loading the sample mould into the instrument, ensure that the drive unit is correctly positioned. There should be a minimum clearance gap of 0.5 mm between the load cell and the collar on the pullrod, after the sample mould is in place (see Figure 3a). Normally the drive unit is automatically positioned correctly after a test run. If this is not the case, then position it as follows:
 - i. Manually controlled instrument: Switch to run, and using the slow controls, move the drive unit up about 1 mm and then down until it stops automatically in the correct starting position. Switch back to standby until ready to test.

- ii. PC-controlled instrument: Using the up/down switch on the motor controller, move the drive unit up about 1 mm and then down until it automatically stops in the correct starting position, which is indicated by the illumination of the ready light on the motor controller module.
- d. Unscrew the mould from its assembly base, and remove the Teflon gasket by squirting it with the freeze spray and pulling it off briskly. If the gasket was coated with silicone grease during mould assembly, then it may be removed without the spray.
- e. Load the sample into the Elastometer. Locate the sample mould in the sample holder, with the flats on the outer cylinder lining up with the holding screws (spindle shaft uppermost). Then twist the mould about a quarter turn and tighten the holding screws.
- f. Ensure a correct counterweight (per mould type) is used (refer to Figure 1).
- g. Lower the pullrod fully over the inner cylinder shaft and tighten the grub screws securely, without using excessive force (see Figure 3). Mould C requires a length extension piece between the inner cylinder and the pullrod (provided).
- h. Slowly lower the Elastometer into the water bath and position the perforated baffle evenly around the sample holder.
- i. Remove any air bubbles trapped under the sample, after it has been immersed in the water bath for about 30 s. This is done by opening the valve on the flushing tube for a short period, which squirts a jet of water under the sample until all trapped air bubbles have been displaced. (On early instruments a hose clamp was used).
- j. Leave the sample for 15 minutes to achieve temperature equilibrium before testing.

5.3 Chart Recorder Adjustments (manual models only)

The following instructions are specific to the Pantos chart recorder. If a different chart recorder is used, some of the specific items will not apply, although the general operation is similar.

- a. Displacement channel - Set the recorder sensitivity to 10 V full scale. This corresponds to a displacement of 10 mm, and is used in conjunction with a break point of 10 mm. For other displacements, when selecting a different break point, set the sensitivity accordingly (eg select 5 V for a 5 mm displacement and break point).
- b. Force channel - Set the recorder sensitivity to 10 V full scale. The full scale chart deflection then corresponds to a force of 10 kg, 100 N, or 200 N, depending on the calibration of the specific load cell fitted. For lower forces, other sensitivities may be used (eg for a 100 N load cell, select 2 V for a force of 20 N).
- c. Zero check - Zero both channels by switching to check mode and using the position control. Switch back to measure mode for testing. Generally, this operation only needs to be done at the start of each day and requires occasional checking during testing.
- d. Chart speed - Set the chart speed to 600 mm/min. This is the initial chart speed appropriate to most of the testing conditions. The control unit is fitted with an

automatic chart drive controller. If the chart recorder has been appropriately modified, the controller either:

- i. automatically starts the chart drive when the start button is pressed and stops the drive when the stop/reset button is pressed or
- ii. automatically changes the chart speed to one-tenth of the selected chart speed when the break point is reached. This occurs when the chart drive switch is in the auto position. In the normal, position the chart speed remains as set.

5.4 Elastometer Adjustments (manual models only)

- a. Speed - Dial the required speed and check the setting accuracy on the meter. With the range switch down (light off), the dial range is 0 to 10 mm/s, while with the switch up (x10 light on), the range is 0 to 100 mm/s.
- b. Break Point - Dial the required Break Point and check the setting accuracy on the meter.
- c. Zero - Adjust the zero controls for both Force and Displacement, until the red indicator lights extinguish and the green light is on. This indicates that the zero is within the acceptable preset limits, and can be checked on the meter. For maximum accuracy, use the meter as a final check.

5.5 Elastometer Adjustments (PC-controlled models only)

The system runs under Windows 3.1, and all operating adjustments are made using the PC.

- a. Select ARRB PMB Test System from the Program Manager to bring up the operations main menu.
- b. Select the Elastometer/Run Test function to bring up the Elastometer Run Parameters window.
- c. Enter all relevant details of the experiment as requested. The test cannot progress until all required information has been supplied. The following information will be required:
 - i. Run number, Date and Time (automatic).
 - ii. Operator.
 - iii. Sample mould. Select A, B or C as required. (Note 4)
 - iv. Temperature.
 - v. Strain rate (or speed)
 - vi. Strain (or break point).
 - vii. Recovery time (duration of recovery phase).
 - viii. Timer - Select required time delay before test starts after pressing START.

- ix. Mode - Select Recovery. (Relaxation is for future development)
- x. Sample description. Two lines of text available. *
- xi. Comments (optional). Three lines of text available. *

* Do not use "Enter" after the second (or third) line, as this will delete first line of text.

5.6 Testing (manually controlled instruments only)

- a. Switch to run on the motor drive (red flashing light will extinguish).
- b. Lower both pens of the chart recorder.
- c. Select auto or normal, as required for the chart drive (see section 5.3 (d)).
- d. Recheck zero for force and displacement on the Elastometer.
- e. Press the start button on the Elastometer. Simultaneously switch on the chart drive of the recorder (see Note 5). The Elastometer will begin shearing the sample and will automatically remove the load when the break point is reached, allowing the sample to recover strain. At this point the chart speed will drop to one tenth the set speed if the chart drive is set to auto.
- f. Switch to a lower chart speed (60 mm/min.) when the break point is reached, if the recorder has not been modified.
- g. On completion of the Loading Phase switch to standby. The timing is not critical and this mode will prevent drifting of the motor drive over longer periods, which can affect the position of the inner cylinder.
- h. Allow the sample to recover for the specified period (see Note 6).
- i. On completion of the Recovery Phase, press stop/reset to stop the chart drive, if automatic, or switch off chart drive on the recorder.
- j. Raise the Elastometer out of the water bath. Inspect the sample for any signs of slippage of the binder on the cylinders, or slippage of the pullrod. If binder slippage occurs, then precautions may be needed as outlined under Section 5.1 (a).
- k. Record all test conditions on the chart, such as:
 - i. Sample description.
 - ii. Sample mould.
 - iii. Temperature.
 - iv. Speed.
 - v. Break Point.
 - vi. Recorder voltage settings and chart speeds used.
 - vii. Recovery time (test duration).

- viii. Comments.
- ix. Operator.

5.7 Testing (PC-controlled instruments only)

The elastometer can be started in two modes, either directly, or via a timer delay function. The delay mode has been provided to allow a 15 minute period for temperature equilibration of the sample, after which the test is automatically started. (Other times are available if required).

- a. Direct mode - Set timer for 0 min. in Run parameters. Leave the sample for 15 minutes to achieve temperature equilibrium, then press START to begin the test.
- b. Timer mode - Set timer for 15 minutes in Run parameters. Press START as soon as the run parameters have been entered and the sample has been lowered into the bath. The timer will then count down for 15 minutes and start the test automatically after this period. The test sequence and data acquisition will progress automatically. While the test is running, progress is displayed on the screen as time elapsed for each of the phases.

6 CALCULATIONS

From the chart, on manual control models, measure the maximum force attained at the end of the loading phase and the recovered displacement(s) corresponding to the various specified recovery times. See Figure B1 in Appendix B for a typical test sequence, as shown on the chart record. Calculate the required properties of Elastic Recovery, Strain Rate, Strain, Consistency and Stiffness as follows (see Note 7):

- a. Elastic Recovery - This is a measure of the elasticity of the binder under the specific conditions of testing. It is defined as the recovered strain, as a percentage of the original strain attained at the break point (end of loading phase). It is calculated using the following equation:

$$\text{Elastic Recovery (\%)} = 100 a / b$$

where

a = recovered displacement (or strain), in mm

b = original displacement (or strain), in mm.

- b. Shear Strain Rate - This parameter is preset by the operator and depends on the sample film thickness (mould gap) and the speed selected for the test.

$$\text{Strain Rate (s}^{-1}\text{)} = S/G$$

where

S = speed of the inner cylinder, in mm/s

G = annular gap of mould, in mm.

- c. Shear Strain - The strain depends on the total displacement and the film thickness (mould gap) of the sample.

$$\text{Strain} = B/G$$

where

B = displacement at break point, in mm

G = annular gap of mould, in mm.

- d. Viscous Shear Stress - The viscous stress is used to calculate the Underlying Viscosity of the binder tested. It is defined as the force attained at the moment of load application (extrapolated to zero strain from the force data recorded within 0.2 to 0.4 strain range), divided by the mean area of the annular sample being sheared.

$$\text{Stress (Pa)} = K \times F$$

where

F = viscous force, in N

K = mould stress factor, $(\text{m}^2)^{-1}$.

Values of K are given in Table 1. $K = 1/0.5 \pi h (d1 + d2)$, which is the reciprocal of the mean area, and the dimensions of h, d1 and d2 used here are in m.

- e. Peak Shear Stress - The (maximum mean) stress is used to calculate the Consistency, or Stiffness of the binder tested. It is defined as the maximum force attained (see Note 8) just at the break point, divided by the mean area of the annular sample being sheared.

$$\text{Stress (Pa)} = K \times F$$

where

F = maximum force, N

K = mould stress factor, $(\text{m}^2)^{-1}$.

Values of K are given in Table 1. $K = 1/0.5 \pi h (d1 + d2)$, which is the reciprocal of the mean area, and the dimensions of h, d1 and d2 used here are in m.

- f. Underlying Viscosity – The UV is given by the following equation:

$$\text{UV (Pa.s)} = \text{Viscous Stress} / \text{Strain Rate}$$

where

Strain Rate is as calculated in Section 6 (b), s^{-1}

Viscous Stress is as calculated in Section 6 (d), Pa.

- g. Consistency - The Consistency is given by the following equation:

Consistency (Pa.s) = Peak Stress / Strain Rate

where

Strain Rate is as calculated in Section 6 (b), s^{-1}

Peak Stress is as calculated in Section 6 (e), Pa.

- h. Shear Stiffness - The Stiffness is given by the following equation:

Stiffness (Pa) = Stress / Strain

where

Strain is calculated as in Section 6 (c)

Stress is calculated as in Section 6 (e), Pa.

7 INFORMATION TO BE REPORTED

The following information, as required, shall be reported:

- a. Elastic Recovery, as a percentage, to the nearest integer, together with the Recovery Time, in s.
- b. Strain Rate, s^{-1} .
- c. Strain.
- d. Underlying Viscosity, Pa.s.
- e. Consistency, Pa.s. (see also the output from the data analysis tools for Consistencies < 1000 Pa.s.)
- f. Stiffness, Pa.
- g. Test temperature, °C.
- h. Test mould (A, B or C)

8 PRECISION

A test result should be considered valid if the measured Consistency is greater than 1000 Pa.s. If the value of Consistency falls within the range of 500 to 1000 Pa.s, then the Consistency result will still be acceptable. However, if the Consistency result is below 1000 Pa.s, then the associated Elastic Recovery result will become unreliable. Consistency results less than 500 Pa.s can be acceptable, however the associated Elastic Recovery results should be discarded.

The upper limits of testing are determined by the maximum capacity of the load cell and the geometry of the sample assembly used. Table 2 gives the upper limits of testing for Stiffness, for the two moulds.

Table 2: Maximum Stiffness allowed per mould type

Mould	A	B	C
Stiffness (kPa)	45	39.5	187

Notes

1. A general description of the Elastometer operation is described in ARRB ATM No.13, and in the Elastometer User Manual (1996). A summary of these features is provided in Appendix B of this test method.
2. The temperatures and times for heating and stirring may need to be varied for certain materials in accordance with recommendations from suppliers.
3. Sample slippage can occur where the sample becomes partially detached from the inner cylinder during testing. It is most likely to occur with samples containing high concentrations of SBS polymer in bitumen. The condition can be identified by examining the sample mould after testing. A means of reducing slippage is to deposit a film of SBS polymer on the cylinders before casting the sample in the mould. This can be done by painting the appropriate surfaces with a 10% by mass solution of polymer in toluene.
4. For the standard test conditions (strain = 1.0 and strain rate = 0.1 s^{-1}), the break point and speed used with Mould A (10 mm gap) are 10.0 mm and 1.0 mm/s, respectively. The strain rate used with Mould B (5.0 mm gap) is 0.3 s^{-1} , giving the break point and speed of 5.0 mm and 1.5 mm/s, respectively. For Mould C (5.0 mm gap), the strain rate to be used is 0.1 s^{-1} , giving the break point and speed of 5.0 mm and 0.5 mm/s, respectively.
5. This will happen automatically if the recorder has been modified to auto / normal operation.
6. The normally specified recovery time is 100 seconds.
7. For PC-controlled instruments, all the relevant parameters, such as Elastic Recovery, strain rate, strain, Consistency and Stiffness, are automatically calculated by the software. Figure B1 in Appendix B shows a typical test sequence. Where levels of Consistency at 60°C are below 1000 Pa.s, greater precision can be obtained by reprocessing the data set using the data analysis tools described in Appendix A.
8. For manual instruments using force measurements in kg, convert the measurement to N (1 kg = 9.8 N).

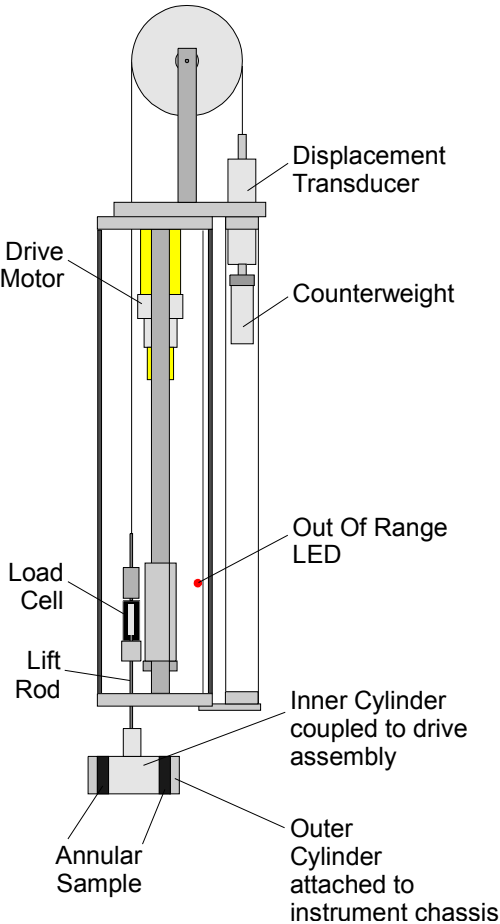


Fig. 1 Schematic of Elastometer.

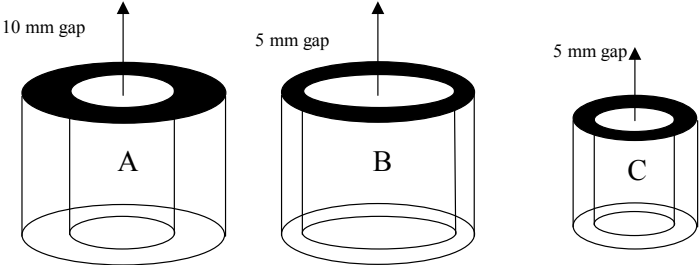


Fig. 2 Schematics of Moulds A, B and C

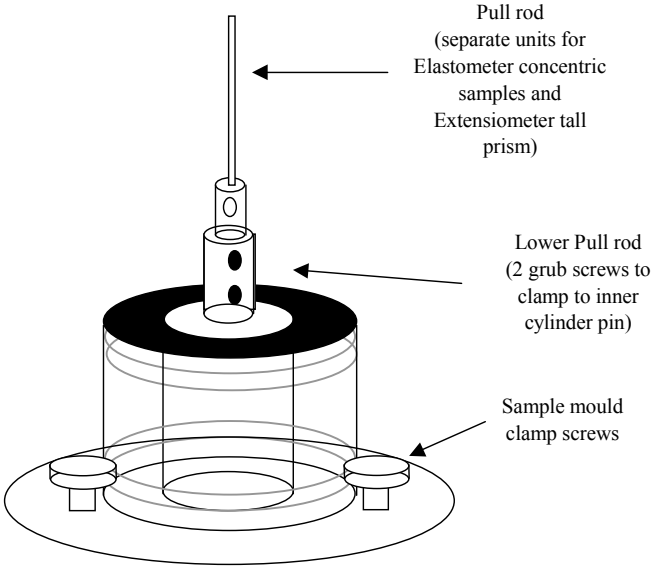


Fig. 3a Sample arrangement, with details and mounting action

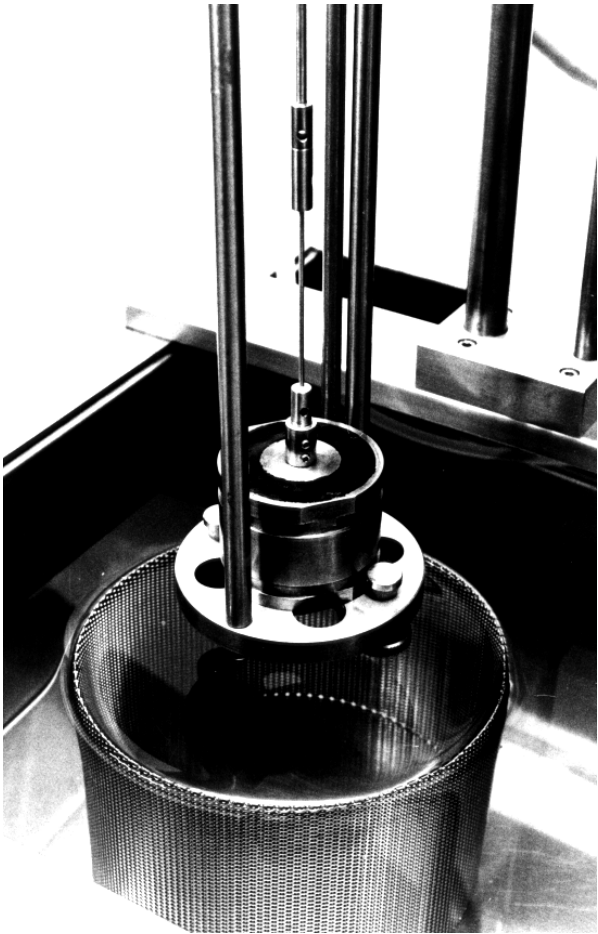


Figure 3b Mould in Elastometer

APPENDIX A

DATA ANALYSIS TOOLS AND TIPS

1. An anomaly in the Elastometer and Extensometer software handling of new file numbers can lead to data losses if a strict run closure protocol is not followed. If the instrument terminates operation because of a fault, the run number counter may not increment to the next logical file number when restarted. This can lead to the over-writing of old data files resulting in losses of previous result. Copying data files to alternative suitable named directories can safeguard old data. Ensuring the program passes through a full closure on completion of each test cycle is strongly recommended.
2. A safeguard in the software prevents the use of the full displacement range (10 mm) in a multi step experiment where two or more tests are conducted on the same sample. The consequence of this limit should be determined to identify the actual testing limits. A 3 step experiment appears to be within the range of the system assuming a better than 70 percent recovery on each element of the test sequence. A simple repeat determination where two strain rates are examined should be well within the testing limits of the system.
3. A detailed examination of the Elastometer software output indicates that the first few data samples can be missing from the data file. Although this has no consequence in the standard Elastometer tests, a correction has been applied in the new data management software to minimise any contribution to the new low temperature properties. The extent of any correction is displayed when the program is applied to the data.

Testing and Data Analysis Protocol

1. On completion of the testing sequence, group the files (*ELASnnnn.HED*, *ELASnnnn.LOD* and *ELASnnnn.REC*) in a common folder. Copy the data analysis program (*SUMMAR42.EXE*) to the same folder.
2. Run the program (*SUMMAR42.EXE*) and follow the direction of the program.
3. For the UV calculation (refer to Section 6 (d) & (f)), enter data range '40' (instead of the default value of '100').
4. An output file is generated and contains a summary of each of the processed data files in processing order.

Data Presentation

Table A1 provides an example of a result set for six individual tests.

Table A1 Example data set

Output file number

N	File	V50	G50	V80	G80	Vs	Vp	Gp	Vnet	Consist
40	6503	514E+00	143E+00	484E+00	173E+00	126E+01	100E-04	162E+01	100E-04	944
40	6504	531E+00	135E+00	499E+00	168E+00	129E+01	100E-04	163E+01	100E-04	921
40	6506	479E+00	194E+00	-157E+01	193E+01	264E+02	100E-04	192E+01	100E-04	1614
40	6507	475E+00	205E+00	-145E+01	191E+01	261E+02	100E-04	190E+01	100E-04	1572
40	6508	375E+00	621E-01	354E+00	831E-01	680E+00	100E-04	159E+01	100E-04	519
40	6509	335E+00	512E-01	320E+00	664E-01	577E+00	100E-04	160E+01	100E-04	449

Data range Underlying Viscosity Consistency

APPENDIX B

ELASTOMETER OPERATION (SUMMARY)

The Elastometer is a further development of the Elastic Recovery Rheometer (Witt 1983) and its principle of operation is similar. The basic construction of the Elastometer is shown in Fig 1. During a test the annular sample is first sheared between an outer, fixed cylinder and an inner moving cylinder. The level of strain is determined by the annular gap (sample film thickness) and the displacement of the inner cylinder. The rate of strain is determined by the annular gap and the speed of the inner cylinder. The moving cylinder is pulled upwards by a motor drive assembly at the selected speed. The force required to deform the sample is measured by a load cell.

When the selected displacement has been reached (the break point), the drive disengages and there are then no external forces acting on the sample. This is achieved by arranging for a counterweight to exactly balance the gravitational forces acting on the inner cylinder assembly via balance wheel. The proportion of the strain which is recovered (% Elastic Recovery) is measured by means of a displacement transducer.

For a case of testing with Mould A, a typical trace of force and displacement for a test is shown in Fig. B1. The chart consists two portions. The first part (up to 10 s in this case is when the sample is being sheared and the period for which this occurs is called the "loading phase". The second portion (after 10 s) is when the load has been removed and this is termed the "recovery phase".

In the test shown in Figure B1, an annular sample of 10 mm thickness was deformed by shear to a strain of 1.0 (i.e. displacement of 10 mm) at a strain rate of 0.1 s^{-1} (ie. speed of 1 mm/s). The Elastic Recovery was 75% and the maximum force was near 30 N.

The displacement vs time plot was initially a straight line indicating constant strain rate. When the desired strain level was achieved after 10 s, the force is released to zero and the recovery of strain took place. The values recorded are maximum force and amount of recovery after a set period of time.

Three moulds are available so that samples of either 5 mm or 10 mm thickness can be prepared. The outer cylinder is the same in both Moulds A and B (45 mm) but the inner cylinder is 35 mm in diameter for Mould B while it is 25 mm for Mould A.

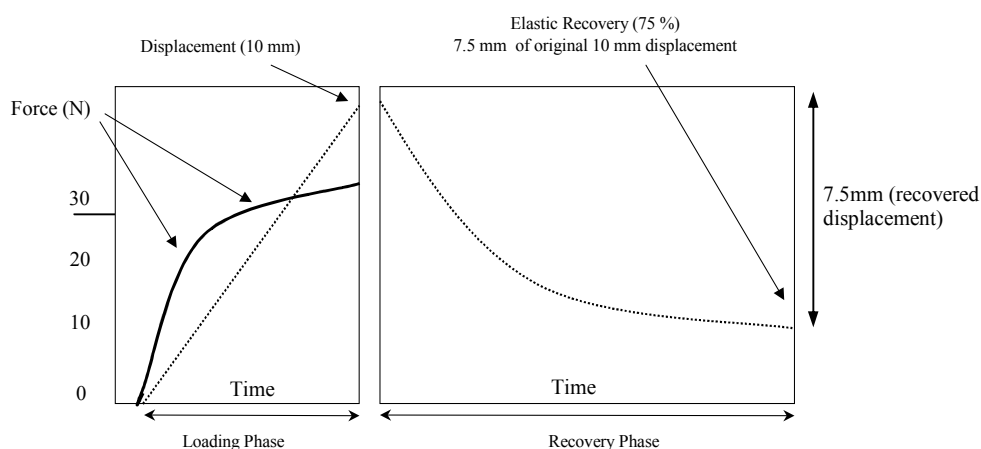


Fig. B1: Typical test sequence.

Version Date: August 2010

AMENDMENT RECORD

Amendment No.	Clauses amended	Action	Date
1	Commentary Page	New	June 2005
	Footer and header	Format	
	Applied revised test method number	Format	
	Applied new styles	Format	
2	Applied new test method numbers	Substitution	March 2006
	Moved notes to end of method	Format	
3	Corrected references within test method	Substitution	June 2006
4	Removed redundant notes	Removed	Oct 2008
5	Addition of Underlying Viscosity terms	New	August 2010
	Safety precaution statement (Item 4.1)	Substitution	

Key

Format	Change in format
Substitution	Old clause removed and replaced with new clause
New	Insertion of new clause
Removed	Old clauses removed